STATE OF NEVADA
DEPARTMENT OF TRANSPORTATION
CONSTRUCTION DIVISION

FIELD INSPECTION GUIDE

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INTRODUCTION

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ABOUT THIS GUIDE

The purpose of this document is to provide the guidelines that, in conjunction with other reference material, ensures compliance and quality of work being performed and materials incorporated for the satisfactory completion of NDOT construction contracts.

This guide is divided into the following chapters:

1. Introduction
2. Construction Activities

This guide should be easily read and understood by anyone with a fundamental understanding of NDOT's construction process. In conjunction with related documentation and supplemental training, this guide will serve as a framework for field inspection of NDOT contracts.

The *Field Inspection Guide* does not address every event throughout the inspection process in detail, nor will it replace good engineering judgment. References to documents and/or related resources are provided throughout this guide where necessary or applicable.

CONVENTIONS USED IN THIS GUIDE

References in this guide include the following:

- "The Department": the Nevada Department of Transportation (NDOT).
- "Project": The lifecycle of an NDOT project up until it is advertised.
- "Contract": The lifecycle of an NDOT project upon advertisement.
- "Standard Specifications": NDOT's *Standard Specifications for Road and Bridge Construction*. (This includes "Special Provisions", unless otherwise stated.)
- "Standard Plans": NDOT's *Standard Plans for Road and Bridge Construction*.
- "Project plans": Plans, as defined in Subsection 101.03, "(Terms and Conditions) Definitions", of the Standard Specifications, specific to the contract/project.
- "Special Provisions": Specifications specific to the contract/project.
- "Contract documents": All documents identified under "Contract" in Section 101.03 "(Terms and Definitions) Definitions", of the Standard Specifications.

Commented [BJE1]: Can revert to "contract plans" if any statement throughout the manual does not invoke the Standard Specifications.

The order of precedence of contract documents is:

1. Supplemental Notices
2. Special Provisions
3. Project Plans
4. Standard Specifications

5. Standard Plans

When discrepancies and/or contradictions exist within the above referenced documents occur, always follow the order of precedence to determine the governing documents. Guidelines when working with Standard Specifications, Standard Plans, Project Plans and/or Special Provisions include:

- Always verify changes to the Standard Plans and Standard Specifications by referencing the Special Provisions, Project Plans and Supplemental Notices.
- Changes to Standard Specifications in between published editions are made as Pull Sheets. When a Pull Sheet is implemented, it is included in a project's Special Provisions. (This incorporation of change in contract documents is a reason why Special Provisions take precedence over Standard Specifications.)
- Changes to Standard Plans are made as Special Details. When Special Details are implemented, they will be included in the Project Plans. (This incorporation of change in contract documents is a reason why Project Plans take precedence over Standard Plans.)
- Changes to contract documents after a project is advertised but before the bid is opened are provided in a Supplemental Notice.

UPDATES, REVISIONS TO THIS GUIDE

The Construction Division is responsible for maintaining an updated *Field Inspection Guide*. The Construction Division will revise and/or issue updates as needed. Users can request a revision to the guide in writing to the Construction Division at ndotconstruction@dot.nv.gov. The Construction Division will review the request and take appropriate action. Between revisions/updates, the Construction Division may issue interim Construction Division policy memorandums that would be incorporated into the next revision.

DISTRIBUTION OF THIS GUIDE

The latest approved version of the *Field Inspection Guide* is posted on the NDOT Internet site [https://www.nevadadot.com/doing-business/about-ndot/ndot-divisions/operations/construction/documentation-handbook-for-inspectors].

CONSTRUCTION ACTIVITIES

OVERVIEW

NOTE: Refer to "Conventions Used in this Guide", in Chapter 1, for terminology used in this chapter and/or the order of precedence of contract documentation.

This chapter contains inspection guidelines for the various construction activities in an NDOT contract. Inspection provides the oversight and documentation to ensure compliance and quality of work being performed and materials incorporated for the satisfactory completion of construction contracts. Resident Engineers, based on their understanding of the skill sets and/or availability of their respective staff, will assign inspectors to specific construction activities and monitor progress in conjunction with their assigned inspectors. Inspectors, along with monitoring the progress of the contract, will ensure the quality of construction and document construction activities.

Construction activities in this chapter correspond to Division II (Sections 200 - 600) of the Standard Specifications. For example, information on clearing and grubbing is found in Section 201, "Clearing and Grubbing" of the Standard Specifications, and in "201 - Clearing and Grubbing", in this chapter.

Refer to the following for more information:

- Contract documents
- Supplemental notices
- Special Provisions
- Project plans
- *Standard Specifications for Road and Bridge Construction*
- *Standard Plans for Road and Bridge Construction*
- *Manual of Uniform Traffic Control Devices* (MUTCD)
- The NDOT *Construction Manual*
- The Construction Division's *Documentation Manual*
- The *Construction Survey Manual*
- The Construction Division's *Field Testing Guide*
- The Construction Division's *Synopsis of Materials Division Testing Manual for Field Testing*
- Applicable submittals (e.g., Traffic Control Plan, shop drawings, Stormwater Pollution Prevention Plan)

201 - CLEARING AND GRUBBING

Clearing and grubbing (urban clearing, rural clearing or removal of trees) consists of removing unacceptable material from the construction limits and right-of-way. A thorough and organized clearing operation can directly affect the final appearance of the work performed. Debris and excess materials left on job sites can affect maintenance costs. Debris from the clearing and grubbing operation can clog drains or create additional maintenance activities.

BEFORE CONSTRUCTION

The Contractor shall protect existing roadway improvements, utility facilities, adjacent buildings, fences and landscaping. The contract documents describe the elements to protect during the clearing and grubbing operation. The Resident Engineer should identify improvements or items that the Contractor shall protect.

Before work begins, the inspector will:

- Discuss with the Contractor the staking and layout of special locations, such as environmentally sensitive areas and other specified avoidance areas.
- Before the Contractor disposes of material outside of the right-of-way, review Subsection 107.14, "(Legal Relations and Responsibility to the Public) Disposal of Material Outside Highway Right of Way", of the Standard Specifications, to determine the Contractor's responsibilities.
- Ensure that any hazardous materials have been mitigated in accordance with contract documents.
- Ensure that the necessary temporary pollution control measures and environmental requirements are in place.
- For multiple tree removal, document the number and size of trees.
- Ensure survey is completed to provide limits of clearing operations.

DURING CONSTRUCTION

The Contractor is responsible for protecting existing property or areas during construction. To prevent damage to certain property or areas on the job site, the Contractor may erect protective fencing or other barriers. The Contractor can place timbers around existing trees and shrubs to protect the bark from equipment or falling rocks. Unless otherwise stated in the contract documents, the cost of providing protective measures is included in other items of work and is not paid for directly.

For clearing and grubbing operations, Contractors may use a variety of equipment. The Contractor selects the appropriate types of equipment for each operation.

When monitoring the Contractor's clearing and grubbing operations, the inspector will:

- Identify any changes in equipment and/or labor force in effect.
- Document any hazards, and inform the Resident Engineer and the Contractor; ensure that safety measures have been safely implemented.
- Monitor adjacent property and environmentally sensitive areas to observe that the Contractor's operations do not damage the areas.
- Monitor the Contractor's compliance with permits and agreements. Document any deviations, and inform the Resident Engineer and the Contractor of required corrective action.
- Review the contract documents to determine if fallen timber or salvaged items are the property of others.
- When the contract documents allow burying debris within the right-of-way, confirm the following:
    - Debris will not act as an impermeable layer
    - Debris does not block drainage
    - Debris will not interfere with maintenance
    - Material is not buried within the roadway prism

  - o Organic material is not buried within the right-of-way

- Keep accurate records when disposing of solid wastes adjacent to the roadway. Also, show this information on the As-Built Plans.

- Do not dispose of debris by burning it.

MEASUREMENT AND PAYMENT

Refer to Subsection 201.04.01, "(Clearing and Grubbing) (Method of Measurement) Measurement" and Subsection 201.05.01, "(Clearing and Grubbing) (Basis of Payment) Payment", of the Standard Specifications and Chapters 5 and 19 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

202 - REMOVAL OF STRUCTURES AND OBSTRUCTIONS

This section provides information about removing structures and other materials within the construction limits. Examples of structures to be removed include buildings, foundations, fences, guardrails, pavements, culverts, curbs, sidewalks, masonry, monuments, manhole and valve covers and bridges. Some structures may include hazardous materials with specific handling requirements. Removed structures and materials may be disposed or salvaged. Removal of materials shall be in accordance with Subsection 107.14, "(Legal Relations and Responsibility to the Public) Disposal of Material Outside Highway Right of Way", of the Standard Specifications, and any salvaged material will be salvaged in accordance with Subsection 202.03.08, "(Removal of Structures and Obstructions) (Construction) Salvage", of the Special Provisions.

Coldmilling is a technique for removing a portion of the asphalt or concrete pavement. Coldmilling, or rotomilling, involves specialized equipment that removes the material to a desired depth to restore the surface to the grade and slope shown in the project plans. Pavement material picked up during the coldmilling process can be recycled for use on the same job or on future projects. Subsection 202.03.08 of the Special Provisions contain the information for the salvage and use of coldmilled bituminous material. When removing surface materials using methods other than coldmilling, the inspector will give attention to the removal method and removal limits identified in the contract documents.

BEFORE CONSTRUCTION

Before work begins, the Resident Engineer, inspectors and the Contractor shall discuss the work to be performed, including special situations or details and resolve issues regarding limits of removal, salvage, storage and disposal of obstructions and materials. Accommodations for traffic shall be considered for all removal items.

The inspector will ensure that all stakeout or marking of structures and obstructions designated for removal are complete prior to removal. Structure removal may include coldmilling of concrete and asphalt pavements. The Resident Engineer will coordinate with the Contractor for disposal or reuse of the milled materials.

When blasting is necessary to remove obstructions, the Contractor prepares a safety plan in accordance with the applicable regulatory agencies and ensures that the plan is in accordance with Subsection 107, "Legal Relations and Responsibility to the Public", of the Standard Specifications and Subsection 108.04, "(Prosecution and Progress) Limitation of Operations", of the Special Provisions. All personnel involved in the blasting operation shall follow the plan. Although the Contractor is liable for damage incurred by the blasting operations, the Resident Engineer and inspectors should address any unsafe or hazardous conditions that can exist.

DURING CONSTRUCTION

Follow these guidelines for disposing of objectionable material during construction:

- Refer to Subsection 107.14, "(Legal Relations and Responsibility to the Public) Disposal of Material Outside Highway Right of Way", of the Standard Specifications for procedures on disposing of material outside the right-of-way.
- In disposal areas that are within the right-of-way, refer to Subsection 202.03.09, "(Removal of Structures and Obstructions) (Construction) Disposing of Materials", of the Standard Specifications. The material shall have a finished appearance.
- In mountainous areas, be aware that disposal sites above the roadway grade may present sliding or maintenance problems. Before approving disposal sites above roadways, the Resident Engineer will evaluate the potential for slides and maintenance problems.
- Avoid disposing of material in a manner that alters existing drainage patterns.
- When removing concrete pavements, curb and sidewalk, existing joints are sawcut to provide a clean separation between remaining and removed concrete. The contract documents require the Contractor to sawcut existing bituminous surface at the limits of removal. The Resident Engineer may modify removal limits based on field conditions.

When removing asphalt by coldmilling, refer to the specific requirements of the contract documents. In addition, the inspector will:

- Monitor the coldmilling depth to confirm compliance with the project plans.
- Verify that stockpiles of milled material do not become contaminated.
- Confirm that the Contractor's utilization and disposal of milled materials is as stated in the contract documents.
- Notify the Resident Engineer of any delamination or stripping areas; use miscellaneous coldmilling where applicable for delaminated or stripped areas.
- Discuss coldmilling texture (drum type), depth uniformity, delaminations, grade control, cross slope, transitions and sawcuts at intersections with the Contractor.
- Ensure that coldmilling placed as shouldering material is in accordance with contract documents and "307 - Shouldering Material", in this chapter.

Removal of a bituminous pavement from a bridge deck involves removing the bituminous surface while protecting the remainder of the bridge deck. The inspector will ensure that the Contractor uses the approved method for removal of bituminous surface on bridge decks, and that the Contractor does not damage the bridge deck. Store salvaged materials in designated areas.

MEASUREMENT AND PAYMENT

Refer to Subsection 202.04.01, "(Removal of Structures and Obstructions) (Method of Measurement) Measurement" and Subsection 202.05.01, "(Removal of Structures and Obstructions) (Basis of Payment) Payment", of the Standard Specifications and Chapter 5 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

203 - EXCAVATION AND EMBANKMENT

Excavation and embankment involves excavating material or similar material and constructing embankments. More specifically, it may include furnishing, hauling, stockpiling, placing, disposing, sloping, shaping, compacting and finishing embankment material. This work may also consist of performing slope scaling and placing geotextile fabric, as required in Section 203, “Excavation and Embankment”, of the Standard Specifications.

BEFORE CONSTRUCTION

Inspection of embankment and excavation operations requires monitoring of several concurrent activities. Effectively monitoring these activities requires the inspector to be familiar with the following:

- Slope staking
- Profile sheets, ditch sheets, summary sheets and typical cross-sections (Contact the Design Division for profile sheets)
- Material sources
- Drainage improvements
- Testing requirements
- Roadway prism (comprised of the roadway surface and the side slopes that integrate the roadway into the surrounding topography)

Before the Contractor begins work, the survey crew typically takes cross-sections every 1,000 feet to verify the original ground elevations used for the design. In variable terrain, field checks are performed at closer intervals. Cross-sections taken before the Contractor begins work are useful in resolving disputes relating to excavation quantity.

During the design phase, the Design Division may identify a need for embankment material. When material is excavated, the volume increases because the material is loose or uncompacted. The difference in volume, expressed as a percentage, is called the swell factor. When material is compacted, the volume decreases. This difference in volume is called the shrink factor. Shrink and swell factors are calculated based on soil type.

Shrink and swell factors are listed in the project plans. Typically, excavation quantities are calculated based on the amount of embankment required. The amount of excavation is estimated by determining the amount of embankment required, then dividing the embankment amount by the difference of 100 percent and the shrinkage factor.

When conditions such as unsuitable material are within the project limits, placement of a geotextile or a geogrid may be required. Geogrids and geotextiles are made of synthetic (manmade) material, typically polypropylene. Geogrids are synthetic materials with uniform openings that resemble netting, and are used to reinforce soil. Geotextiles are permeable fabrics that are either woven (looks like burlap), non-woven (looks like felt) or heat bonded (looks like ironed felt). Geotextiles are used for the following purposes:

- Separation: The geotextile separates and prevents mixing of two layers of soil having different particle sizes or properties.
- Drainage: The geotextile collects water and drains it.
- Filtration: The geotextile acts as a filter between soil and a drain material, allowing water and small soil particles to pass through the filter.
- Reinforcement: The geotextile provides strength to reinforce soil.

Geotextiles and geogrids shall conform to the requirements contained in Section 731, "Engineering Fabrics" of the Standard Specifications, which describe the physical characteristics such as tensile strength, stretch or elongation, puncture strength, average opening size, weight and ultraviolet resistance.

If, during construction, unsuitable and unexpected material are encountered, notify the Resident Engineer. Methods for identifying unexpected/unsuitable materials include but are not limited to:

- Visual identification of change in material.
- Failing test results.
- Change in compactive effort.
- Contaminated and/or foreign materials.
- Significant changes in moisture content.

The Contractor's means and methods for earthwork operations vary by site and material conditions, preferences and resources. Specifications typically describe acceptable equipment that the Contractor may use for compaction. When material must be hauled on existing roads or streets, ensure that the Contractor follows all regulations for weight restrictions.

For various soil types, the Contractor selects the appropriate equipment:

- Steel wheel roller (vibratory or non-vibratory): For granular materials, the Contractor may use vibratory steel wheel rollers. The vibratory roller effectively compacts clean, granular soils containing little or no clay particles. The vibratory roller can vibrate a uniform, granular soil to high density. The vibratory roller becomes less effective, however, as the amount of clay particles increases.
- Sheepsfoot roller: These most effectively compact clays and silts. They work well in cohesive soils, but will compact most soils containing granular material if the soil contains a reasonable proportion of cohesive material. Tamping foot and sheepsfoot rollers can operate in only about a 6-inch lift because of the length of their feet (protrusion) from the drum. In thicker lifts, the drum will ride on the surface of the loose soil and the feet will not reach into and compact the lower portion of the lifts.
- Pneumatic tired roller: Applies a kneading action on the material, which can increase the compactive effort for fine grained soils such as silty clays.

Figure 1: Steel wheel vibratory roller

Figure 2: Sheepsfoot roller

Figure 3: Pneumatic tired roller

Slopes are usually finished with motorized equipment. The type of equipment varies depending on slope steepness, access, type of material and availability of equipment. Although the type of equipment used is the Contractor's decision, it must produce acceptable results.

The success of constructing an embankment depends on the proper preparation of the foundation. Specifications may describe requirements, such as benching, related to constructing embankments. The inspector will monitor construction of embankment to confirm that slippage planes, areas of soft materials and water in the form of springs or seeps are addressed. Identifying possible problems and discussing them with the Contractor before work begins can reduce disruption during construction.

Blasting, which loosens solid rock outside of the planned slopes, requires strict adherence to safety measures because of the potential for flying debris and slides. The Contractor prepares a safety plan in accordance with the applicable regulatory agencies and ensures that the plan conforms with Section 107, "Legal Relations and Responsibility to the Public", of the Standard Specifications and Subsection 108.04, "(Prosecution and Progress) Limitation of Operations", of the Special Provisions.

On projects that require shaping slopes or removing rock debris, review the requirements described in the contract documents. Depending on the complexity of the slope scaling, a Contractor may be required to submit qualifications to perform the work. In addition to providing qualifications, a Contractor may be required to provide a submittal or fulfill other requirements as described in the contract documents. Review ingress and egress to work areas, haul routes and traffic control requirements with the Contractor.

DURING CONSTRUCTION

ROADWAY EXCAVATION

During roadway excavation, as defined in Subsection 203.02.02, "(Excavation and Embankment) (Materials) Roadway Excavation", of the Standard Specifications, verify proper elevations, depth of excavations and conformance to the typical sections shown in the project plans. The inspector will consult with the surveyor for cross-sections of the existing roadway prism and check for conformity with the contract documents. Notify the Resident Engineer of any discrepancies.

UNSUITABLE MATERIAL

Unsuitable material, as defined in Subsection 203.03.02, "(Excavation and Embankment) (Construction) Unsuitable Material", of the Standard Specifications, is any material that adversely affects roadbed stability. During roadway excavation, unforeseen conditions, such as unsuitable materials, may be encountered. Preliminary investigations may identify materials as being unsuitable for roadway construction. The contract documents identify these areas and the measures that the Contractor shall take. The Resident Engineer will contact the Materials Division's Geotechnical Section for direction when the contract documents do not address unsuitable materials. The Resident Engineer directs the Contractor to remove and dispose of unsuitable material encountered. After consulting with the Materials Division, the Resident Engineer directs the Contractor on the limits of removal.

Contact the Resident Engineer to determine the payment method for excavation and disposal of unsuitable material that is not shown in the contract documents.

DRAINAGE EXCAVATION AND CHANNEL EXCAVATION

Excavation for the construction of open ditches is performed as a drainage excavation or a channel excavation in accordance with Subsection 203.02.03, "(Excavation and Embankment) (Materials) Drainage Excavation" and Subsection 203.02.04, "(Excavation and Embankment) (Materials) Channel Excavation", of the Standard Specifications. When an open ditch is modified, ensure that existing open ditches are properly connected to new construction.

After ditch construction, assess the ditch's ability to pass runoff without causing erosion or other damage. Notify the Resident Engineer of any potential issues.

EMBANKMENT

An embankment refers to a volume of material that is placed and compacted to raise the grade of a roadway above the level of the existing surrounding ground surface to the subgrade.

Embankment is constructed from excavation and/or borrow. Excavation can be obtained from roadway, drainage channels and/or structure, and it is paid according to the excavation item. Borrow is required when excavation quantities are not sufficient to complete embankment to subgrade elevation and is paid for as borrow embankment or borrow excavation.

NOTE: Embankment is neither a pay item nor a bid item.

BORROW

If the quantity of roadway excavation material is insufficient to construct an embankment, the additional material imported is called borrow. Borrow material, as defined in Subsection 203.02.05, "(Excavation and Embankment) (Materials) Borrow", of the Standard Specifications, is used to balance the embankment quantity and can be either excavated from a location on the job site outside of the roadway prism or from an offsite material source. If the excavated material is unsuitable for use as embankment, the material is disposed of and borrow material is placed in the embankment. Typically, the contract documents designate a borrow material source.

When the excavation is substantially complete, the need for borrow material is confirmed. If additional borrow material is needed, the location where the borrow will to be obtained is cleared and grubbed, and then cross-sectioned. Borrow measured in this manner is called borrow excavation. In urban areas, borrow may be obtained from a variety of locations and is measured in-place. Borrow measured in this manner is called borrow embankment.

If final measurements are necessary, the site is cross-sectioned again to determine the volume of material excavated. Although quantities shown in the project plans may be used for payment, the Resident Engineer may use or the Contractor may request payment based on quantities calculated from initial and final cross-sections.

SELECTED BORROW

Selected borrow, as defined in Subsection 203.02.06, "(Excavation and Embankment) (Materials) Selected Borrow", of the Standard Specifications, is the same as borrow but with tighter specifications. Contract documents will show the limits of the material, although this can vary based on type structure (typically a bridge abutment) and should be closely coordinated with the Structures Division.

SURPLUS MATERIAL

If a project requires excavation of more material than can be used in the embankment, the excess is called surplus material. As soon as possible, the Resident Engineer should reconcile preliminary quantity calculations, including shrinkage and swell factors, with actual quantities and factors. Deviations may require wasting of material, adjustments in haul, or adjustments in grade or alignment. When wasting surplus material, the Resident Engineer will consider flattening slopes to provide additional recovery areas for vehicles.

Plans typically direct the Contractor to place surplus material alongside an embankment, between embankment and right-of-way lines, or in interchange areas, if such areas are available. The Contractor shall dispose of surplus materials in areas that will not interfere with drainage, will benefit future improvements, or will improve the appearance or stability of the roadway. Surplus material placed adjacent to an embankment shall be compacted. If the contract documents do not address the disposal of surplus material, the Contractor shall dispose of the surplus material with no additional payment.

SELECTED MATERIAL

Selected material is typically used for structure backfill, topsoil, or for other purposes shown in the project plans. Selected material shall meet requirements of the contract documents. The Contractor shall not use selected material for any purpose other than that designated in the contract documents unless approved by the Resident Engineer.

SLIDES AND SLIPOUTS

Slides and slipouts are unplanned earth movements. When a slide or slipout has occurred, corrective action or resloping a slide area may be required. The Resident Engineer will refer to the Materials Division's Geotechnical Section to determine corrective actions.

FOUNDATION FOR EMBANKMENT

The inspector will monitor construction of the embankment foundation to verify proper preparation. The following conditions may require corrective measures for a proper foundation:

- Proper compaction of the original ground
- Drainage seepage
- Springs
- Lush growth of vegetation in local areas, indicating ground water
- Trees and brush leaning downhill, indicating slippage of the surface mantle
- Rolling terrain
- Twisted trees or lack of vegetation in otherwise timbered areas, indicating a large slide

The following are common causes of embankment failure:

- The weight of the embankment displaces or consolidates material in the foundation.

- The embankment traps water in the foundation which forces the water to escape at the edges of the embankment, causing sloughing of the embankment.
- The embankment moves on a slippage plane in the underlying foundation.

If any failures occur, the Contractor shall submit a plan for corrective measures and the Resident Engineer will contact the Materials Division's Geotechnical Section for guidance.

When embankment material contains scattered boulders, the Contractor shall distribute the boulders throughout the fill. Rock fills are constructed with a bulldozer to manipulate the rock into a compact mass. The Contractor shall water the boulders and rock fills to wash fine material into the voids. In swampy or marshy areas, uncompacted thick layers of rock are placed across the area to act as a bridge over the marshy area. Typically, the Contractor installs settlement-measuring devices in large embankments or surcharge areas and the Resident Engineer's survey crew monitors the settlement. The Materials Division typically directs the placement of settlement measuring devices.

If embankment settlement is anticipated, the survey crew will offset slope stakes to allow for the anticipated settlement. After settlement occurs, the offset slope stakes remain valid for the settled embankment.

COMPACTION

Compaction directly affects the ability of soil to support vertical forces such as soil, water-bearing soil and traffic loadings. (Insufficient compaction reduces the supporting strength needed for subsequent layers.) The Contractor may use a variety of methods to achieve the required compaction. The inspector will not direct the Contractor's compaction operation, but will monitor the thickness of the material layer placed by the Contractor to verify that the Contractor does not exceed thicknesses allowed by Section 203, "Excavation and Embankment", of the Standard Specifications. Refer to the *Field Testing Guide* for testing requirements.

Successful compaction depends on uniform moisture content in the material. The Contractor may do the following when working with soil and moisture:

- Some soil materials do not mix with moisture as easily as others do. The Contractor may mix or manipulate the soil and water with a bulldozer, disk, or motor grader.
- Contractors may apply water during excavation to improve the mixing of water and soil. Applying water during excavation allows additional mixing time during excavating, loading, unloading and placing of the material.
- When experiencing soil moisture difficulties, the Contractor mixes soil and moisture and then compacts the mixed material in thinner layers.

In confined areas, the Contractor obtains compaction by watering and using small manual or motorized compaction equipment such as hand tampers, vibrating hand compactors, small hand-operated motorized rollers, or impact-type compactors. For rock fills, the Contractor may use the proof rolling method for compaction. Proof rolling is repeatedly driving over the fill with a loaded truck, heavy equipment, or roller until no deflection is observed in the surface of the material being compacted. Section 203 of the Standard Specifications describe acceptable methods of proof rolling. The Resident Engineer should not allow proof rolling unless the material has a significant quantity of rock greater than 4 inches.

When haul vehicles travel over the embankment material, the Contractor shall stagger the vehicle paths so that as much of the fill area as possible is compacted.

SLOPE SCALING

Slope scaling is the process of removing loose rock debris from a slope. Slope scaling can be the first step in stabilizing a slope from further rock debris accumulation. Rock debris can create an unsafe condition for traveling motorists due to the potential for falling rocks. Scaling is performed with hand tools or power tools such as jackhammers, hydraulic splitters, drills, crowbars, pry bars, jacks and shovels. Heavy equipment is used when hand tools are inadequate. Blasting removes larger wedges of fractured material and overhanging cemented soils, but may be used only with prior approval. Caution is taken to prevent over steepening of the slope face, which may make the slope unstable.

Review the contract documents for qualification and submittal requirements. The Resident Engineer shall consult with the Materials Division's Geotechnical Section to understand the intent of the slope scaling project. In addition, the Resident Engineer invites a representative from the Geotechnical Section to the Pre-Activity Meeting.

Slope scaling begins at the top of the slope and proceeds down slope, removing rock. The Contractor removes or stabilizes material on the slope face that is loose, hanging, or creating a dangerous situation. Qualified scalers (workers that traverse the face of a slope while attached to ropes) perform slope scaling.

If the potential exists for damage to the roadway during scaling operations, the Contractor shall use protective mats or a soil cover on the roadway for protection. Before work begins, the Contractor shall obtain approval to place a temporary protective barrier, which prevents the slope material from reaching the travel lane that is open to traffic, at the near edge or center of the roadway. The Contractor shall maintain this barrier during slope scaling operations. The Contractor bears the costs for repairing any damage to the roadway. The Contractor reshapes ditches after work is complete so all water drains freely. The Contractor shall clean debris from the roadway before traffic is returned to the roadway.

GEOTEXTILE

When geotextiles are specified to address unsuitable soil conditions, the inspector verifies that the material delivered to the job site conforms to the requirements of Section 731, "Engineering Fabrics", of the Standard Specifications. The inspector will also verify that the certificate of compliance that accompanies the geotextile delivered to the site in accordance with Section 731 of the Standard Specifications. The Contractor shall stockpile geotextile fabric in a manner that protects it from moisture and sun exposure. If the fabric is stored outdoors, the geotextile rolls shall be stored off the ground.

Prior to placing geotextiles, the inspector will confirm that the surface that receives the geotextile has been properly prepared. The surface should be smooth and free from cavities, large stones, or other irregularities that could puncture or damage the geotextile.

Geotextiles are placed by unrolling the fabric onto the surface. Adjacent pieces of geotextile may be joined by sewing or by overlapping. Contractors typically overlap geotextiles. The inspector will review the contract documents to identify seam or overlap requirements. Prior to placing material over the geotextile, confirm that the geotextile is smooth and without gaps, tears, folds, wrinkles or stretching. Do not operate equipment on the exposed geotextile.

Overlying material is placed on the geotextile by dumping from the edge of the geotextile or from previously placed lifts. The Contractor shall exercise care during placement of overlying material to ensure that the geotextile is not damaged. To protect the geotextile from damage, the Contractor may reduce the size of the equipment used to place the overlying material or reduce the size of the loads being placed on the geotextile. Damaged geotextile shall be repaired or replaced before material is placed on it.

MEASUREMENT AND PAYMENT

Refer to Subsection 206.04.01, "(Excavation and Embankment) (Method of Measurement) Measurement" and Subsection 203.05.01, "(Excavation and Embankment) (Basis of Payment) Payment", of the Standard Specifications and Chapters 6 and 14 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

206 - STRUCTURE EXCAVATION

Structure excavation is the removal of materials to accommodate the construction of structures such as culverts, drainage structures, abutments and footings.

BEFORE CONSTRUCTION

Before excavation begins, the Contractor shall submit a safety plan to the Resident Engineer that includes detailed shop drawings of any shoring, cribbing, sloping or other protective systems that conform to the contract documents and Occupational Safety and Health Administration (OSHA) regulations.

At least 2 weeks before excavation begins, coordinate with the Contractor to reduce possible problems regarding measurements for payment. The Contractor may excavate outside of the excavation limits shown in the project plans, at no cost to the Department, but the Contractor cannot excavate to less than the prescribed limits because of possible interference with backfill or testing operations.

DURING CONSTRUCTION

Observe excavation operations as they progress so that alterations or changes can be made without causing delays. Observe safety procedures during excavation and throughout the installation process.

Inspect excavation depth and verify that the compaction of the excavation floor meets the requirements of the contract documents before the Contractor constructs or installs the structures.

MEASUREMENT AND PAYMENT

Refer to Subsection 206.04.01, "(Structure Excavation) (Method of Measurement) Measurement" and Subsection 206.05.01, "(Structure Excavation) (Basis of Payment) Payment", of the Standard Specifications and Chapter 14 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

207 - BACKFILL

Backfill includes placing and compacting material in excavations for bridges, retaining walls, headwalls, culverts and other structures. Improper backfilling can cause future failures of culverts or structures.

BEFORE CONSTRUCTION

Before backfill activities begin, the inspector will review the locations where culverts and other structures require backfill. The inspector will also note the different types of backfill, such as backfill from the excavation, granular backfill or slurry cement backfill, and will review Section 207, "Backfill", of the Standard Specifications to determine which one the Contractor will use. The use of "pea gravel" is prohibited. The Contractor may stockpile approved backfill material near the structure site where the backfill material will be used.

The inspector will coordinate with the Contractor for efficient inspection and testing activities. The inspector will discuss with the testers to verify that the backfill material meets requirements before it is used. The inspector will confirm the source for backfill material has received source acceptance from the Materials Division.

DURING CONSTRUCTION

Place backfill uniformly on all sides of the structure. Unequal backfilling may push the structure out of line or subject it to stresses. The inspector should be aware of the maximum allowable placement depth of each layer, typically 8 inches, and observe that the Contractor adheres to the specification requirement. The inspector will closely monitor the compaction operations. Although it is difficult for the Contractor to compact backfill under the pipe haunches (refer to "601 - Pipe Culverts: General", in this chapter, for more information), compacted material under the haunches is necessary to support the pipe. In addition, the Contractor shall not over-compact the backfill, which can lift the pipe out of position. Compaction testing is performed consistent with requirements of the applicable *Minimum Required Samples and Tests: Project* table.

MEASUREMENT AND PAYMENT

Refer to Subsection 207.04.01, "(Backfill) (Method of Measurement) Measurement" and Subsection 207.05.01, "(Backfill) (Basis of Payment) Payment", of the Standard Specifications and Chapter 6 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

209 - DRAIN BACKFILL

When water is encountered below grade, trenches are constructed to intercept and remove water from the embankments or excavated areas. Typically, these trenches contain perforated pipes that allow groundwater to enter the pipe and flow from the area. The gradation of drain backfill allows water to pass through the backfill and enter the pipe. These trenches typically involve considerable quantities of excavation, drain backfill, geotextile and perforated underdrain pipe.

BEFORE CONSTRUCTION

Review the contract documents to determine locations, limits and requirements for drain backfill. A thorough understanding of the trenching and backfill requirements helps to reduce problems during construction. For more information regarding trench construction and materials placement, refer to "607 - Underdrains", in this chapter.

DURING CONSTRUCTION

Drain backfill allows water to drain from the surrounding soil and enter the underdrain pipe. Therefore, to ensure a fully functioning underdrain, the backfill requires a specified gradation, adequate compaction and proper trench bedding. The Contractor may need to remove water from the trench during construction to allow equipment and laborers to construct the drainage system properly.

MEASUREMENT AND PAYMENT

Refer to Subsection 209.04.01, "(Drain Backfill) (Method of Measurement) Measurement" and Subsection 209.05.01, "(Drain Backfill) (Basis of Payment) Payment", of the Standard Specifications and Chapters 6 and 14 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

211 - EROSION CONTROL

*NOTE: This section works in conjunction with "*212 - Landscaping and Aesthetics*", in this chapter.*

Erosion control consists of construction or installation of permanent pollution and erosion control measures. These measures reduce air pollution, erosion, sedimentation and pollution of water and wetlands that a completed roadway project can cause. Pollution control measures related to construction activities are contained in "637 - Temporary Pollution Control", in this chapter, and in Subsection 637, "Temporary Pollution Control", of the Standard Specifications.

Erosion and sediment control measures properly applied are key elements in preventing water and air pollution.

BEFORE CONSTRUCTION

Before work begins, the inspector will:

- Ensure that the necessary temporary pollution control measures and environmental requirements are in place.
- Ensure that any hazardous materials have been mitigated in accordance with contract documents.
- If topsoil is imported:
    - Ensure the topsoil is in accordance with Subsection 726.02.01, "(Roadside Materials) (Requirements) Certificates and Samples", of the Standard Specifications.
    - Ensure that the all certifications have been submitted prior to placement of topsoil.
- If topsoil is salvaged, ensure that the topsoil is in accordance with Subsection 211, "Erosion Control", of the Standard Specifications.
- Ensure that the Contractor uses seeds, fertilizers, inoculants and amendments that are packaged and show content analysis, and that the contents on the packaging (or certification of the seed or fertilizer) are in accordance with Subsection 726.03.11, "(Roadside Materials) (Physical Properties and Tests) Seeds", of the Standard Specifications.
- Inspect each bag of seed to ensure compliance prior to application.

DURING CONSTRUCTION

When monitoring the Contractor's operations, the inspector will:

- Review Section 211, "Erosion Control", of the Standard Specifications, for project-specific requirements.
- Ensure topsoil required to be salvaged from the contract is stockpiled in accordance with Subsection 211.03.01, "(Erosion Control) (Construction) Topsoil (Salvage)", of the Standard Specifications.
- Identify any changes in equipment and/or labor force in effect.
- Document any hazards and inform the Resident Engineer and the Contractor; ensure that safety measures have been safely implemented.
- Prior to seeding, identify the slope of the area to be seeded and ensure the application is correct for the area (slopes 3:1 and flatter = drillseeding, slopes steeper than 3:1 = hydroseeding).
- Ensure that the Contractor follows the manufacturer's recommendations and that the topsoil, compost, seeds, fertilizers, inoculants or amendments are uniformly spread at the specified rate or depth. For additional information about planting and fertilizing, refer to "212 - Landscaping and Aesthetics", in this chapter.

MEASUREMENT AND PAYMENT

Refer to Subsection 211.04.01, "(Erosion Control) (Method of Measurement) Measurement" and Subsection 211.05.01, "(Erosion Control) (Basis of Payment) Payment", of the Standard Specifications and Chapters 6 and 7 of the *Documentation Manual* for measurement/payment guidelines and/or related instructions.

212 - LANDSCAPE AND AESTHETICS

Landscaping consists of preparing areas for planting; applying pesticides and fertilizers; and furnishing, planting, and maintaining plants. The Resident Engineer should adjust the locations of shrubs and trees to avoid obstacles whenever possible. Generally, mature trees are placed more than 30 feet from the traveled way if they will grow to or have a diameter of 4 inches or more. Landscaping is placed to meet the intended look and purpose, as planned by the landscape designer.

The inspector will be aware of the appearance and intent of the landscape design. The landscape designer should be contacted to determine what changes may be acceptable, if changes are needed. Field adjustments for placement of landscape elements may be required when impacting site distance of the traveling public.

BEFORE CONSTRUCTION

The Resident Engineer shall determine if container grown plants furnished by the Contractor are acceptable and meet the requirements of the contract documents. The inspector can make this determination by visual inspection after removing the plants from the containers.

When evaluating container grown plants, the inspector will:

- Verify the correct variety and size as identified in the Plant Schedule or Plant Legend identified on the contract documents within the landscaping sheets.
- Rejection of plants may be based upon, root condition, size (above ground), insects, disease, general appearance, damage or missing identification labels.
- Confirm that the Contractor stores containerized plants in a protected and shaded area.
- Monitor plants to confirm the Contractor keeps plants moist at all times. The ball of earth around the plant roots must be wet at all times. Plants in containers are more exposed to wind and heat and dry out more readily.
- Verify that the Contractor only removes plants from the container when planting.
- Verify that the Contractor cuts back container grown plants as necessary to encourage plant growth while being stored in the storage area.

Refer to the contract documents for additional information on quality, handling, inspection and storage of potted plants. Contact the landscape designer regarding questions related to planting.

DURING CONSTRUCTION

Site preparation varies according to the bid items in the contract estimate. Understand the relationship of the, Clear and Grub and Salvage Topsoil items, have on the site preparation for planting. After planting, the Contractor shall control weed growth during the plant establishment period.

Except on slopes, follow this common planting process:

- Dig the planting holes for container grown plants. Dig to the required depth below the bottom of the completed basin.
- Mix the fertilizer with the backfill material in the planting hole. Thoroughly mix the fertilizer with the backfill material to the full depth of the planting hole.
- Saturate the mixture before constructing the basin and basin walls to the specified size. Thoroughly saturate the backfill mixture to the depth of the drilled hole. Occasionally, when planting slope areas, the basin is formed first.

The Resident Engineer determines which rocks to remove. Typically, only large rocks that will interfere with planting operations are removed from the planting area.

Construct basins and basin walls to the planned dimensions before planting. After the backfill material is saturated in the planting holes, the inspector will observe that the material has settled and that it retains sufficient moisture before the Contractor places the plant in the basin.

The Contractor shall not tamp or compact the backfill around the plant roots. Tamping or compacting around the plant root inhibits the natural penetration of water around the plant.

The Contractor shall plant trees and shrubs before ground cover plants and turf. To prevent unnecessary compaction of the soil, the Contractor shall keep foot traffic to a minimum after planting ground cover plants.

When planting trees, the Contractor shall:

- Securely stake and tie trees as soon as possible after planting. If trees are not staked immediately after planting, the wind tends to shift and move the trees and damage them.
- Place ties sufficiently high on the tree to contain the major portion of the top growth.
- Do not damage the plant ball when driving stakes.
- Place the mulch, if required, as soon as possible after planting to retain moisture and discourage weed growth. An exception is during extremely wet weather when trampling the areas while placing the mulch would compact the soil and the mulch would hold excessive moisture around the plant.

With the initial watering, the inspector will closely monitor the amount of water applied, and the manner in which it is applied. The Contractor waters most plants immediately after planting them. Following the initial watering, the Contractor shall water all plants and planted areas as often as conditions require. Ultimately, the Contractor shall keep the plants in good growing condition through the time of final acceptance (the “plant establishment” period; a 1-year period). During the plant establishment period, the inspector completes NDOT form 040-046 (Monthly Summary of Plant Establishment Activities). Refer to Subsection 212.03.09, “(Landscape and Aesthetics) (Construction) Plant Establishment Work”, of the Standard Specifications for additional requirements related to the plant establishment period. The Resident Engineer will not direct the Contractor on watering activities, but will advise the Contractor if the plant conditions deteriorate and watering can correct the condition.

INSPECTION

The inspector will:

- Inspect planted and stored plants weekly.
- Mark unhealthy plants for removal
- Inspect replacement plants before planting.
- Coordinate final inspection with the Contractor.
- Follow any requirements for plant establishment and document timeframes to verify specification conformance.

The Resident Engineer should coordinate attendance of the landscape designer and the District landscape maintenance supervisor.

MEASUREMENT AND PAYMENT

Refer to Subsection 212.04.01, “(Landscape and Aesthetics) (Method of Measurement) Measurement” and Subsection 212.05.01, “(Landscape and Aesthetics) (Basis of Payment) Payment” of the Standard Specifications and Chapter 7 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

213 - IRRIGATION SYSTEMS

Irrigation systems are installed to apply water to roadway landscaping. The contract documents provide detailed requirements for irrigation systems. Except for a small piece of Interstate 80, NDOT no longer maintains irrigation systems.

They will only be installed at the request of an outside entity and could be required to meet the entity's specifications and material requests.

BEFORE CONSTRUCTION

The inspector obtains representative samples of pipes and fittings proposed for use in the watering system. In most cases, sprinklers and valves are clearly marked with the manufacturer's name and model number and are not tested for compliance. (The project plans provide a diagram layout of the watering system.) The inspector can adjust the installation as needed to avoid conflicts.

The Resident Engineer coordinates with the District utility inspector who works with the utility companies to obtain power and water for the irrigation system. If water and electrical services have not been completed, coordinate service points and meter locations with the District utility representative. Verify the availability of water in the quantities and the pressure required for the irrigation system.

DURING CONSTRUCTION

The Contractor may make adjustments to the irrigation to obtain complete and uniform coverage. These adjustments are made because of variations in water pressure, slope or size of the coverage area. The inspector will:

- Inspect the installation and location of backflow preventers to verify conformance to the requirements of local codes and contract documents.
- Inspect the installation of gate valves and unions on each side of the backflow preventer.
- Observe trenching and the placement of conduit and pipe.
- Measure the depths and setbacks of irrigation lines to verify conformance with the contract documents.
- Not allow backfilling until all piping has been inspected, pressure tested, and accepted.

The Contractor shall locate and repair leaks and repeat the test as many times as necessary to obtain satisfactory test results. The Contractor shall also refill trenches that have settled below the level of the surrounding area.

MEASUREMENT AND PAYMENT

Refer to Subsection 213.04.01, "(Irrigation Systems) (Method of Measurement) Measurement" and Subsection 213.05.01, "(Irrigation Systems) (Basis of Payment) Payment", of the Standard Specifications and Chapter 7 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

214 - MAILBOX SYSTEMS

This section includes the removal of existing mailboxes, the relocation of mailboxes, and the installation of new mailboxes. Close coordination with the United States Postal Service and the mailbox owner is important to ensure that no disruption of mail delivery service occurs and to reduce owner complaints. For more information, refer to Subsection 108.04, "(Prosecution and Progress) Limitation of Operations", of the Standard Specifications.

BEFORE CONSTRUCTION

The Contractor, the Resident Engineer, the United States Postal Service and the owner shall coordinate and plan mailbox placement before construction begins. In addition, the inspector will document the condition of existing mailboxes, including photographs. Mailboxes may need to be moved several times during construction. If possible, mailboxes shall be set once, at their final location.

DURING CONSTRUCTION

Any mailbox relocation for Contractor convenience is the Contractor's responsibility. The Contractor shall maintain proper position and access to mailboxes for postal deliveries and owner pick-up. The Contractor shall also coordinate with the United States Postal Service 5 working days before any mailbox installation or relocation, and then inform the owner of scheduled removal or installation.

MEASUREMENT AND PAYMENT

Refer to Subsection 214.04.01, "(Mailbox Systems) (Method of Measurement) Measurement" and Subsection 214.05.01, "(Mailbox Systems) (Basis of Payment) Payment", of the Standard Specifications and Chapters 5 and 19 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

302 - AGGREGATE BASE COURSES

The project plans include roadway cross-sections that detail where to place aggregate base, and to show the aggregate base thickness.

The Department distinguishes aggregate bases by type, as defined in to Section 704," Base Aggregates", of the Standard Specifications, and by the manner in which the material is processed and placed on the roadway, as defined in Section 302, "Aggregate Base Courses", of the Standard Specifications:

- Class A aggregate is mixed with water before delivery to the roadway, where it is placed and spread in a single operation.
- Class B aggregate is typically mixed with water, and processed on the roadway before being spread and compacted.

Because Class A aggregate requires greater control in processing, placing, and spreading than Class B aggregate, Class A aggregate is typically more costly than Class B. The Contractor is not required to mix Class B aggregate in a mixer; but if the Contractor elects to do so, payment is made only at the Class B aggregate price. For the aggregate base requirements, refer to Section 302 of the Standard Specifications. It is important the material being placed, whether Class A or Class B, is consistently proportioned and of uniform moisture. Consistency in proportion and uniform moisture will reduce the potential for defects and aid in compaction efficiency.

CLASS A AGGREGATE BASE

Class A aggregate is mechanically mixed to create a homogenous material. This processing takes place at a central mixing plant before delivery to the roadway. After transport to the roadway, the Contractor places and spreads the processed aggregate in a single operation using a self-propelled spreader with a screed. (See Figure 4.) If approved by the Resident Engineer, the Contractor may use a motor grader if the blade is equipped with wings, the blade is locked into position and the blade has an electronic grade-sensing device. Once the aggregate is placed, the Contractor compacts it to the required density and trims it to the required elevation.

Figure 4: Class A aggregate spreader

BEFORE CONSTRUCTION

In reviewing the contract documents, pay attention to the following areas:

- Material gradation
- Moisture content
- Mechanical mixing requirements
- Placement and spreading method
- Typical sections and profile sheets
- Compaction requirement
- Surface tolerance
- Weather limitations
- Measurement and payment

Before the Contractor delivers aggregate for placement, the inspector coordinates and schedules required testing with the field tester. Before placing the aggregate, the Contractor finishes the subgrade. The subgrade is acceptable when compaction tests have been taken and have passed minimum requirements. To determine if the grade and surface tolerances are acceptable, the inspector confirms that the subgrade has been graded to the correct elevation. The inspector then checks the subgrade surface for defects. Refer to the *Construction Survey Manual* for additional guidance.

Figure 5: Setting grade controls for machine placement

Before placement, determine which equipment the Contractor plans to use for aggregate and water mixing, and for spreading and placement. Confirm that the equipment in accordance with Subsection 302.03.02, "(Aggregate Base Courses) (Construction) Spreading Class A Aggregates", of the Standard Specifications. Ensure that the proper depth is achieved in accordance with Subsection 302.03.06, "(Aggregate Base Courses) (Construction) Compaction", of the Standard Specifications. The Contractor and the surveyor need to confirm that sufficient grade controls are in place. The Contractor can then use the established grade controls for the automated grade control operation, such as a wire line, a common technique in which a wire is set along the roadway shoulder. Placement equipment electronically senses the wire elevation and adjusts the grade of the aggregate base.

DURING CONSTRUCTION

As the material arrives at the roadway, the inspector monitors the placement and spreading operation. Observe that the aggregate remains homogenous and is moist. A homogenous mix reduces the potential for defects. With the proper moisture content, the Contractor can efficiently achieve compaction. Contact the tester for the optimum moisture content.

As the material spreading progresses, the surveyor will periodically check that the Contractor is constructing the proper grade. The inspector will continuously monitor the finished surface to verify conformance with the contract documents. Early monitoring of grade and surface tolerances allows time for adjustments before a substantial amount of material is placed. During the placement operation, tests and frequencies must be consistent with the *Field Testing Guide*. Immediately following acceptance of the compacted aggregate base, the Contractor is typically required to apply a prime coat to reduce moisture loss and retain compaction. For guidelines, refer to "406 - Prime Coat", in this chapter, and Section 406, "Prime Coat", of the Standard Specifications.

The inspector will keep complete and accurate records of material quantities. Inspector Daily Reports (IDRs) shall include information and observations relating to the equipment, operations and materials incorporated into the work.

CLASS B AGGREGATE BASE

Class B aggregate does not require mixing before delivery to the roadway; it is typically transported and placed in a windrow directly on the roadway. To achieve the required moisture content, the Contractor applies water before and during processing and spreading. A motor grader processes the aggregate on the roadway, then spreads or distributes the material. Once the material is spread, it is then compacted by approved methods in accordance with Section 302, “Aggregate Base Courses”, of the Standard Specifications.

Figure 6: Windrow conditioning

BEFORE CONSTRUCTION

Successful inspection of aggregate processing and placement depends on a thorough understanding of the contract documents relating to aggregate base. Class B aggregate is typically mixed on the roadway, which creates a homogenous mixture of aggregate sizes and evenly distributes moisture.

In reviewing the contract documents, consider the following:

- Material gradation
- Moisture content
- Mixing requirements
- Placement and spreading method
- Typical sections and profile sheets
- Compaction requirement
- Surface tolerance
- Weather limitations
- Measurement and payment

In addition, review the sequence of operations with the Contractor so testers and inspectors can perform their tasks effectively and efficiently. Discuss the thickness of each placement layer with the Contractor, making sure not to exceed the maximum as stated in Section 302, “Aggregate Base Courses”, of the Standard Specifications. Before the Contractor transports the aggregate for placement, the inspector confirms that the tester is scheduled to perform the required tests.

Before placing aggregate, the Contractor finishes the subgrade. The subgrade is acceptable when compaction tests have been taken and have passed minimum requirements. To determine if the grade and surface tolerances are acceptable, the inspector confirms that the subgrade has been graded to the correct elevation of the grade stakes (red heads) that are placed to indicate the elevation of the finished aggregate base. The inspector then checks the subgrade surface for defects. Refer to the *Construction Survey Manual* for policies and guidelines.

Before placement, discuss the equipment, methods and sequence of operations with the Contractor.

DURING CONSTRUCTION

After the Contractor has prepared the subgrade, the inspector monitors the placement and processing of the Class B aggregate. The inspector will observe that the hauling operation does not disturb the prepared subgrade. Examples of disturbances include rutting, shoving, pumping, cracking and raveling.

As the material arrives at the roadway, the inspector monitors the placement and spreading operation. The inspector periodically calculates the yield, which is the amount of material placed per station for the spread width. The inspector will ensure that the aggregate remains homogenous with a consistent moisture content. A homogenous mix reduces the potential for defects.

To achieve a homogenous mix, the Contractor shall:

- Spread the material in a uniform windrow on the roadway.
- Thoroughly blend the material by blading the mix from one shoulder to the center of the roadway, and back to the shoulder to achieve a uniform gradation and color.
- Uniformly distribute the water to efficiently achieve compaction.

After processing, spreading and compacting the material, the Contractor finishes the aggregate base to the red heads. For more information refer to the *Construction Survey Manual* for policies and guidelines.

Because red heads are placed after processing, spreading, and compaction, the inspector coordinates with the survey crew to reduce Contractor delays. Early monitoring of grade and surface tolerances allows time for adjustments before placing a substantial amount of material. During the placement operation, tests and frequencies must be consistent with the *Field Testing Guide*. Immediately following acceptance of the compacted aggregate base, the Contractor is typically required to apply a prime coat to reduce moisture loss and retain compaction. For guidelines, refer to “406 - Prime Coat”, in this chapter, and Section 406, “Prime Coat”, of the Standard Specifications.

The inspector will keep complete and accurate records of material quantities and qualities. Inspector Daily Reports (IDRs) should include information and observations relating to the equipment, operations, yield and materials incorporated into the work, and wasted material, especially anything considered uncommon.

When the measurement and payment method is by weight, adjust the measured weight for moisture. Excessive water in the aggregate creates an artificially high weight for payment. The maximum weight for payment includes only the optimum moisture content plus 1 percent. Optimum moisture can be obtained from the results of tests performed during placement (refer to Nev. T112 test for moisture content in soils and aggregates). Only material that is incorporated into the work is included for payment. Materials wasted or not incorporated into the work will not be considered for payment.

MEASUREMENT AND PAYMENT

Refer to Subsection 302.04.01, “(Aggregate Base Courses) (Method of Measurement) Measurement” and Subsection 302.05.01, “(Aggregate Base Courses) (Basis of Payment) Payment”, of the Standard Specifications and Chapter 9 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

304 - PORTLAND CEMENT TREATED BASE

Cement treated bases (CTB) are used under both plantmix bituminous pavements and Portland cement concrete pavements. With cement treated bases, the structural section thickness is less than that required for untreated aggregate bases. The addition of cement to the aggregate increases the structural strength.

BEFORE CONSTRUCTION

Successful inspection of CTB processing and placement requires a thorough understanding of the contract documents. In reviewing the contract documents, consider the following:

- Consistent material gradation/lack of segregation
- Uniform moisture content
- Mechanical mixing requirements
- Placement and spreading method
- Typical sections and profile sheets
- Compaction requirement
- Surface tolerance
- Weather limitations
- Measurement and payment

In addition, the inspector will coordinate the sequence of operations with the Contractor so testers and inspectors can perform their tasks effectively and efficiently.

Before placing CTB, the subgrade is finished. The subgrade is acceptable when compaction tests have been taken and have passed minimum requirements. To determine if the grade and surface tolerances are acceptable, consult with the survey crew. Finally, visually inspect the subgrade surface for defects.

Two methods of mixing cement treated base are plantmix or roadmix. The Department only specifies mixing cement treated base using the plantmix method.

The plantmix method of mixing CTB utilizes a central mixing plant to combine the aggregate, Portland cement and water. The material is then transported to the roadway, where it is placed and spread. Once in place, the CTB is compacted, sealed, and cured. Typically, one inspector monitors the mixing of the material at the plant, and another inspector oversees the placement operation.

Subsection 304.03.02, “(Portland Cement Treated Base) (Construction) Mixing - Roadmix Method” and Subsection 304.03.03, “(Portland Cement Treated Base) (Construction) Mixing - Plantmix Method”, of the Standard Specifications allow using various types of mixing equipment. Any type is acceptable if it produces a satisfactory product. The most common type of mixer is the pugmill, which consists of revolving blades or paddles on a shaft. Depending on the capacity, the pugmill may have more than one shaft. The mixer is loaded, or charged, at one end and discharged at the other. Batch weights or volumes control the quantity of material in the mixer when material is prepared a batch at a time. For continuous mixing, adjustable vertical gates control the material proportions. Introducing water into the mixture and maintaining uniform moisture in the mixture is critical. Use positive controls to maintain uniformity.

Mixing equipment has paddles, studs, or flights located inside the revolving drum. As the drum rotates, the paddles or flights create a mixing action. Although the Standard Specifications do not state the number or arrangement of the paddles, they require complete mixing and prohibit collection of unmixed materials in the mixer. (Areas in the mixer that collect unmixed materials are called “dead areas” in the Standard Specifications.)

Adding water in the mixing operation is important to the quality of the cement treated base. The best time to add water is several seconds after mixing the dry materials; this creates a more homogenous mix of aggregate and cement.

Review Section 304, “Portland Cement Treated Base”, of the Standard Specifications, for more information.

DURING CONSTRUCTION

Coordinate with the Contractor to confirm that sufficient equipment and labor are available for spreading, compacting, and trimming before the Contractor spreads the material. The Contractor determines the method and amount of spread, but closely cooperating and checking the spread will lead to a more efficient operation. In addition, confirm the placement width of each spread before starting operations. For improved quality in the base, the Contractor minimizes construction joints both longitudinally and transversely.

Because time is an important factor in CTB construction, discuss the timing of the various activities with the Contractor. Three hours is the maximum time allowed between adding water to the mixture and final compaction and trimming. After 3 hours, the mixture begins to harden and can be damaged. Refer to Subsection 304.03.07, “(Portland Cement Treated Base) (Construction) Time Requirements”, of the Standard Specifications for additional time limitations.

Because the Contractor shall maintain the appropriate water content throughout the mixing and placement process, the Contractor typically does the following:

- Keeps the exposed subgrade moist to suppress dust, maintain compaction and hydrate the cement.
- Covers the material during transport to protect the traveling public, suppress dust and pollution, and prevent contamination of the material.
- Maintains the moisture of the compacted mixture until application of the curing seal or a subsequent layer of material to hydrate the material for proper curing.

To determine the actual cement content to be added to the aggregate, take a sample after mixing and before compaction. If the material is mixed at a central mixing plant, test the cement content at the plant after mixing. Take sufficient samples to monitor uniform distribution of cement in the mixture.

Closely monitor the Contractor’s spreading operation. During the spreading of the mixture on the subgrade or base, confirm that the depth of placement and the surface conform to tolerances stated in the contract documents. Continuously monitor the screed settings because they determine the cross-section of the completed roadway.

The thickness of the compacted cement treated base is important to the strength of the completed section. During placement, make allowances for consolidation of the base caused by rolling. If the grade of the material placed exceeds the planned grade by more than 0.05 feet, the Contractor shall take corrective action. The Contractor’s spreading operation may need to be modified if it needs an unusual amount of trimming. (Excessive trimming is costly to the Contractor and results in wasted material.)

If the thickness of the cement treated base is greater than 6 inches, Subsection 304.03.04, “(Portland Cement Treated Base) (Construction) Spreading”, of the Standard Specifications requires the Contractor to place it in more than one lift, each lift being approximately equal thickness. If placed in multiple lifts, each layer must be kept moist after meeting compaction requirements. Pay particular attention to construction joints, making sure they are smooth and thoroughly compacted. Be aware that bumps or depressions at these joints invariably show up in the finished surface.

Because surface irregularities transfer to the finished surface, the inspector uses a 12-foot straightedge to identify variations in the surface of the cement treated base. The Contractor shall use methods approved by the Resident Engineer to correct areas that are not smooth or are otherwise defective.

Once the surface is finished and compacted, the Contractor maintains the moisture content of the cement treated base until the curing seal is applied. The Contractor is typically required to apply the curing seal within 24 hours of final rolling to maintain the moisture content until fully cured. A curing seal is typically an asphalt product, such as MC-250. The Contractor shall protect the seal from construction operations. Traffic is not allowed on the cement treated base for 72 hours after applying the curing seal.

The inspector will keep complete and accurate records of material quantities. The Inspector Daily Report (IDR) shall include information and observations relating to the equipment, operations and materials incorporated into the work, especially anything considered uncommon. When the method of payment is by weight, collect and record load tickets for each truck as the load is delivered to the job site.

MEASUREMENT AND PAYMENT

Refer to the following for measurement and payment guidelines:

- Subsection 304.04.01, “(Portland Cement Treated Base) (Method of Measurement) Roadmix Method Designated for Use”, of the Standard Specifications
- Subsection 304.04.02, “(Portland Cement Treated Base) (Method of Measurement) Plantmix Method Designated for Use”, of the Standard Specifications
- Subsection 304.04.03, “(Portland Cement Treated Base) (Method of Measurement) General”, of the Standard Specifications
- Subsection 304.05.01, “(Portland Cement Treated Base) (Basis of Payment) Roadmix Method Designated for Use”, of the Standard Specifications
- Subsection 304.05.02, “(Portland Cement Treated Base) (Basis of Payment) Plantmix Method Designated for Use”, of the Standard Specifications
- Chapter 12 of the *Documentation Manual*

305 - ROADBED MODIFICATION

Roadbed modification rehabilitates an existing bituminous roadway. To rehabilitate the roadway, the existing surface is pulverized or milled depending on the depth of the existing material. Sometimes a portion of the existing base material is pulverized along with the bituminous surface. If the depth of the existing material is greater than the depth to be pulverized, the Contractor will typically use a coldmilling machine to avoid disturbing the remaining material. The pulverized or milled material is mixed with cement and water, spread, and compacted. This construction method is typically used on roadways with a weak structural section or with a non-uniform structural section.

BEFORE CONSTRUCTION

The project plans specify the depth and width of the existing roadway to be pulverized. Throughout a project, the depth of pulverization may change. Review the project plans to identify changes in the specified depth.

Because roadbed modification projects rehabilitate existing roadways, traffic is maintained during construction. Review the contract documents to determine the following:

- Maximum delay times for traffic
- Compatibility with Contractor operations
- Provisions for appropriate work zones
- Hours of operation
- Other limitations to construction operations
- Access to abutting properties
- Weather limitations
- Typical sections

Confirm that the Contractor's equipment is able to produce the specified product. For example:

- The pulverizing equipment must have the ability to pulverize to the specified depth. If the specified depth goes beyond the existing bituminous surface and into the base, the pulverizing equipment must be capable of pulverizing only to the specified depth and not disturb the underlying base. If the existing bituminous surface section is deeper than the specified depth for roadbed modification, the Contractor typically uses a coldmilling machine instead of a pulverizer.
- The cement-spreading machine must be able to regulate the amount of cement added to the pulverized material.
- The mechanical mixing machine must have sufficient capacity to produce a homogenous mixture and must be able to control the quantity of water added during mixing. The mixing machine must not have excessive water leaks. Excessive water leaking will adversely affect the mix by altering the water-to-cement ratio which will affect overall strength and durability. Conversely, inadequate water content will impose mixing complications and contribute to an improper curing process.

Compaction equipment shall be the type and size described in Section 305, "Roadbed Modification", of the Standard Specifications.

Because existing traffic is typically maintained throughout a roadbed modification project, efficiency in performing all operations is important. As the roadbed modification operation progresses, the paving operation should be staged to begin as soon as the cement treated roadway is cured. Before starting the roadbed modification activities, a plantmix bituminous surface mix design should be approved. In addition, all equipment and materials needed for the bituminous surface paving operation should be on site and staged. For the time limitations related to curing and traffic, refer to Subsection 305.03.07, "(Roadbed Modification) (Construction) Protection and Curing", of the Standard Specifications.

DURING CONSTRUCTION

To pulverize the existing roadway, the Contractor can use a variety of equipment. The Contractor is required, however, to meet specified gradation requirements. The tester checks the material gradation at specified frequencies to determine if the material is acceptable.

After pulverizing a portion of the roadway, the Contractor grades and compacts the pulverized material to within 1 inch of the adjacent travel lane surface. The excess material is moved to the shoulder of the roadway or removed. Traffic is only allowed on the pulverized and compacted untreated base for limited amounts of time.

The pulverized material is used to determine the maximum density. After the density is determined, the spread rate for Portland cement is calculated in accordance with Subsection 305.03.03, “(Roadbed Modification) (Construction) Proportioning”, of the Standard Specifications. Typically, cement is added at the rate of 2 percent by weight to the pulverized material. The inspector checks the cement spread by placing a canvas, usually 1 sq. yd. in area, on the roadway ahead of the cement spreader. After the spreader has passed, carefully pick up the canvas and weigh the cement collected on it. Because cement is measured and paid by the ton, the Contractor shall weigh the cement before spreading. Use the weight of the cement in the spreader to calculate a theoretical spread rate. The cement is spread on the re-compacted material. The cement and the material are mixed while water is added in the mixer. The Contractor uses a motor grader to grade the cement treated mixture to conform with the planned cross slope and existing adjacent travel lanes. During the mixing and grading, the inspector observes the operation to confirm that the material is homogenous and that there are no defective areas. The inspector also checks that the uncompacted depth will yield the required compacted depth. After grading, the Contractor compacts the material to the specified compaction rate as per approved methods. Refer to subsection 305.03.05, “(Roadbed Modification) (Construction) Compacting and Finishing”, of the Standard Specifications for more information.

While checking the depth of the roadbed modified base or during a compaction test, a hole is dug in the material. When the hole is exposed, the inspector or tester can check the uniformity of cement distribution by spraying a phenolphthalein solution on the vertical face of the hole. The solution changes color when it contacts cement. The intensity of the color varies depending on the amount of cement in the base material. Because the chemical characteristics of the phenolphthalein change with time, solutions that have aged may not give accurate indications.

After the surface is finished, the Contractor maintains the moisture content of the treated base until the curing seal is applied. The curing seal is applied within 24 hours of final rolling to maintain the moisture content until fully cured. Most Contractors place the curing seal near the end of each production day. A curing seal is typically an asphalt product, such as MC-250. If the cured cement treated base must carry public traffic, spread sand at the specified application rate over the curing seal. Make sure the sand blotter meets gradation specifications, as large aggregate particles can damage vehicle windshields and small particles can create excessive dust. Verify that the Contractor installs dust hazard signs throughout the work zone. Do not allow traffic on the roadbed modified surface until after the curing seal and sand blotter are applied.

Subsection 108.04, “(Prosecution and Progress) Limitations of Operations”, of the Special Provisions, limit the amount of time that roadbed modification can progress before paving must start, and maximum distances that are allowed between the two operations. The inspector will review these requirements and monitor the progress of both operations.

The inspector will keep complete and accurate records of material quantities. The Inspector Daily Report (IDR) shall include information and observations relating to the equipment, operations, and materials incorporated into the work, especially anything that is considered uncommon.

MEASUREMENT AND PAYMENT

Refer to Subsection 305.04.01, “(Roadbed Modification) (Method of Measurement) Measurement”, and Subsection 305.05.01, “(Roadbed Modification) (Basis of Payment) Payment”, of the Standard Specifications and Chapter 9 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

307 - SHOULDERING MATERIAL

Shouldering material is a graded material placed and compacted against the edge of the plantmix bituminous surface or Portland cement concrete pavement. Shouldering material aids roadway drainage by diverting water away from the structural section. The material is part of the finished roadway slope, which also acts as a recovery area for vehicles.

BEFORE CONSTRUCTION

Review the contract documents to determine the type of shoulder material specified for the contract. When the surface of an existing roadway is ground, or milled, Subsection 307.03.01, "(Shouldering Material) (Construction) Shoulder Preparation", of the Standard Specifications may allow ground or milled material as shouldering material. To ensure that gradation requirements are met, samples of the milled material are tested before placing milled material as shouldering material.

Contract documents state the requirements that the Contractor shall meet regarding the placement of shouldering material. Before placing the shouldering material, the Contractor shall clear and grub the shoulder a minimum of 10 feet from the edge of the existing pavement. The Contractor shall also dispose of trash, vegetation and non-organic material as described in Subsection 107.14, "(Legal Relations and Responsibility to the Public) Disposal of Material Outside Highway Right of Way", of the Standard Specifications.

DURING CONSTRUCTION

Placement of shouldering material must not alter existing drainage channels. Shouldering material is placed before paving in accordance with Subsection 307.03.02, "(Shouldering Material) (Construction) Placement and Compaction", of the Standard Specifications. The Contractor shall place the material in a windrow along the roadway shoulder, prior to paving, in accordance with Subsection 108.04, "(Prosecution and Progress) Limitation of Operations", of the Standard Specifications. Windrows exceeding 4 inches in height are prohibited when the adjacent lane is open to traffic. Avoid placing additional shouldering material after open-graded paving because this can damage the open-graded pavement surface. However, in unique situations and to shape the shoulder properly, the Contractor may place additional shouldering material after open-graded paving if necessary.

MEASUREMENT AND PAYMENT

Refer to Subsection 307.04.01, "(Shouldering Material) (Method of Measurement) Measurement" and Subsection 307.05.01, "(Shouldering Material) (Basis of Payment) Payment", of the Standard Specifications and Chapter 9 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

NOTE: When coldmilled material is utilized as shouldering material, no direct payment is made.

401 - PLANTMIX BITUMINOUS PAVEMENTS: GENERAL

The process of constructing a plantmix bituminous pavement consists of the following three principal operations:

- Mixing of the paving material, including aggregate preparation, storage and handling, mixing plant calibration and operation
- Preparation of the roadway surface
- Placement of the mixed material on the roadway, including equipment, paving methods and compaction

Before construction, each of the three operations requires observation and monitoring in preparation of paving activities. During construction, the inspector continues to monitor production operations at the mixing plant and paving operations on the roadway. The Asphalt Institute publication "Construction of Hot Mix Asphalt Pavements" or MS-22 contains helpful information relating to bituminous pavement and other asphalt-related topics.

BEFORE CONSTRUCTION

MIX DESIGN DEVELOPMENT

Development of a mix design for plantmix bituminous material consists of producing and preparing aggregate, testing aggregate, obtaining asphalt samples, and transmitting aggregate and asphalt samples to the Materials Division. Using the samples submitted by the Resident Engineer, the Materials Division develops a plantmix bituminous mix design that conforms to the requirements of Section 401, “Plantmix Bituminous Pavements - General”, of the Standard Specifications.

Aggregate production and stockpiling significantly influence the quality of the pavement. Although aggregate production and stockpiling are the responsibilities of the Contractor, the Department observes how these operations are performed to monitor the quality of the material. To obtain acceptable quality in the pavement, aggregate production should be uniform and steps should be taken during stockpiling to reduce segregation of the aggregate.

Aggregate is commonly produced by mining, crushing and then passing the material through a series of screens to obtain the aggregate sizes. Any changes in this production process, such as adjustment of crusher openings, screen changes, or equipment wear, can change the aggregate gradations.

After aggregate is screened, it is stored in stockpiles. When stockpiles are constructed, aggregate particles of similar sizes may collect at the base of the stockpile, resulting in a non-homogeneous material. This collection of similar particles, or separation of particles, is called segregation. Aggregate production and stockpiling is discussed in “Overview”, in this chapter.

Because the Contractor is responsible for the quality of the aggregate being produced and stockpiled, the Contractor conducts informational tests throughout the process. (Refer to Section 106, “Control of Material”, of the Standard Specifications.) A benefit of frequent testing is development of a history of each material produced. The testers also conduct informational testing to monitor and verify the quality of the material. The Resident Engineer may offer input to the Contractor by clarifying specifications relating to storing and stockpiling aggregate.

After the Contractor has produced a quantity of aggregate representative of the material to be incorporated into the work, the Contractor requests development of a mix design. At the time of the request, the Contractor proposes an initial proportioning, or percentage, of aggregate from each stockpile (bin percentages). For the minimum quantity of aggregate that the Contractor shall produce before requesting development of a mix design, refer to Subsection 401.03.08, “(Plantmix Bituminous Pavements - General) (Construction) Preparation of Aggregates”, of the Standard Specifications.

The Resident Engineer’s testers then obtain and test aggregate samples from each stockpile. The Resident Engineer compares test results with the Contractor’s test results. The Resident Engineer’s test results and the Contractor’s test results should correlate. If test results do not correlate, the Resident Engineer notifies the Contractor. Although the Contractor is not required to do so, they may choose to make modifications. After the Resident Engineer confirms that test results are representative of the stockpiles and that the test results comply with the contract documents, the Contractor then provides asphalt samples to the Resident Engineer. The Resident Engineer confirms that the type of asphalt, as stated on the sample container, conforms to the contract documents. The Resident Engineer sends the aggregate samples with the aggregate test results and asphalt sample to the Materials Division.

The Materials Division performs tests on the aggregate and asphalt samples, confirming the Resident Engineer’s aggregate test results and that the asphalt conforms to the contract documents. Based on the test results and bin percentages proposed by the Contractor, the Materials Division develops a mix design and sends it to the Resident Engineer. The mix design establishes the amount of asphalt that will be added to the aggregate (bitumen ratio).

Bitumen ratio is a percentage calculated by dividing the amount of asphalt by the dry weight of the aggregate. A similar but different term, Asphalt Content, is a percentage calculated by dividing the amount of asphalt by the total weight of the aggregate and asphalt mixture. (The terms bitumen ratio and asphalt content are often confused as having the same meaning, but they are different.) In determining the mix design bitumen ratio, the Materials Division prepares several batches with varying amounts of asphalt, then performs a series of test on the resulting mixtures Once an appropriate bitumen ratio is determined, the Materials Division sends the approved mix design to the Resident Engineer. The Resident Engineer transmits the approved mix design to the Contractor. The Contractor uses the mix design to develop a proposed job mix formula, which is discussed in "(401 - Plantmix Bituminous Pavements: General) (Before Construction) Job Mix Formula", in this chapter.

After aggregate is produced and stockpiled, hydrated lime is added to the aggregate to reduce plasticity and moisture sensitivity. The most common process of mixing aggregate, water, and hydrated lime is called marination. Subsection 401.03.08, "(Plantmix Bituminous Pavements - General) (Construction) Preparation of Aggregates", of the Standard Specifications, refers to this process as the marination method. The marinated aggregate must be stockpiled for a minimum of 48 hours before being mixed with asphalt. This allows the lime sufficient time to hydrate and react with the aggregate as needed. The equipment used in the marination process includes a lime storage silo, aggregate bins with feeder belts, a pugmill for mixing, and a conveyor system to a stockpile or hauling truck. (See Figure 7.)

Figure 7: Aggregate marination plant

The Contractor shall calibrate the equipment used in the marination process before materials are marinated. The Construction Division will approve the calibration of this equipment as described in "(401 - Plantmix Bituminous Pavements: General) (Before Construction) Marination Plant Calibration", in this chapter.

In the marination process, the Contractor brings the aggregate to a moisture content where enough free surface moisture is available to thoroughly wet the aggregate and activate the lime. The appropriate amount of moisture in the aggregate allows each individual piece of aggregate to be coated with lime, whereas too much moisture has a clumping effect, causing several pieces of aggregate to stick together. The Resident Engineer visually determines the appropriate amount of moisture. The appropriate moisture content is determined using the following guidelines:

- Before the addition of hydrated lime, the coarse aggregate has a wet sheen on the surface of the aggregate particle without water dripping from it.
- Before the addition of hydrated lime, the fine aggregate holds its shape after squeezing without water dripping from it.
- After the addition of hydrated lime, the aggregate is completely coated with lime, without clumping of lime or aggregate particles.

Subsection 401.03.08, "(Plantmix Bituminous Pavements - General) (Construction) Preparation of Aggregates", of the Standard Specifications specify the amount of hydrated lime (also referred to as mineral filler) to be used in the marination process.

The moist aggregate is transported by conveyor belt to the pugmill for mixing. All additional water needed to bring the aggregates to the appropriate moisture content will be incorporated prior to the addition of hydrated lime. To ensure that sufficient moisture is available to activate the hydrated lime, any water added after the addition of lime could possibly wash the lime from the aggregate. The hydrated lime is added to the moist aggregate at the pugmill. The marinated aggregate is discharged from the pugmill and transported to a stockpile.

To verify the amount of lime added to the aggregate, the inspector performs hourly checks during the marination process. During the check, flow rates of aggregate and lime are measured during a 10-minute period. Using the flow rates of aggregate and of lime during the 10-minute period, the inspector can calculate the percentage of lime added to the aggregate. Coarse and fine aggregates are marinated and monitored separately. The following example is a 10-minute check for fine aggregate.

EXAMPLE

Between 5:30 pm and 5:40 pm, total fine aggregate across the weigh belt was 50.23 tons. The daily moisture content measured by the tester was 4.1 percent. The hydrated lime across the weigh belt was 0.817 ton. The required amount of hydrated lime for fine aggregate, is 2 percent of the dry weight of aggregate.

Calculation:

Weight of aggregate:	50.23 tons
Aggregate moisture:	4.1%
Weight of hydrated lime:	0.817 ton

$$WT_{\text{dry aggregate}} = \frac{WT_{\text{aggregate}}}{1 + (\%\text{moisture})} = \frac{50.23\text{ tons}}{1 + 0.041} = 48.25\text{ tons dry aggregate}$$

$$\text{Percent of hydrated lime} = \frac{WT_{\text{hydrated lime}}}{WT_{\text{dry aggregate}}} \times 100 = \frac{0.817\text{ ton}}{48.25\text{ tons}} \times 100 = 1.7\%$$

In this example, the inspector would inform the Contractor that corrective action is necessary because the actual hydrated lime percentage is below the required amount of 2 percent.

The calculated percent of hydrated lime for each 10-minute check is recorded in the Inspector Daily Report (IDR). In addition, for the day's production, the percentage of lime and total dry weight of the aggregate is recorded in the plant IDR for each aggregate size stockpiled.

The inspector verifies that the discharged marinated aggregate is uniformly coated with hydrated lime. (See Figure 8.)

Figure 8: Marinated aggregate uniformly coated with lime

To verify that the hydrated lime is uniform throughout the marinated aggregate, the inspector can apply a stream of phenolphthalein across the aggregate mix. The phenolphthalein reacts with the hydrated lime and changes from clear to a pinkish purple color. By observing the coloring of the phenolphthalein strip, the inspector can determine the uniformity of the hydrated lime distribution within the marinated aggregate. The inspector will visually affirm that there is no flaking (too much) of lime off the aggregate and that there are no bare spots (not enough) on the aggregate.

Marinated aggregate must cure for at least 48 hours before use. After the 48-hour cure time, the aggregate is approved for use. Use the wet cured aggregate in the stockpile within 60. If aggregate is cured longer than the maximum number of days specified and the Contractor plans to use the aggregate in the work, the Resident Engineer should contact the Materials Division. The Materials Division may recommend re-marinating the aggregate to ensure the effectiveness of the hydrated lime, using half the amount of lime originally specified for the marination process.

The marination inspector will document when the stockpiled material was mixed and how long each stockpile has cured. Accurate documentation reduces the risk of introducing the wrong material into the mix. To help monitor which stockpiles are incorporated into the mix, create a diagram of the stockpiled materials, showing the location and the marination date. Provide a copy of the diagram to the NDOT plant inspector, and to the Contractor’s plant operator and loader operator to assist in managing the material being incorporated into the plantmix. In addition, the marination inspector marks the stockpiled material with a lath listing the date, time, and other relevant information. Painting the date on the stockpiled aggregate is also acceptable.

JOB MIX FORMULA

After an approved mix design has been received from the Materials Division, the Contractor submits a proposed job mix formula. The Resident Engineer reviews the proposed formula and may make minor adjustments. (The purpose of the job mix formula is to produce a uniform plantmix material by narrowing the tolerances.) The aggregate gradation specification for plantmix pavements allows a wide range of values to accommodate a variety of aggregates. The durability of the pavement is directly related to the uniformity of the mixture. If aggregate gradation or the amount of asphalt fluctuates, even though the mixture remains within specified limits, the pavement durability is reduced. The job mix formula narrows the gradation specifications to limit variability, improve uniformity, and increase durability.

The Contractor can do the following to improve the mixture’s uniformity:

- Build stockpiles using techniques that reduce segregation
- Build two or more stockpiles of various size aggregates
- Use multiple aggregate bins at the mixing plant

Based on the proposed job mix formula, the Resident Engineer establishes the job mix formula used on the contract. The job mix formula includes the following:

- Mix design number, assigned by the Materials Division, on which the job mix formula is based
- Job Mix Formula number, assigned sequentially by the Resident Engineer, commencing with JMF#1
- Names and locations of aggregate sources
- Percentage of each type of aggregate being used (bin percentage)
- Percent of aggregate passing each specified sieve
- Percent (to the 0.1 percent) of asphalt to be added, which is the bitumen ratio
- Asphalt type and producer
- Actual total percent of hydrated lime, based on coarse and fine aggregate stockpiles
- Statement of whether baghouse fines are used or not, and maximum percentage allowed
- Temperature of mixture leaving the mixer
- Minimum temperature of the mixture in the hopper of the paving machine

While the job mix formula sets a single value for the items listed, Subsection 401.02.02, “(Plantmix Bituminous Pavements - General) (Materials) Composition of Mixtures”, of the Standard Specifications, provides a range of tolerances within which the Contractor shall produce the plantmix material. Single values with tolerances provide a uniform mixture, yet allows for minor fluctuations in the production process. Throughout the life of a project, the job mix formula may be modified for various reasons. The Contractor shall request modifications to the job mix formula and the Resident Engineer reviews and, if reasonable, approves the request. If approved, the Resident Engineer establishes a new job mix formula. Discussions with other Resident Engineers using the same mix design may be helpful in establishing the initial job mix formula. To maintain uniformity, limit changes to the job mix formula. The Resident Engineer documents the job mix formula in a letter to the Contractor. Refer to the Quality Assurance Documents library on the Construction Division’s SharePoint site [https://nevadadot.sharepoint.com/sites/040/QAQC%20Section/] for an example of a job mix formula letter and explanation of the process for developing a job mix formula letter.

The Resident Engineer may modify portions of the job mix formula without contacting the Materials Division, although consultation with the Materials Division and the Construction Division’s Quality Assurance Section is encouraged.

Bin percentages, on which the mix design is based, may only be modified within limits. The Resident Engineer may allow changes in bin percentages that do not exceed a total of 6 percentage points for all bins. For example, if a mix uses three bins of aggregate, and the amount of Bin #1 aggregate is reduced by 2 percent and Bin #2 aggregate is increased by 3 percent then Bin #3 may be reduced by only 1 percent to maintain the total of 100 percent and keep the total percentage change at 6 percent or less. Because the bin percentages have been changed a total of 6 percent (2 + 3 + 1 = 6), no additional changes are allowed without Materials Division approval. Changes greater than 6 percent must be approved by the Materials Division. For changes greater than 10 percent total, the Materials Division may require a new mix design.

MIXING PLANT

The mixing plant combines the prepared aggregate and asphalt to meet the job mix formula. The mixture produced at the plant is loaded into hauling trucks and transported to the paver on the roadway, where it is spread and compacted. The controlled conditions and operations at the mixing plant significantly influence the quality and durability of the plantmix placed on the roadway. For additional support and guidance, contact the Construction Division’s Quality Assurance Section.

In general, two types of plants are used to mix materials for plantmix bituminous pavements: batch plant and continuous mixing plant. A batch plant produces plantmix material a single batch at a time. A continuous mixing plant produces plantmix material continuously. Another significant difference is that, in a batch plant, aggregate is proportioned after it is dried and heated. With a continuous mixing plant, the aggregate is proportioned and then dried and heated. While the plants have distinct differences, many elements of the plant components and operations are similar. The following are common elements that require a plant inspector’s attention:

- Aggregate Bins: Bins store aggregate that has been processed and screened into various sizes, ready for proportioning. The partitions separating one bin from another must be solid, free of holes, and high enough to prevent the aggregate from spilling over into an adjacent bin. Fine dust may collect in the corners of the bins. Material can also stick together, forming clumps that result in aggregate segregation. An accumulation of fine dust or clumps of material may be detrimental to the mix. The inspector will observe the bins to monitor the uniformity of the aggregate. The Contractor shall take measures to minimize accumulation of fines in the bins.

- Aggregate Cold Feed: The aggregate cold feed belt is a conveyor belt that delivers the aggregate from the aggregate bins to the mixer. Each aggregate bin is equipped with a feed belt that delivers aggregate from the bin to the cold feed belt. It is at this point that the combined aggregates are weighed using a belt scale. The cold feed belt scale is used to regulate the addition of the binder in the mixing chamber. The speed of each aggregate bin feed belt, as well as the aggregate bin gate setting, determines the proportion of the aggregate. After calibration of the aggregate cold feed, no changes in the bin gate settings should be made. Loading of the belts can affect the uniformity of the aggregate gradation. Malfunctioning belt feeders or gates, overloading the bins, and inconsistent aggregate moisture can adversely affect the operation of the aggregate cold feed.

- RAP Feed: Rap (Reclaimed Material) feed belt delivers the RAP into the upper portion of the mixing chamber or drum, just ahead of the asphalt cement injection point. After calibration of the RAP feed, no changes in the bin gate settings should be made.
- Aggregate Screens: Screens located between the aggregate bins and the mixer are commonly called scalping screens. A scalping screen vibrates and separates oversized or clumped aggregate for removal before the aggregate enters the mixer. Inspect the screen to verify that the screen size opening is correct. The correct size screen opening is slightly larger than the largest aggregate size of the mix. Production rates that exceed the capacity of any screen may alter gradation. During the screening process, the following factors can affect aggregate gradation:
    - Types and sizes of screen openings
    - Tendency for screens to plug
    - Foreign matter in the aggregate
    - Wear, holes, or breaks in screen
- Plant Scales: The completed mixture is weighed at the plant with a scale at the storage silo or with a platform scale that weighs the loaded truck. The scale that weighs the completed mixture is typically the scale used to determine payment quantities. The Nevada Bureau of Weights and Measures or a firm approved of by the Bureau of Weights and Measures must certify the payment scale. The Resident Engineer coordinates the certification of the scales with the Contractor and the Nevada Bureau of Weights and Measures. Refer to Section 109, "Measurement and Payment", of the Standard Specifications. The Nevada Bureau of Weights and Measures certifies the plant scales and places a sticker on the scale indicating the certification. Allow sufficient time to schedule certification by the Nevada Bureau of Weights and Measures. The inspector will verify that the payment scale is certified within the last 12 months.
- Storage Tanks: Inspect storage tanks to verify that no material is in the tank, other than the material designated for the mix. The bituminous storage tank must be capable of uniformly heating and maintaining the asphalt at the temperature stated in Section 401, "Plantmix Bituminous Pavements - General", of the Standard Specifications. This may require certain bituminous materials be continuously circulated during storage. To reduce cooling, the Contractor insulates the pipe that conveys asphalt from the storage tank to the mixer. The type of burner fuel the Contractor uses shall be in accordance with Subsection 401.03.01, "(Plantmix Bituminous Pavements - General) (Construction) Bituminous Mixing Plant", of the Standard Specifications, and have required certifications. The asphalt and the burner fuel may be stored in a multi-compartment storage tank, provided the asphalt and the burner fuel do not share a common wall.
- Bituminous Metering Device: Subsection 401.02.02, "(Plantmix Bituminous Pavements - General) (Materials) Composition of Mixtures", of the Standard Specifications shows the tolerance allowed for the bitumen content used in the mix. One of the most common causes for bituminous paving mixture failures is incorrect amounts of asphalt. The plant inspector will frequently check and monitor the amount of asphalt introduced in the mixture for consistency throughout the production as well as visually monitor the completed mix for variations in appearance. Any inconsistencies should be relayed to the testers and the street inspector.
- Mixer: The mixer is a revolving drum or cylinder in which aggregate is dried and heated by burning fuel oil or gas. The cylinder walls are lined with longitudinal cups or channels called "lifters" or "lifting flights" that drop the aggregate as a veil or curtain through hot gases. The mixer slope, diameter, length, arrangement of lifters, number of lifters, and RPM control the time the aggregate is in the mixer.

Air is used to atomize the fuel oil as it is ejected from the burner nozzle to provide for complete combustion and to provide draft or suction necessary to carry combustion gases through the mixer. If complete combustion does not occur, the fuel oil tends to deposit a black, oily residue on the hot aggregate material making it difficult to coat the aggregate with asphalt. Black smoke coming from the mixer exhaust indicates incomplete fuel oil combustion in the mixer. Intermittent puffs of smoke at the exhaust end of the mixer or a flame that enters the mixer at a short distance, indicates insufficient draft through the mixer. With complete combustion, the flame penetrates about 1/3 to 1/2 the length of the mixer. Overloading the mixer may prohibit sufficient heating and drying of the aggregate. In a continuous mixing plant, the drum serves as the mixer and mixes asphalt with the dry aggregate producing the final mix.

- Dust Collector: Dust and fine aggregate particles are emitted during the mixing process. A dust collection system captures the dust that is exhausted during the heating process. Typically, there are two components in the dust collection system: Primary dust collector and secondary dust collector.
    - Primary Dust Collector: The primary dust collector is the first point of extracting dust and fine aggregate particles from the mixer exhaust system. Primary dust collectors are either a knockout box or a cyclone dust collector. Collected dust particles are returned to the mixer to be re-mixed with the aggregate and asphalt.
    - Secondary Dust Collector: Because of more stringent air quality standards, secondary collectors will generally be required. A secondary dust collector is either a wet scrubber or a baghouse. The dust collector system serves two purposes: (1) to provide an adequate draft through the mixer, and (2) to collect and return a uniform amount of the dust. If a baghouse is used for dust collection, and the Contractor wants to reintroduce the fines back into the mix, the Contractor shall be able to measure and control the amount of baghouse fines being reintroduced into the mix. The hot plant inspector verifies that the amount of fines reintroduced into the mixture does not exceed the limits stated in Subsection 401.03.01 of the Standard Specifications. If the system has not been calibrated, then the Contractor cannot reintroduce baghouse fines into the mixture and the job mix formula will reflect the exclusion of baghouse fines from the mix.

Thermometers determine temperatures at various locations in the mixing plant. Specifications describe temperature requirements. Subsection 401.02.02, "(Plantmix Bituminous Pavements - General) (Materials) Composition of Mixtures", of the Standard Specifications show the temperature requirements of the asphalt entering the mixer and temperature requirements of the mixture exiting the mixer. An armored thermometer, capable of detecting temperature ranges expected in the asphalt entering the mix, are fixed in the asphalt feed line as the asphalt enters the mixer. The thermometer is located so that the inspector can observe the readings conveniently and safely. Plants may also be equipped with a dial scale thermometer, a mercury-actuated thermometer, an electric pyrometer, or other thermometric instrument placed at a discharge chute of the mixer to register or indicate the temperature of the heated aggregates automatically. Such a device is in full view of the plant operator and convenient to the inspector to make observations.

Any thermometers used by the inspector shall be correlated with the Contractor's thermometers. The inspector will have a calibrated thermometer prior to the correlation. By correlating thermometers, disputes involving temperature readings are reduced. If unresolved questions remain, contact the Resident Engineer, who may request replacement or verification of the temperature readings.

In a mixing plant, the mixture components (aggregate, RAP, asphalt, and baghouse fines) are combined in a mixer. First, the aggregate is introduced into the mixer where it passes over a series of flights, creating a sheet of aggregate that passes in front of the hot gases from the burner. This heats the aggregate and drives off the moisture before the asphalt introduction. Then, the asphalt is introduced into the mixer. The asphalt introduction point varies, depending on the individual plant characteristics. Aggregate coating occurs through a foaming action caused by the steam driven from the aggregate. Mixer slopes affect the amount of time that mixing action occurs. Mixers typically slope between 5 percent and 2-1/2 percent.

Plantmix can be produced at a Contractor's portable job-site plant or at a commercial plant that serves multiple customers. The Contractor shall provide a copy of the Nevada Department of Environmental Protection permit, which addresses the plant production limitations, to the Resident Engineer at least 48 hours before beginning operations.

MIXING PLANT CALIBRATION

After the Contractor processes and stockpiles the aggregate and assembles the mixing plant and the Resident Engineer receives the mix design, the Contractor calibrates the mixing plant. Even though the Contractor calibrates the mixing plant, the Construction Division's Quality Assurance Section observes and verifies the calibration process.

Mixing plant calibration is the process of determining the accuracy of plant instruments that produce the mixture in accordance with the job mix formula. Feed rates of the component materials that make up the mixture are identified and recorded. After the Contractor calibrates the plant and the Quality Assurance Section has observed and verified the calibration, the plant inspector uses these calibration results to monitor plant operations during plantmix production.

Calibration is a step-by-step process that is done without operating the burner or introducing asphalt to the aggregate. Components of the mixture that require calibration are aggregate, RAP, asphalt, baghouse fines. For aggregate and RAP, the Contractor adjusts the bin gate opening and the feed belt speed from each of the bins to produce a cold feed mixture that is consistent with the job mix formula. Asphalt feed rates are measured by a flow meter, which requires calibration. Contractors use a variety of methods to introduce baghouse fines into the mix, which requires calibration methods specific to the equipment used. The calibration process includes operating the mixing plant at several speeds (tons per hour) to establish a range of production rates. The composition of the mixture depends on the proportioning of each component material, and is based on the feed rate of aggregate. The feed rates of asphalt, RAP, and baghouse fines are interlocked with the aggregate feed rate to maintain consistent proportioning.

Mixing plants are calibrated and documented at least every 12 months. Recalibration is required, however, if the plant was moved or components of the plant were altered or rearranged. If a plant is shut down for an extended period, such as during the winter months, the Resident Engineer should check the plant calibration before full production begins. The Resident Engineer may require recalibration of the plant at any time if the accuracy is questioned. Even though the Resident Engineer is responsible for checking the accuracy of the plant control settings, the Resident Engineer will notify the Quality Assurance Section before calibrating a plant. Subsection 401.03.01, "(Plantmix Bituminous Pavements - General) (Construction) Bituminous Mixing Plant", of the Standard Specifications requires the Contractor to notify the Resident Engineer, typically 48 hours in advance, when the plant is ready to be calibrated. The plant should be operating in a consistent manner before the plant calibration is scheduled.

The following sections provide information on calibrating component parts of the mixing plant. The Forms library on the Construction Division's SharePoint site [https://nevadadot.sharepoint.com/sites/040/FormServerTemplates/] contains NDOT Form 040-038 (Hotplant Calibration Sheet). A hot plant calibration guide is available from the Construction Division's Quality Assurance Section.

AGGREGATE AND RAP FEED CALIBRATION

Aggregate feed calibration consists of first calibrating the individual feed belts from each aggregate bin. Second, the weigh belt that delivers aggregate from the individual aggregate feed belts into the mixer is calibrated. (See Figure 9).

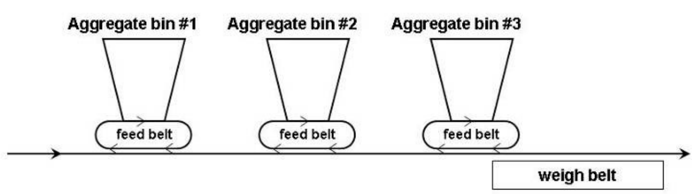

Figure 9: Configuration of a weigh belt and aggregate feed belts

If the hot plant does not visually display on screen the bin percent amounts and cold feed weight being introduced, the Contractor develops bin graphs for each of the aggregate feed belts. A bin graph is a plot of the relationship between aggregate feed, measured in tons per hour, and percentage of belt speed. The plant is operated at low, medium, and high production rates. For each plant production rate, the belt speed (measured as a percentage of the maximum belt speed) and aggregate feed rate (measured in tons per hour) for each bin is noted. (See Figure 10.)

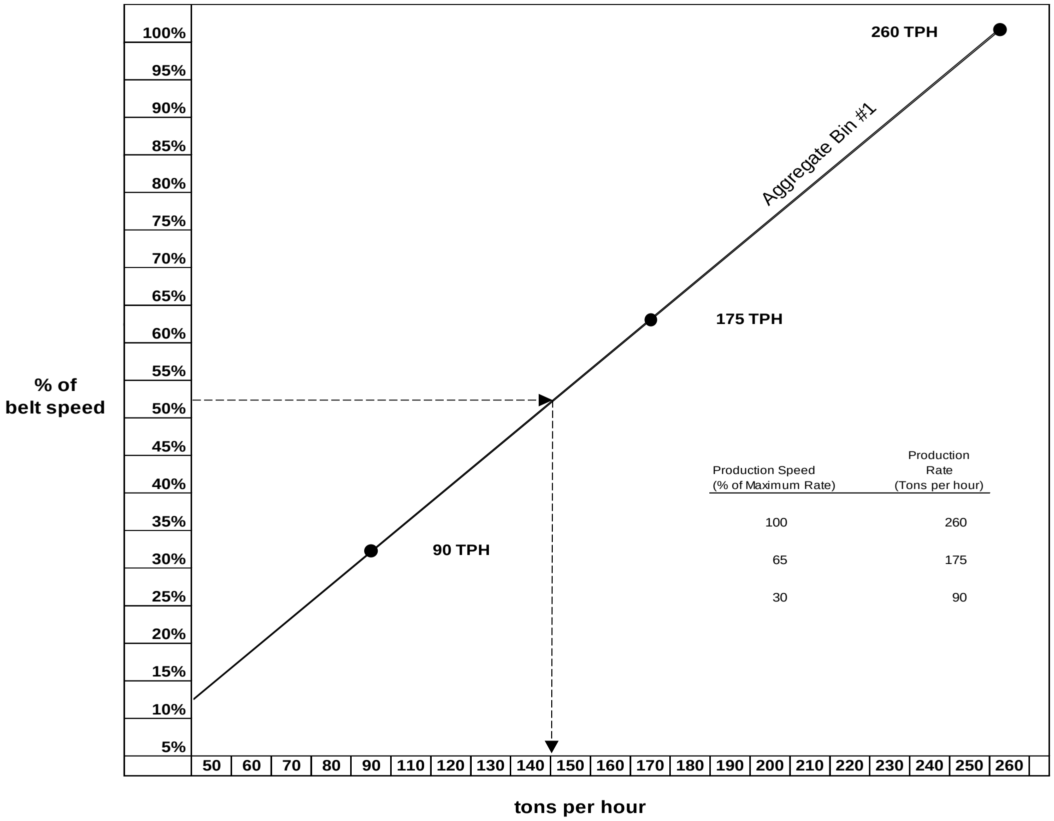

Figure 10: Sample bin graph developed by the Contractor

After the Contractor develops the bin graphs, the weigh belt is calibrated. The weigh belt calibration determines the actual weight of aggregate introduced into the mix. A scale weighs the aggregate on the conveyor belt as it passes over the scale (belt scale). The belt scale system sends a reading to the mixing plant control house. The reading is used to determine the weight of aggregate introduced into the mixer. When using a belt scale system, the Contractor conducts a weight calibration according to the manufacturer's recommendations. The purpose of the weight calibration is to show the relationship between the actual weight of the aggregate and the metered weight of the aggregate indicated by the control house instruments. This relationship is then used to determine the actual weight of aggregate introduced into the mix.

After the Contractor completes the initial weight calibration, checks are made at low, medium, and high production rates within the rated operating range of the plant. Each aggregate weigh check should be at least 10 tons. For a given production rate, the plant scale readings are compared to the certified platform scale readings. The percentage of error between the readings must be 1 percent or less. The percentage of error is then calculated for each of the other two production rates. The range of the percentages of error between the low, medium and high production rates must also be within 1 percent of each other. The weight calibration should be conducted each time the belt scale is set up, and whenever the Resident Engineer questions the accuracy of the weigh system, but not less than once a year. After the weigh belt has been calibrated, the inspector notes and, if possible, marks the location of the settings of the bin gates.

ASPHALT FEED CALIBRATION

The asphalt feed calibration determines the actual weight of asphalt introduced into the mix. Because the amount of asphalt in the mixture is directly related to the amount of dry aggregate in the mix, the asphalt feed rate is interlocked with the aggregate feed rate to maintain consistent proportioning.

A measuring device, such as an in-line flow meter or an asphalt pump revolution counter, measures the amount of asphalt introduced into the mixture from the storage tank. The measuring device should compensate for the temperature of the asphalt. The asphalt measuring device sends a reading to the mixing plant control house. The reading is used to determine the weight of asphalt introduced into the mixer.

The measuring device is calibrated to show the relationship between the actual weight of asphalt and the metered weight of asphalt indicated by the control house instruments. The inspector should be aware that plant control consoles may indicate a percent of asphalt that differs from the percent of asphalt required by the job mix formula because plants may utilize total weight of aggregate instead of dry weight of aggregate. The relationship between the weighed asphalt and indicated asphalt weight is then used to determine the actual weight of asphalt introduced into the mix. The metered quantity of asphalt, measured in gallons (minimum of 1,000 gallons) and converted to weight, should correlate within 1/2 percent of the actual weight as measured on the certified scales. Instead of gallons, the meter may read the quantity of asphalt by weight, measured in pounds or tons. Refer to the Bill of Lading of the delivered oil for its specific gravity. Regardless of the units of measurement, a minimum of 1,000 gallons of asphalt is required for calibration. After the Contractor completes the initial weight calibration, checks are made at low, medium, and high production rates within the rated operating range of the plant. The Resident Engineer can request recalibration of the asphalt meter whenever the meter's accuracy is in question.

BAGHOUSE FINES CALIBRATION

The Contractor may introduce baghouse fines into the mix, provided the fines do not exceed 2 percent by dry weight of aggregate. If the Contractor decides to introduce baghouse fines into the mix, the Contractor shall provide a positive weighing device that is interlocked with the aggregate feed system. Baghouses collect fines at varying rates. However, the fines must be introduced into the mixture at a uniform rate to produce a consistent mix. The Contractor shall have a system that eliminates the sporadic delivery of baghouse fines returned to the mix. The system must provide continuous uniform flow within tolerances stated in Subsection 401.03.01, "(Plantmix Bituminous Pavements - General) (Construction) Bituminous Mixing Plant", of the Standard Specifications. The types of systems that measure reintroduced baghouse fines can vary. The Contractor is not required to introduce fines. The Contractor may dispose of the fines.

If the Contractor chooses to introduce baghouse fines, the measuring system must be calibrated. Baghouse fines calibration compares plant weight readings to actual weights as determined by accurate scales. The weight readings of baghouse fines should correlate within 5 percent of the actual weight as measured on accurate scales. Because the quantity of baghouse fines is small, these fines may be weighed on a scale smaller than a platform scale used to weigh trucks.

Because baghouse fines are available only after a plant has operated for a period of time, calibration procedures for commercial and job site plants are different. When using baghouse fines from a commercial plant, the baghouse fines must be calibrated before any plantmix is produced, including mixture for field trial mixtures or the first half day of paving. When using baghouse fines at a job site plant, baghouse fines are calibrated after producing field trial mixture or the first half-day of paving. Calibration must be completed before any additional plantmix is produced.

HYDRATED LIME (MINERAL FILLER) CALIBRATION

Subsection 401.03.08, "(Plantmix Bituminous Pavements - General) (Construction) Preparation of Aggregates", of the Standard Specifications direct the Contractor to add hydrated lime by using the marination method or, in rare cases, by the cold feed method. Regardless of which method is used, calibration of the measuring system used is the same as calibrating baghouse fines. The weight readings of hydrated lime should correlate within 5 percent of the actual weight as measured on accurate scales. Because the quantity of hydrated lime is small, the hydrated lime may be weighed on a scale smaller than a platform scale used to weigh trucks.

MARINATION PLANT CALIBRATION

Marination plant calibration is the process of determining the accuracy of plant instruments that produce the marinated aggregate. Feed rates of the aggregate and hydrated lime are identified and recorded. After the Contractor calibrates the marination plant and the Construction Division's Quality Assurance Section has observed and verified the calibration, the plant inspector uses these calibration results to monitor plant operations during the marination process.

The feed belt speed is adjusted to maintain consistency in marination. The calibration process includes operating the mixing plant at several speeds (tons per hour) to establish a range of production rates. The composition of the mixture depends on the proportioning of each component material, and is based on the feed rate of aggregate and hydrated lime. The feed rates of hydrated lime and water are interlocked with the aggregate feed rate to maintain consistent proportioning.

Aggregate feed calibration consists of first calibrating the aggregate weigh belt that delivers aggregate from the aggregate bin into the pug mill mixer. The weigh belt calibration determines the actual weight of aggregate introduced into the mix. The belt scale system sends a reading to the marination plant instruments. The purpose of the aggregate weight calibration is to show the relationship between the actual weight of aggregate and the metered weight of aggregate. This relationship is then used to determine whether the meter is within the tolerances allowed.

After the Contractor completes the initial weight calibration, checks are made at low, medium and high production rates within the rated operating range of the plant. Each weigh check should be at least 10 tons. For a given production rate, the plant scale readings are compared to the certified platform scale readings. The percentage of error between the readings must be 1 percent or less. The percentage of error is then calculated for each of the other two production rates. The range of the percentages of error between the low, medium, and high production rates must also be within 1 percent of each other. The weight calibration should be conducted each time the belt scale is set up, and whenever the Resident Engineer questions the accuracy of the weigh system.

After calibration of the aggregate weigh belt, the weigh system for the hydrated lime is calibrated. Hydrated lime calibration compares plant weight readings to actual weights as determined by accurate scales. Because the quantity of hydrated lime is small, hydrated lime may be weighed on a scale smaller than a platform scale used to weigh trucks. The Contractor determines the amount of hydrated lime for each weigh check, typically several hundred pounds. For a given production rate, the metered plant readings are compared to the accurate scale readings. The percentage of error between the readings must be 5 percent or less. The percentage of error is calculated for each of the two production rates.

The water metering system does not require calibration because accurate measurement of the amount of water is not needed. The appropriate amount of water is visually determined. Water must be added to the aggregate prior to the addition of hydrated lime.

ROADWAY

The roadway surface must be prepared prior to placing plantmix material. Preparing the roadway for paving includes the following:

- Constructing the base course
- Preparing the surface
- Conducting required tests
- Applying liquid or emulsified asphalt

The contract documents describe how the Contractor shall prepare the roadway surface for paving. After the Contractor prepares the surface, the inspector determines the acceptability of the prepared surface. The surface to receive plantmix paving is acceptable when it conforms to grade, profile, and other requirements described in the contract documents. Visually inspect the surface to confirm that no surface defects exist.

When liquid asphalt materials are applied, such as a prime coat, tack coat or seal coat, the sealed surface must be protected from damage. Prime coats protect the compacted base courses from the destructive action of traffic, minimizes moisture evaporation from base material, and reduces weather damage. A tack coat is applied to serve as an adhesive between pavement surfaces. Seal coats are applied to a finished pavement surface to serve as a moisture barrier. Theoretical application rates and types of liquid asphalts to be applied are determined by the Materials Division and are included in the project plans.

Before applying a prime coat, the inspector and Contractor shall discuss the planned application rate, traffic conditions, and paving schedule. Applying too much liquid asphalt is wasteful and may cause slippage, instability and migration of asphalt to the roadway surface, called bleeding of the pavement. Applying too little liquid asphalt may require repairs before paving operations begin.

When prime coats are not used, the placement of hot paving material may cause rapid drying of the top of the base, leaving a loose dust film that may cause slippage. If a bituminous dust palliative has been used on the base material, it may be possible and desirable to eliminate the prime coat. Tack coats are used to bind one asphalt surface to another.

In addition to the materials and condition of the roadway surface, the inspector will discuss the operational aspects of the paving operation with the Contractor. Operational aspects are addressed during the Pre-Pave Conference. The Quality Assurance Documents library on Construction Division's SharePoint site [https://nevadadot.sharepoint.com/sites/040/QAQC%20Section/PrePour%20and%20PrePave%20Agendas] contains a Pre-Pave Conference checklist. In general, operational aspects to consider are:

- Equipment and labor for spreading and compacting plantmix material. By knowing the types of equipment that the Contractor plans to use, the inspector can confirm that the equipment meets Subsection 401.03.02, "(Plantmix Bituminous Pavements - General) (Construction) Hauling Equipment", Subsection 401.03.03, "(Plantmix Bituminous Pavements - General) (Construction) Pavers" and Subsection 401.03.04, "(Plantmix Bituminous Pavements - General) (Construction) Rollers", of the Standard Specifications. Knowledge of the Contractor's operations allows the Resident Engineer to schedule testing and inspection.
- Plantmix material placement width and depth, and longitudinal and transverse joints placement. Specifications limit the depth of material that can be placed in a single pass of the paver. Specifications also restrict the location of joints. Conferring with the Contractor on these issues allows the inspector to address potential problems.

After the inspector discusses with the Contractor on the operational aspects of paving, and after the equipment is on-site, the inspector verifies that the equipment is in accordance with Subsection 401.03.02, "(Plantmix Bituminous Pavements - General) (Construction) Hauling Equipment", 401.03.03, "(Plantmix Bituminous Pavements - General) (Construction) Pavers" and Subsection 401.03.04, "(Plantmix Bituminous Pavements - General) (Construction) Rollers", of the Standard Specifications. The inspector will also determine the adequacy of the equipment to produce the final product and report concerns of inadequacy to the Resident Engineer.

PAVING MACHINE

Plantmix material produced at the mixing plant is transported to the paving machine which spreads it on the roadway. Paving machines typically consist of a hopper for receiving the plantmix, augers to spread the mixture uniformly across the surface to be paved, a screed to strike off and smooth the mix, and a grade-sensing device used to raise and lower the screed to level the plantmix to the proper grade. (See Figure 11).

Figure 11: Plantmix paving machine

Hauling trucks deliver plantmix material from the plant to the roadway. The material is unloaded from the hauling truck into a windrow in front of the paving operation or into a material transfer vehicle. When the material is placed in a windrow on the roadway, either a pick-up machine, attached to the front of the paver, lifts the windrowed material into the hopper or a material transfer vehicle delivers material into the hopper. If approved by Resident Engineer, hauling trucks may deliver material directly into the hopper of the paver for areas requiring small quantities of material. The inspector will review the contract documents to determine if a specific material delivery method is required.

Material in the hopper of the paver is conveyed to the rear of the paver where augers distribute the material across the full width of the paver. Once the material is distributed, the screed strikes off excess material leaving a level, partially compacted plantmix surface. Screeds are controlled manually or automatically. When pavers begin a pass, screeds are commonly operated manually. Manual control is transferred to automatic control after the position of the screed has been stabilized. Paving operations usually begin and end at a slow speed because the paver operator may need to revert to manual control.

An important aspect of automatic screed control is the sensitivity of the controls. An overly sensitive grade sensor, or excessive manual control adjustment, frequently produces false control signals that can produce a wavy pavement surface. An under-sensitive grade sensor does not detect deviations in the grade soon enough to adjust the pavement depth. The paver operator should adjust the sensor sensitivity so that the chatter or bounce of the grade-sensing device is not transmitted for correction. Screed adjustments are not completely transmitted to the actual pavement until after the paver has traveled a distance of five tow lengths. Tow length is the distance between the screed and the tow attachment point where the screed is pulled by the paver.

The inspector will discuss with the Contractor which type of grade sensing device will be used. Inspect the grade-sensing device to verify that it is in good working order and that it will produce the desired finished product and is in accordance with the contract documents.

Grade reference devices are of two general types: (1) transverse control, used to provide cross slope, and (2) longitudinal control, used for grade elevation. A transverse beam mounted above the screed controls the cross slope. An external reference device controls the longitudinal grade. External reference devices include the following:

- The floating beam is a rigid beam, approximately 30 feet long, supported every 2-1/2 feet by spring-loaded shoes. The spring-loaded shoes provide an average grade reference, or they can be locked to provide reference control similar to the long ski. When matching an adjacent, newly paved roadway on which the beam will ride, the beam may be as short as 10 feet in length.

- An electronic grade control system uses a non-contacting sonic sensor. The non-contact averaging ski must have a minimum of four sensors. The system controls grade and cross slope without skis or string lines and matches joints without requiring the sensors to touch any surfaces.

- The long ski is a semi-rigid truss or a pipe with a wire-line. This assembly is loosely attached to the paver. The paver has a grade-sensing device to detect slope changes in the wire. Use a wire-line to check or control long skis (not less than 30 feet long). When matching an adjacent, newly paved pad on which the ski will ride, the ski may be as short as 10 feet in length.

- String-line or wire-line is supported above the base course and provides grade reference with a high degree of accuracy. Keeping these lightweight lines at the proper tension is important to prevent sagging.

Regardless of the type of grade-sensing device, the inspector will verify that the paver can produce a finished product that conforms to the contract documents.

ROLLERS

After the paver places the plantmix material on the roadway, rollers compact the material to the required thickness and density. Rollers come in many configurations, sizes, and weights. The two most common types of rollers are steel wheel and rubber tired pneumatic. Rollers perform breakdown rolling (steel wheel, with or without vibration), kneading (rubber tired pneumatic), and finish rolling (steel wheel).

- Breakdown Roller: This roller immediately follows the paver and performs breakdown rolling. The breakdown roller is a tandem axle steel wheel roller, which meets the requirements of Subsection 401.03.04, "(Plantmix Bituminous Pavements - General) (Construction) Rollers", of the Standard Specifications. Typically, a breakdown roller weighs at least 10 tons and is capable of vibrating.

- Pneumatic Roller: This roller follows the breakdown roller. A pneumatic roller has rubber tired wheels, typically weighs at least 10 tons, and must have skirting surrounding the tires to retain heat in the tires. The pneumatic roller aids in compacting the mix. It also kneads the mix, which can repair cracked areas in the pavement while the plantmix is still hot. The pneumatic roller may pick up plantmix material on the wheels if the paving mat is too hot or the roller tires are too cold. Tire pressure can also affect whether a pneumatic roller picks up material. The pneumatic roller is most effective when the pavement temperature is above 185°F. Some Contractors provide roller operators with an infrared hand-held thermometer. The thermometer readings help the roller operator determine appropriate optimum times to begin compactive efforts.

- Steel Wheel Roller: This roller follows the pneumatic roller, which performs the finish rolling of the mat. A finish roller typically weighs at least 8 tons. Although most steel wheel rollers are equipped with a vibrator, the finish roller operator does not use the vibrator during final pass of finish rolling on the mat. The purpose of finish rolling is to remove irregularities and provide a smooth surface.

Rollers could pick up plantmix material during rolling. If this occurs, the Contractor applies a release agent to the roller wheels or drum. The release agent must be approved for use in the Qualified Products List.

IMPORTANT: The Contractor is prohibited from using diesel or kerosene as a release agent because of the detrimental effects on the plantmix.

The inspector will confirm the availability of an appropriate number and types of rollers and verify each roller's weight before placement of the plantmix. Steel wheel rollers should be in good condition and should be checked for minimum weight. Pneumatic rollers must also comply with Subsection 401.03.04, "(Plantmix Bituminous Pavements - General) (Construction) Rollers", of the Standard Specifications. The inspector will report concerns of inadequacy of the equipment to the Resident Engineer. (See Figure 12 and Figure 13.)

Figure 12: Steel wheel roller

Figure 13: Rubber-tired pneumatic roller with skirting

MISCELLANEOUS EQUIPMENT

The contract documents direct the Contractor on the types of miscellaneous equipment to be provided and other requirements such as the specific time when the equipment must be on the job site. Typical miscellaneous equipment includes a material transfer vehicle and core-drilling machine.

With a material transfer vehicle, a hauling truck conveys material directly into a transfer vehicle, which continuously feeds material into the hopper, or the material transfer vehicle transfers material from a windrow into the hopper. A material transfer vehicle has advantages over other delivery methods because it allows uninterrupted delivery of material to the paver and reduces temperature variability and segregation of the plantmix material. (See Figure 14.)

Figure 14: Material transfer vehicle

The Contractor shall furnish a pavement core-drilling machine for coring samples of compacted bituminous mixtures for density testing. The inspector will verify that the drill is able to drill the required cores without distorting or tearing the pavement, and is of the correct size. The inspector will confirm with the Contractor that the coring machine will be available on the job site.

The Contractor shall furnish a vehicle-mounted inertial profiling system meeting the applicable requirements of AASHTO M328, R56, and R57.

DURING CONSTRUCTION

MIXING

The plant inspector will monitor a variety of operations that affect the production and quality of the plantmix. Material and equipment, such as storage tanks for asphalt cement, burner fuel, hydrated lime, aggregate bins, baghouse, and aggregate feed belts, require inspection to ensure a uniform quality mix. After calibration and before full production begins, the Contractor operates the mixing plant to verify that it produces a mixture that conforms to the job mix formula. After verification that the plant can produce the specified plantmix, the plant may begin full production of plantmix. During production, whether it is preliminary or full production, the plant inspector monitors the production to verify that the specified mixture is produced consistently. Inspecting the plant requires attention to multiple details and activities.

Before plantmix production begins, the plant inspector will have available all records and documents prepared during material preparation and equipment operation, as well as records and forms needed during construction. The plant inspector shall have the following items:

- Contract documents
- Mix design
- Job mix formula
- NDOT Form 040-038 (Plant Calibration Worksheet)
- Aggregate marination records and sketches detailing marinated stockpiles
- Delivery records of hydrated lime, asphalt cement and samples.
- NDOT Form 040-011 (Daily Plant Report of Asphalt Mixtures)
- Inspector Daily Report (IDR)
- Sample containers and transmittal sheets (NDOT Form 020-016 (Transmittal for Asphalt Samples)), black marking pen, masking tape, plastic bags for transmittals
- NDOT Form 040-045 (Daily Hotplant Worksheet) if the plant is a non-commercial, job site plant (for information only)
- Calibrated thermometer that has been correlated with plant thermometer

For additional information, refer to the *Hot Mix Asphalt Materials, Mixture Design and Construction,* by the National Center for Asphalt Technology and *Principles of Construction of Hot-Mix Asphalt Pavements,* by the Asphalt Institute.

Delivered materials, such as asphalt cement and hydrated lime, are stored on or near the job site. When asphalt cement is delivered, a shipping notice (Bill of Lading) and a copy of the Refinery Material Test Report must accompany each delivery. Section 703, “Bituminous Materials”, of the Standard Specifications, describes the required information contained in the Bill of Lading and Refinery Material Test Report.

Before starting production, the inspector will discuss plant procedures with the plant operator. The discussion should include identifying inspection points to observe mixture production and where to take samples and temperatures. Sufficient notice should be given to the field tester to allow time to calibrate plantmix testing equipment. Certain testing equipment cannot be calibrated until after the mixing plant is calibrated, allow a minimum of 24 hours prior to beginning production for the testing equipment calibration process. Confirm that each haul truck will have a delivery record indicating the load weight. The inspector will confirm with the Contractor that the truck beds will be clean and discuss the method used to reduce plantmix from adhering to the haul truck beds. Contractors commonly apply a releasing agent to the truck bed to reduce the plantmix from adhering.

Before full production begins, Subsection 401.02.02, “(Plantmix Bituminous Pavements - General) (Materials) Composition of Mixtures”, of the Standard Specifications, requires the Contractor to complete a verification process showing that the plantmix complies with the job mix formula and meets specifications. The verification process for mobile plants includes producing a hot drop, an amount of material produced that is representative of the plantmix produced for placement on the roadway and conforms to the job mix formula. The Contractor determines the amount of material to be produced. Typically, the larger the hot drop sample, the more representative the sample is of the final product. The Resident Engineer’s tester samples the material produced from the hot drop and tests the material to verify conformance to the job mix formula.

After the Resident Engineer determines that the hot drop material meets specifications, the Contractor may begin producing plantmix for the required field trial mixture, as described in Subsection 401.02.02, "Plantmix Bituminous Pavements - General (Materials) Composition of Mixtures", of the Standard Specifications. Production is limited on the first day of paving to ensure conformance with the Standard Specifications and the job mix formula prior to production paving.

The Contractor shall carefully consider the test section location. If the Contractor decides to place the field trial mixture material on the travel lane, the Contractor may need to remove the material if it is determined to be unacceptable.

After the trial mixture is produced, the Resident Engineer suspends assessing working days. The Contractor cannot continue producing mixture for 3 days while the Materials Division tests the field trial mixture. The Materials Division forwards the results of the field trial mixtures to the Resident Engineer. The field trial mixture test results will either verify the mix design bitumen ratio or determine the new bitumen ratio that will be used for full production. If the bitumen ratio determined from the field trial mixture test results differs from the initial job mix formula bitumen ratio, then the Resident Engineer establishes a new job mix formula, which is assigned the next sequential job mix formula number. If the field trial mixture does not meet specifications, an additional field trial mixture may be required.

The mixing plant is now ready to run at full production. The Contractor shall produce plantmix that conforms to the job mix formula and the Standard Specifications. The inspector reviews, observes, and monitors operations at the plant to determine if the Contractor's plantmix processes are consistent with Section 401, "Plantmix Bituminous Pavements - General", of the Standard Specifications. In addition, the inspector performs calculations based on information obtained from the plant instrument readings to determine if the material is being produced within the calibrated tolerances.

To determine the bitumen ratio, the inspector conducts plant checks (periodically observes and notes the aggregate and asphalt cumulative totals and the production rate for the plantmix). Plant checks are used to determine bitumen ratio analytically and to monitor consistency of the mix. During production, the inspector typically performs hourly plant checks. Each hour during production, the inspector performs a plant check, monitoring aggregate and asphalt feed rates for a 10-minute period. During the plant check, the inspector notes the plant readings at the beginning and end of the ten-minute period for aggregate and for asphalt. Using the noted plant readings, the bitumen ratio is calculated using the following formula:

$$\frac{WT_{asphalt}}{WT_{dry\ aggregate}}$$

WTasphalt = weight of asphalt, tons

WTdry aggregate = weight of dry aggregate, tons

Typically, plant readings are based on total aggregate weight, which includes the weight of hydrated lime and water. To calculate the dry aggregate weight, the weight of water and the weight of hydrated lime are deducted from the total weight of the aggregate. The following example illustrates how to calculate a bitumen ratio based on an hourly plant check.

EXAMPLE

A plant inspector makes a ten-minute plant check every hour. The inspector notes the plant readings for aggregate and for asphalt at the beginning and end of the 10-minute period. The readings are as follows:

Aggregate Feed:	Beginning reading: 890 tons	End reading: 965 tons
Asphalt meter:	beginning reading: 6.00 tons	End reading: 9.50 tons

The lime content from the job mix formula or as calculated from the bin percent settings is 1.48 percent of the dry weight of aggregate.

The aggregate moisture obtained from a belt sample during that day's production is 3.65 percent.

Calculation:

Lime:	1.48%
Aggregate moisture:	3.65%
Total lime and moisture:	5.13%
Weight of aggregate:	965 tons - 890 tons = 75 tons
Weight of asphalt:	9.50 tons - 6.00 tons = 3.50 tons

$$WT_{\text{dry aggregate}} = \frac{WT_{\text{aggregate}}}{1+(\%\text{ lime} + \%\text{moisture})} = \frac{75\text{ tons}}{1+0.0513} = 71.34\text{ tons dry aggregate}$$

$$\text{Bitumen ratio} = \frac{WT_{\text{asphalt}}}{WT_{\text{dry aggregate}}} \times 100 = \frac{3.50\text{ tons}}{71.34\text{ tons}} \times 100 = 4.91\%$$

The calculated bitumen ratio for each ten-minute check is recorded in the plant Inspector IDR.

The moisture content of the aggregate influences the amount of asphalt added to the mix. During full production, adjustments may be required to compensate for changes in the aggregate moisture. Because aggregate moisture affects the amount of asphalt added to the mix, aggregate moisture tests should be taken twice daily (morning and afternoon).

The plant inspector records daily observations in the following documents:

- IDR
- Plant Inspectors Report (part of NDOT Form 040-011 (Daily Plant Report of Asphalt Mixtures))

In the IDR, the plant inspector records the hourly bitumen ratio obtained from the plant checks. The inspector records the hourly bitumen ratio calculated throughout the day, and the average daily bitumen ratio, calculated from daily totals of mix, aggregate, and asphalt. The inspector records quantities of material delivered to the plant, plant settings, and moisture corrections. The IDR also includes the plant production rate and plant operation times, noting any time the plant is not in operation and the reason why.

The inspector will also consider the following:

- Acceptable mixing produces coated aggregate particles with a homogenous and uniform appearance. Unacceptable plantmix material is characterized by some or all of the aggregate particles not being coated with asphalt. (Aggregate particles that are not coated with asphalt are often described as "white rock").

- If unmixed material comes out of the mixer, either the pugmill or mixer, the mixer could have dead spaces, where complete mixing does not occur. The Contractor periodically inspects the mixing flights or paddles for excessive wear or other problems that result in incomplete mixing.
- If unmixed material comes out of the mixer, the mixer could be overloaded. Compare the production rate with the operating capacity.
- The inspector will view the mixture before the mixture is placed in a silo or haul truck. The Contractor shall provide an access point in accordance with Subsection 401.03.01, "(Plantmix Bituminous Pavements - General) (Construction) Bituminous Mixing Plant", of the Standard Specifications. View the material to verify complete mixing and uniform coating of the aggregate. Poorly mixed material or material that is not completely coated with asphalt should be rejected and the Contractor shall correct any problems.
- Two important elements of producing a quality mixture are bitumen ratio and a homogenous mix. Air voids and stability are sensitive to the bitumen ratio, and a homogenous mixture significantly contributes to a durable pavement.
- The inspector will observe the Contractor's loader operator to confirm that the correct aggregate is supplied to the appropriate bin. Also, check the aggregate feed gates to verify that they are set at the calibrated settings.
- The inspector will inspect the hauling truck beds to see that they are clean. The truck drivers should use only an approved release agent, listed in the current Qualified Product List (QPL), on the truck beds. Observe the application of release agent, making sure that any excess material is drained from the bed of the hauling vehicle before loading with plantmix.
- If the plantmix material is not satisfactory, such as not being uniformly mixed or temperatures not within specification, the inspector would then discuss any problems with the mixture immediately with the plant operator and the Resident Engineer so that corrections can be made.
- The Contractor issues a haul ticket (scale ticket) to each hauling vehicle before the vehicle leaves the plant and goes to the job site. If the loaded truck is weighed on platform scales not at the plant, the weighmaster issues the haul ticket to the truck driver.
- To reduce material segregation, haul trucks with long beds are typically loaded with three smaller batches spaced within the bed (front, back and center) instead of a large single batch.
- The inspector will note any wasted material at the production site as well as any overloaded haul trucks.

Many variables affect the consistency and uniformity of plantmix. The Construction Division's Quality Assurance Section is available to provide support and technical guidance.

The plant inspector, street inspector, and tester must communicate with each other. The Contractor may make adjustments at the plant and at the paver. If the plant inspector detects changes in the mixture being produced, the observation should be communicated to the street inspector and tester, documented, and appropriate action taken. If the street inspector detects any changes in the delivered plantmix, the observation should be communicated to the plant inspector and tester, documented, and appropriate action taken. During mixture production, an intermittent, stop-and-go operation by the Contractor may reduce the quality and consistency of the mix. Therefore, planning and constant communication between the plant and the placement operation keeps the production of plantmix at a constant pace, leading to a uniform material.

PLACEMENT

At the roadway, the street inspector is responsible for monitoring the Contractor's plantmix placement and compaction operation. Haul trucks transport plantmix material from the plant to the paving operation. The plantmix is unloaded into the paver hopper, windrowed on the ground in front of the paver or transferred into a pickup machine or material transfer vehicle. The paver spreads the plantmix to the appropriate width and depth. The plantmix is then compacted using two or more rollers.

As the plantmix is delivered to the paving operation, the inspector records the amount of material incorporated into the work. Haul tickets are used to record and document the amount of plantmix that each truck delivers to the paving operation. The truck driver receives a haul ticket after the truck is loaded with plantmix and weighed. When the truck arrives at the paving operation, the street inspector takes the ticket and records the information in the Record of Delivery - Plantmix Surface sheet. This confirms that the truck left the plant and arrived at the job site. The street inspector records daily observations in the following documents:

- Record of Delivery sheet: In the Record of Delivery sheet, the street inspector or the ticket taker records the delivery of each truck hauling plantmix to the job site. The quantity of material the inspector records is used to calculate the amount of plantmix placed per station, which is the yield. The yield is a means to compare actual placed quantities to planned quantities. While the yield serves as a guide, the inspector will confirm that the actual pavement dimensions conform to those contained in the project plans. Deviations from the planned quantity can cause overruns that can be costly or underruns that fail to meet structural requirements. Notify the Contractor if the required depth is not being achieved. Then, notify the Resident Engineer of the deviation.

- Street inspectors report (part of NDOT Form 040-011 (Daily Plant Report of Asphalt Mixtures)): The street inspector's report is one part of the three-part form. The street inspector records information collected while performing inspection duties at the paver, such as temperatures, placement information (stationing and thickness of pavement), and weather conditions.

- Inspector Daily Report (IDR): The street inspector uses the IDR to record information and observations that are not specifically recorded in the street inspector's report. The street inspector also records in the IDR the straightedge readings that the street inspector is responsible for taking. This report also includes conversations and other events or activities that may influence the final pavement.

Temperature is important for proper placement and compaction of plantmix. Not only is the temperature of the mixture important, but Subsection 401.03.05, "(Plantmix Bituminous Pavements - General) (Construction) Weather Limitations", of the Standard Specifications requires minimum atmospheric and surface temperatures before paving can take place. The street inspector takes the temperature of the mixture to determine if it is within specified ranges for spreading and compaction. The temperature in the windrow gives an indication of the suitability of the mixture for placement in the hopper. Specifications require minimum temperatures of the material at the hopper of the paver. Behind the paver, temperatures of the plantmix must be above specified minimums for various stages of compaction.

As paver augers spread plantmix through the screed, the paver creates an unconsolidated layer of plantmix, called a mat. The inspector observes the surface of the mat for irregularities and cross slope uniformity. Typical irregularities are lumps of cold asphalt, drag marks, pockets of rock (coarse aggregates or fines). If the inspector observes irregularities, the Contractor corrects the irregularities before compacting the mat. The inspector will check the depth of the uncompacted mat frequently. The uncompacted mat thickness will be greater than the design thickness to allow for compaction. IN general, for every inch of uncompacted plantmix placed, the mat will compact approximately 1/4 inch. For example, 2-1/2 inches of plantmix would compact to approximately a 2-inch thick compacted pavement. The compacted plantmix depth should be checked to confirm pavement thickness.

Rolling the mat for compaction is an important step in the paving process. The compactive effort, which comes from rolling, increases the density of the plantmix by reducing air voids in the material. For the acceptable range of density and air voids, refer to Subsection 401.02.02, "(Plantmix Bituminous Pavements - General) (Materials) Composition of Mixtures", of the Standard Specifications. The first roller performs initial breakdown rolling with a steel wheel roller to set the mixture and reduce lateral displacement. The second roller is a pneumatic-tired roller. The last roller is a steel wheel tandem roller that provides a smooth finished surface. If density test results indicate that the hot mat has not achieved the required compaction, the inspector, in coordination with the tester, should work closely with the Contractor. While the Contractor is responsible for achieving the required density, the tester can provide testing information so that the Contractor can modify rolling patterns to achieve the required results before the mat cools.

The street inspector will monitor the delivery, spreading, and compaction procedures to ensure that samples and tests are performed at the required frequencies. Ongoing communication with the testers ensures they take samples in a timely manner. Well-coordinated sampling and testing provides timely confirmation that the placement and compactive effort yields a product that meets requirements.

The inspector will also consider the following:

- If a pneumatic roller causes excessive wheel marks, the Contractor can correct the wheel marks by either reducing tire pressure or delaying rolling until the plantmix temperature decreases (but above 185°F). Although some wheel marks occur with pneumatic rollers, excessive deformation of the surface indicates decompaction of the plantmix.
- With a pneumatic roller, the roller operator must warm the tires before the roller gets onto the mat. The operator proceeds slowly with rolling while the tires gain heat; and, if pickup occurs, immediately remove it from the tires. Typically, pneumatic rollers use an approved release agent, as listed on the current Qualified Products List (QPL), to reduce asphalt pickup.
- The Contractor shall protect longitudinal joints between traffic lanes from damage or distortion by traffic or other causes until the adjacent lane is constructed. During construction of the abutting lane, excess material that accumulates along the joint during spreading should be wasted and not cast over the surface of the uncompacted material.
- When rolling a cold transverse joint, the roller operator cross-rolls the joint, perpendicular to the paving direction, starting with the roller on the cold mat with about 6 inches of the roller extending onto the new hot mat. The operator moves the roller onto the new mat in successive increments of 12 inches until the entire roller is on the new mat.
- A continuous paving operation minimizes irregularities in the finished surface caused by stopping and starting the paving equipment.
- The Contractor typically uses screed heaters to heat up the paver screed until the plantmix can maintain the screed's temperature.
- When the paving operation is halted and delayed for any appreciable amount of time, the paver operator may run material out of the paver, stopping the paver as the screed begins to run out of material. Before restarting the paver, the operator augers sufficient plantmix material to the screed, and allows the paver to stand until the cooler material in front of the screed is warmed by freshly delivered plantmix.
- If end-dump trucks are used, the truck is held against the front of the paver, avoiding bumping the machine. Bumping the paver creates bumps or dips in the mat and spills material in front of the paver. The Contractor shall clean up any material spillage in front of the paver to prevent bump formation. The Contractor should never use trucks to pull the paver.
- The operator should avoid frequent screed adjustments.
- Monitor the cross slope produced by the screed to confirm construction of the planned cross slope.
- Changes in temperature, height, and amount of material in front of the screed; the weight of the screed; and the forward speed of the paver all affect the thickness of the mat without any change of the thickness controls.
- Paving is a continuous operation, during which the Contractor makes adjustments to achieve a quality product in accordance with the contract documents. Provide the Contractor with timely test results so that the necessary adjustments can be made.
- The inspector will continually verify that the project testing frequencies are consistent with the minimum frequencies.
- When constructing a tapered transverse joint to match an existing pavement, the operator starts the paver using manual controls. As the paver progresses, the operator adjusts the screed manually until it reaches full thickness, about 20 feet from the joint.
- The Contractor shall correct areas that have a non-uniform mixture or where aggregate segregation is evident.

After final rolling, the street inspector checks the pavement smoothness with a 12-foot straightedge, both longitudinally and transversely. The street inspector reports the straightedge results on the IDR. The street inspector will carefully inspect all paving joints to verify compliance with 401.03.12, "(Plantmix Bituminous Pavements - General) (Construction) Joints", of the Standard Specifications. The Contractor performs test of the smoothness of the plantmix surface before allowing traffic on the surface, preferably within 48 hours of placement and before the newly paved section is opened to public traffic. (Traffic can adversely affect the pavement's smoothness). The profile measurement system is operated to take test readings in the planned vehicle wheel paths and in the direction of traffic.

Copies of the profile measurement test reports are supplied to the Resident Engineer as soon as possible, typically within 24 hours after the tests are taken. If the smoothness test results indicate an unacceptable pavement profile, corrective action may be required by the Contractor to meet surface tolerance requirements. Excessive high points in the pavement (areas of localized roughness) as described in Subsection 402.03.05, "(Plantmix Bituminous Surface) (Construction) Surface Tolerances" and Subsection 403.03.04, "(Plantmix Bituminous Open-graded Surface) (Construction) Surface Tolerances", of the Standard Specifications, should be marked with paint immediately upon completion of the smoothness testing. With timely notification, the Contractor may be able to alter placement operations to reduce areas of localized roughness and improve the pavement smoothness.

Inspectors from the Construction Division's Quality Assurance Section will verify the smoothness testing for each project using Department-owned profile measuring devices. The Resident Engineer will notify the Quality Assurance Office when the Contractor plans to perform smoothness testing so that the verification testing can be performed at as close to the same time as the Contractor is performing the acceptance testing.

MEASUREMENT AND PAYMENT

Refer to the following for measurement/payment guidelines and related instructions:

- Subsection 401.04.01, "(Plantmix Bituminous Pavements - General) (Method of Measurement) Measurement", of the Standard Specifications
- Subsection 401.05.01, "(Plantmix Bituminous Pavements - General) (Basis of Payment) Payment", of the Standard Specifications
- Subsection 402.04.01, "(Plantmix Bituminous Surface) (Method of Measurement) Measurement", of the Standard Specifications
- Subsection 402.05.01, "(Plantmix Bituminous Surface) (Basis of Payment) Payment", of the Standard Specifications
- Subsection 403.04.01, "(Plantmix Bituminous Open-graded Surface) (Method of Measurement) Measurement", of the Standard Specifications
- Subsection 403.05.01, "(Plantmix Bituminous Open-graded Surface) (Basis of Payment) Payment", of the Standard Specifications
- Subsection 404.04.01, "(Cold Recycled Bituminous Surface and Premixed Bituminous Paving Material) (Method of Measurement) Measurement", of the Standard Specifications
- Subsection 404.05.01, "(Cold Recycled Bituminous Surface and Premixed Bituminous Paving Material) (Basis of Payment) Payment", of the Standard Specifications
- Chapter 10 of the *Documentation Manual*

402 - PLANTMIX BITUMINOUS SURFACE

Plantmix Bituminous Surface is a layer of the roadway structural section. This layer is often called "dense-grade" because it is the densest of the bituminous pavements. In the roadway structural section, the dense-grade layer provides the greatest load-bearing capacity per inch of thickness than other elements of the structural section.

The project plans designate the type of plantmix to be placed. Section 705, "Aggregates for Bituminous Courses", of the Standard Specifications, describes three types of plantmix bituminous surface. The types of plantmix surface are related to the types of aggregate used in the plantmix. Plantmix surface types are:

- Type 2: Commonly used on roadways having typical traffic loading. A Type 2 plantmix may have little or no 3/4-inch aggregate.
- Type 2C: Contains higher percentage of coarse aggregate than Type 2 to improve load-bearing capacity. A Type 2C plantmix has at least 5 percent of 3/4-inch aggregate. It is typically used on roadways that carry high traffic loads, such as Interstate highways and urban arterials
- Type 3: Contains no aggregate greater than 3/8 inch and is typically used as a leveling course or stress-relief course prior to placing a Type 2 or 2C plantmix surface

For construction techniques, processes and details that apply to plantmix bituminous surface before and during construction, refer to "401 - Plantmix Bituminous Pavements: General", in this chapter.

BEFORE CONSTRUCTION

Refer to the corresponding section of "401 - Plantmix Bituminous Pavements: General", in this chapter, for details.

DURING CONSTRUCTION

Refer to the corresponding section of "401 - Plantmix Bituminous Pavements: General", in this chapter, for details. The following subsections provide additional information on compaction and surface tolerances for plantmix bituminous surface (dense-grade).

COMPACTION

Although Subsection 402.03.06, "(Plantmix Bituminous Surface) (Construction) Compaction", of the Standard Specifications, describes three methods of compaction (standard rolling pattern, test section and control strip), the Special Provisions state the specific method to be used on the job site. The Standard Specifications refer to the three methods of compaction as Method A, Method B, and Method C. (Refer to the Standard Specifications for requirements for each compaction method.) After the rollers compact the plantmix, the Resident Engineer's testers use nuclear density gauges to measure the density of the plantmix. Regardless of the compaction method, proper compaction and density at pavement joints is important to the life of the pavement. Poor compaction at joints may result in pavement aging by allowing moisture and air into the pavement.

The following additional information is provided for the three methods of compaction:

- Standard Rolling Pattern (Method A): The standard rolling pattern method describes the minimum rolling requirements that must be met, including the number of roller passes. The Contractor shall establish the rolling pattern. The standard rolling pattern method for achieving density is typically used only for small areas.
- Test Section (Method B): The test section compaction method specifies an acceptable density range, based on the maximum density. This method correlates nuclear density gauge readings with pavement core sample density test

results taken at the same locations. The test section method is the most common compaction method used with new plantmix surface construction.

- Control Strip (Method C): The control strip method establishes an average density using 10 nuclear density gauge readings. Density tests are not performed on core samples with this compaction method. To establish a target density value, the pavement is rolled until nuclear density gauge readings show no increase in density. Once the pavement has reached this density, nuclear density gauge tests are taken at 10 randomly selected locations to establish the average density, which is now the Contractor's target value.

SURFACE TOLERANCES

The pavement surface smoothness is a measure of the Contractor's ability to place the material within the tolerances specified. Several studies have shown that a smooth ride is the most important quality to the motorist. In addition, a smooth surface reduces vehicle impact loading caused by surface irregularities. Impact loading can reduce the life of the pavement and cause premature wear for various components on the vehicles that are using the pavement.

The Special Provisions for each contract describe pavement smoothness requirements. Smoothness specifications include using the straightedge and profile measurement systems to assess pavement smoothness. The straightedge and the profile measurement systems measure different characteristics of surface smoothness. A 12-foot straightedge is used to spot measure pavement irregularities longitudinally and transversely. A profile measurement system is an instrument that measures pavement smoothness longitudinally. A profile measurement system can be in the form of a device called a walking profiler that is typically used to measure very short runs, typically less than 500 feet in length, or an inertial profiler that uses equipment mounted to a vehicle to determine the profile of the roadway and can cover much greater distances.

Walking profilers use a fixed wheel /fixed wheelbase system with onboard inclinometers to determine the pavement smoothness. Inertial profilers use a system consisting of a height referencing device, such as a laser, on board accelerometers, distance measurement device, and an on-board computer that is programmed with an algorithm that will allow it to combine the information from the height referencing device, accelerometer, and distance measuring device to provide a measurement of the actual roadway profile.

Inertial profilers typically come in two configurations; a lightweight inertial profiler and a high-speed inertial profiler. The lightweight inertial profiler is generally based on a lightweight vehicle such as a golf cart or UTV. The speed of the lightweight inertial profiler will be in the range of 12-25 mph depending on the host vehicle. The high-speed inertial profiler will be installed on an automobile such as a light-truck or van as the host vehicle. The speed of the high-speed profiler will be in the range of 25-70 mph depending on the profile measurement system being used.

In most cases, the profile measurement equipment will be similar between the lightweight and high-speed inertial profiler and in some cases, the components may be interchangeable within the manufacturer's systems. The key difference being the host vehicle used for the inertial profiling system. Profile measurements are reported as inches per mile in a format called the International Roughness Index (IRI). The profile measurements are taken in the direction of traffic in both vehicle wheel paths, as described in the Special Provisions. The results from the individual wheel paths will be mathematically combined by the onboard computer with the results being reported as the Mean Roughness Index, or MRI. The profile measurement system can also be set up to locate any bumps in the pavement surface. These will be reported as inches per mile as "areas of localized roughness" in IRI format.

The inspector may use straightedge testing at any location. However, the inspector will straightedge longitudinal and transverse pavement joints. Pavement joints are seams between adjacent pavement sections. Because construction of pavement joints requires matching an existing surface with newly placed plantmix, surface smoothness can vary. The inspector will straightedge these areas to verify that the Contractor has constructed a joint with a smooth surface. The inspector records straightedge test results on their Inspector Daily Report (IDR).

Surface smoothness tolerances measured by a profile measurement system must comply with tolerances listed in the contract documents. (See Figure 15, Figure 16 and Figure 17.) Subsection 401.03.13, "(Plantmix Bituminous Pavements - General) (Construction) Surface Tolerances", of the Standard Specifications, lists four pavement smoothness types: Type A, Type B, Type C, and Type D. The Special Provisions will state the smoothness type that the Contractor shall meet for the contract. To measure the pavement smoothness, the Contractor shall furnish, maintain and operate an approved profile measurement system. The Resident Engineer verifies that the profile measurement system is in accordance with Subsection 402.03.03, "(Plantmix Bituminous Surface) (Construction) Equipment", of the Standard Specifications. The calibration of the device is important to obtain accurate and representative readings.

Figure 15: Walking profiler

Figure 16: Lightweight inertial profiler

Figure 17: High-speed inertial profiler

After being notified by the Resident Engineer that the roadway is ready to be measured, the Construction Division's Quality Assurance Section will observe the calibration and the operation of the profile measurement system before use. To ensure accurate representation of the new pavement smoothness as placed, the Contractor shall take profile measurement readings before placing traffic on the surface. Traffic can alter the smoothness of pavement. Within 24 hours, the Resident Engineer receives the profile measurement readings, which are depicted as a table showing the pavement smoothness, in inches per mile for each 528 feet (0.1 miles) of pavement surface measured. The Construction Field Crew analyzes the readings and checks to ensure accurate data entry and to make sure there are no gaps in the measurement or errors that will require a new measurement. The Contractor may use the profile measurement test results to make modifications to the paving operation to improve the plantmix surface smoothness.

If the surface smoothness is does not meet requirements, the Contractor shall take corrective action to bring the pavement into the designated smoothness tolerance. Typically, the Contractor will hire a specialty grinding company to remove high points by grinding the pavement surface. The equipment used to grind pavement must be able to grind the surface to the surface texture requirements as described in Subsection 402.03.05, "(Plantmix Bituminous Surface) (Construction) Surface Tolerances" and Subsection 403.03.04, "(Plantmix Bituminous Open-graded Surface) (Construction) Surface Tolerances", of the Standard Specifications. After grinding, the area is measured again using the profile measurement system to determine if the area complies with the contract documents. Ensure that the measurement of the corrected section is performed using the same stations or mileposts as the initial measurement. The results of the corrected segment or segments will be provided to the Resident Engineer. Those results will be attached to the initial smoothness report and identified as corrected section measurements. The inspector will ensure that all failing segments have been satisfactorily corrected.

After the grind area meets surface tolerance specifications, the Contractor cleans the grind area, allows it to dry and then seals it with emulsified asphalt. An exception to applying emulsified asphalt after grinding is if the pavement will receive another layer of plantmix bituminous pavement within 2 weeks.

MEASUREMENT AND PAYMENT

Refer to Subsection 402.04.01, "(Plantmix Bituminous Surface) (Method of Measurement) Measurement" and Subsection 402.05.01, "(Plantmix Bituminous Surface) (Basis of Payment) Payment", of the Standard Specifications and Chapter 10 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

NOTES:
Measurement and payment are usually by the ton, which requires accurate weighing of the material. Prior to placing material on the roadway, the material is weighed. Do not pay for material that has not been weighed. Record the placed material quantity on the proper forms.
Plantmix miscellaneous paving areas are measured for surface area payment in addition to the weight of the material placed. It is only paid once for the entire area, regardless of the number of lifts.

403 - PLANTMIX BITUMINOUS OPEN-GRADED SURFACE

Plantmix bituminous open-graded surface is the final layer of a roadway section. The open-graded surface provides a friction surface for vehicles, helps dissipate surface water, and improves the appearance and rideability of the roadway. In contrast to plantmix bituminous surface (dense-grade), open-graded plantmix is a thin layer of plantmix with a maximum size aggregate of 1/2 inch or 3/8 inch. The project plans designate the open-graded aggregate size and course thickness to be placed. The open-graded surface provides no structural strength to the pavement section.

The open-graded course is the final wearing surface, which establishes the public perception of the quality of the work. The appearance of the open-graded surface reflects the workmanship incorporated into the roadway. Because of the impact that the open-graded surface has on the traveling public, it is important to exercise care during placement of the open-graded surface. The freshly placed surface must be protected from damage and defects must be corrected before the material cools. Damage typically occurs from walking or driving on the hot mat.

Because the open-graded course is a thin layer, typically 3/4 inch, the placement operation can move significantly faster than placement of dense-grade. Although the paver may move at a fast pace, the progress of the paving operation is limited to the rollers producing a compacted smooth mat. In addition, the progress of the paving operation may be limited when pavement marking tape is inlaid in the fresh surface during final rolling of the mat. If the paver is placing material far in advance of the tape placement operation, the placed open-graded course may cool below the minimum temperature required by Subsection 634.03.02 “(Pavement Marking Film) (Construction) Pavement Marking Tape”, of the Standard Specifications, for placement of the tape. Inlaid striping, similar to the finished open-graded surface, is a reflection of the workmanship incorporated into the roadway.

For construction techniques, processes and details that apply to plantmix bituminous surface before and during construction, refer to “401 - Plantmix Bituminous Pavements: General”, in this chapter.

BEFORE CONSTRUCTION

Refer to the corresponding section of “401 - Plantmix Bituminous Pavements: General”, in this chapter, for details.

DURING CONSTRUCTION

Because plantmix bituminous open-graded surface is the final surface on which vehicles ride, surface smoothness is important. To reduce the number of ridges and ruts, the Contractor can minimize the number of transverse joints.

Refer to the corresponding section of “401 - Plantmix Bituminous Pavements: General”, in this chapter, for more information. The following subsections provide additional information on compaction and surface tolerances for plantmix bituminous surface (dense-grade).

COMPACTION

Although density testing of the open-graded surface is not required, it is still compacted using at least two rollers in accordance with Subsection 401.03.08, “(Plantmix Bituminous Pavements - General) (Construction) Preparation of Aggregates”, of the Standard Specifications. The first roller, commonly called a breakdown roller, is a tandem axle roller, typically weighing at least 10 tons. The second roller, the finish roller, has a typical minimum weight of 8 tons. Although not required to have vibratory capability, most rollers are so equipped. Refer to Subsection 401.03.04, “Plantmix Bituminous Pavements - General) (Construction) Rollers”, of the Standard Specifications to determine if vibration is prohibited. Each roller must complete two coverages of the open-graded mat. The breakdown roller should start compacting immediately after open-grade is spread. The finish roller will be close behind the breakdown roller, while the open-graded is still warm. The finish roller removes wrinkles or ridges left by the breakdown roller. Vibratory rollers must turn off the vibrator on the final pass of finish rolling. Pneumatic rollers are not used on open-graded surfaces.

SURFACE TOLERANCES

Coordinating production, delivery, and placement of open-graded material improves the riding surface quality. Repeated starting and stopping of the paver reduces the pavement smoothness. The pavement smoothness requirements of open-graded surfaces are similar to those of dense-grade. for additional information, refer to “(402 - Plantmix Bituminous Surface) (During Construction) Surface Tolerances”, in this chapter. For open-graded surfaces that do not meet surface tolerance requirements, the Contractor shall repair, or remove and replace the material as described in the Special Provisions. The Contractor may request to leave the non-conforming material in-place. If the District Engineer approves the request, the Resident Engineer will assess the Contractor liquidated damages. Because open-graded paving is the final surface course, grinding is kept to a minimum because it detracts from the appearance. Because the decision to grind open-grade is significant, the District Engineer and the Resident Engineer make the decision to grind. The Special Provisions describe the terms of assessing liquidated damages for open-grade that does not conform to surface tolerances.

MEASUREMENT AND PAYMENT

Refer to Subsection 403.04.01, "(Plantmix Bituminous Open-graded Surface) (Method of Measurement) Measurement" and Subsection 403.05.01, "(Plantmix Bituminous Open-graded Surface) (Basis of Payment) Payment", of the Standard Specifications and Chapter 10 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

NOTE: Unlike plantmix bituminous dense-grade paving, miscellaneous paving areas are not measured for surface area payment for open-graded surfacing. Payment is only made for the weight of the material placed.

404 - COLD RECYCLED BITUMINOUS SURFACE AND PREMIXED BITUMINOUS PAVING MATERIAL

Existing roadways that have distressed surfaces but acceptable structural strength may only require rehabilitation of the pavement surface. A common rehabilitation method is to remove the existing bituminous surface by coldmilling, mix the milled material with emulsified asphalt and other additives and place the mixed material back onto the roadway. This process is called cold recycling of bituminous surfaces. The equipment used to perform cold recycling, commonly called a recycle train, consists of several connected components. Section 404, "Cold Recycled Bituminous Surface and Premixed Bituminous Paving Material", of the Standard Specifications describes requirements of the recycle train and other equipment needed for cold recycling. The recycle train produces a windrow of cold recycled material that is spread and compacted as described in this chapter in "(401 - Plantmix Bituminous Pavements: General) (During Construction) Placement".

BEFORE CONSTRUCTION

Prior to the start of cold recycle operations, the inspector will review Section 401, "Plantmix Bituminous Pavements - General", Section 402, "Plantmix Bituminous Surface" and Section 404, "Cold Recycled Bituminous Surface and Premixed Bituminous Paving Material", of the Standard Specifications. Due to the inherent variability of the materials encountered during cold recycling of existing roadway surface, it is critical that the inspector is able to recognize when and where minor adjustments may be needed to keep the recycled mix within specification limits and notify the Resident Engineer of those adjustments.

Every effort should be made to locate and identify areas of insufficient pavement thickness and areas where the subgrade has failed; these areas shall be corrected prior to recycling operations. If areas of insufficient pavement thickness or failing subgrade are identified during recycling operations, they shall be addressed as they are discovered. If repairs are not made in a timely manner, they could result in suspension of work, causing a delay to the Contractor while they make the repairs.

Shoulder material must be delivered and placed at least 3 miles ahead of the cold recycle operation. This will reduce the amount of truck traffic on the cold recycled surface and limit the potential damage that the shoulder material hauling and placing operations could cause.

The Contractor shall submit a premixed bituminous material mix design and receive approval for the mix design from the Materials Division, calibrate the bituminous mixing plant to the approved mix design, and in many cases, produce a certain amount of premixed bituminous material before cold recycle operations can begin. If the cold recycled surface will be overlaid with plantmix bituminous pavement, all appropriate mix designs must be submitted and approved and the bituminous mixing plant must be calibrated to those mix designs before cold recycle operations can begin. Representatives from the Construction Division's Quality Assurance Section and the Materials Division, along with the inspector, will observe and approve the calibration.

The recycle train must be calibrated as required in Subsection 404.03.01, "(Cold Recycled Bituminous Surface and Premixed Bituminous Paving Material) (Construction) Cold Recycle Equipment", of the Standard Specifications.

Representatives from the Construction Division's Quality Assurance Section and the Materials Division, along with the inspector, will observe and approve the calibration.

A Pre-Activity Meeting and training session, typically conducted by a representative of the Materials Division, will be scheduled for all Contractor and construction crews that are involved in the cold recycle work.

COMPOSITION OF MATERIALS

Typically, materials include reclaimed asphalt pavement, a recycling agent and lime. (Dry lime is called quicklime.) After water is added, the lime is called hydrated lime slurry. After the pavement is milled, a recycling agent, approved or specified by the Materials Division and dry lime/quicklime is mixed with the milled material. All ingredients are blended to produce a homogeneous mixture. Water, used to activate the lime in the cold recycle process, is also subject to pre-approval by the Materials Division because certain minerals in water can be detrimental to the cold recycle material. Based on the material requirements contained in Subsection 404.02.01, "(Cold Recycled Bituminous Surface and Premixed Bituminous Paving Material) (Materials) Composition of Cold Recycle Mixtures", of the Standard Specifications, the Contractor, in consultation with the Resident Engineer and the Materials Division, may make adjustments based on field conditions.

EQUIPMENT

For the requirements of the recycle equipment, refer to Subsection 404.03.01, "(Cold Recycled Bituminous Surface and Premixed Bituminous Paving Material) (Construction) Cold Recycle Equipment" of the Standard Specifications. A typical recycle train consists of a coldmilling machine, where a hydrated lime slurry and additional water is added as the pavement is milled up. Included in the train is a crusher that reduces oversized recycled materials, as well as a portable plant pugmill mixer for the addition of emulsified asphalt, and water, if required. The metering system of the cold recycle train must be interlocked and functioning properly.

Figure 18: Recycle train

A paver is also part of the recycle train and places the recycled material on the roadway. The Contractor selects the paver size based on the width and depth of the cold recycle mat shown in the project plans. A paver used for pavement recycling generally requires more horsepower than would typically be used for plantmix paving. In contrast to plantmix paving in which the paving material is hot and flowable, cold recycled material is placed at a cooler temperature and as a rule, does not flow through the paver as well. The paver must be able to place the cold recycled mixture to the established grade and cross slope.

Multiple rollers are required to sufficiently compact the cold recycled mixture. Rollers are subject to minimum weight limits unique to recycle projects and are described in Subsection 404.03.03, "(Cold Recycled Bituminous Surface and Premixed Bituminous Paving Material) (Construction) Rollers" of the Standard Specifications.

Typically, the following equipment is required:

- Two pneumatic rollers are required: one weighing no less than 15 tons and no more than 20 tons, and the second weighing no less than 25 tons and no more than 30 tons
- Two double-drum vibratory steel wheel rollers weighing at least 10 tons.

The inspector will verify the roller weights before they are used.

Figure 19: Rubber tired pneumatic roller

Figure 20: Double drum steel wheel vibratory roller

DURING CONSTRUCTION

The inspector or tester observes as the Contractor takes a sample of the emulsified asphalt from each load as it is being delivered. The emulsified asphalt is tested for viscosity before it is applied to the roadway.

WEATHER LIMITATIONS

Cold recycle operations are best performed in the summer months when hot, dry weather is expected. Cold recycling requires overnight low temperatures above 35º F. During paving, the surface temperature must be at least 60º F and rising. Because warm, dry weather is required for proper curing, the success of the recycling operation and the quality of the pavement are strongly influenced by weather. Work will need to be suspended during rain. If work is suspended because of rain, verify that the maximum moisture content in the recycled pavement is in accordance with Subsection 404.03.04, "(Cold Recycle Bituminous Surface) (Construction) Weather Limitations", of the Standard Specifications.

SPREADING, COMPACTING AND FINISHING

The recycling operation, once underway, should progress at a steady rate sufficient to provide continuous operation of the paver. If the forward progress of the recycle train is halted after emulsified asphalt is added to the aggregate, the delay may allow the emulsified asphalt to break before the mixture is placed on the roadway. If this occurs, placing and compacting the material may be difficult.

The quality of the cold recycled pavement is in close relation to the frequency of stopping and starting of the paver during the placement of the cold recycled material. Regulating the forward travel of the paver to match the rate of the cold recycle operation with a minimum amount of stopping will provide a smoother and more consistent surface.

Compacting a recycled plantmix mat is different from compacting a plantmix bituminous surface mat. Because recycled material contains moisture, the recycled material must be given time for some moisture to dissipate. (Refer to Subsection 404.03.07, "(Cold Recycle Bituminous Surface) (Construction) Spreading, Compacting, and Finishing", of the Standard Specifications, for more information) Performing compaction during early morning or late evening hours, when atmospheric temperatures are low, is undesirable. Recycling operations must be scheduled to accomplish compaction during warmer hours. In the heat of the day, the time between spreading and initial compaction may be reduced. As a guide, the roller may begin compacting the mat when the mat changes color. By recording the rate of placement, the inspector and the Resident Engineer can determine the optimal time that the recycled material may sit before compaction begins. Monitoring the compaction, timing and effort is a significant part of the inspector's duties during this operation. Contact the Construction Division's Quality Assurance Section for additional guidance when the recycle operation begins.

The control strip compaction method (Method C) is used for compaction of cold recycled material. For additional information, refer to Subsection 402.03.06, "(Plantmix Bituminous Surface) (Construction) Compaction", of the Standard Specifications for a description of Method C, and in this chapter under "(402 - Plantmix Bituminous Surface) (During Construction) Compaction". Cold recycle operations are comprised of an initial compactive effort, performed within hours of the placement of the cold recycled material followed by recompactive effort several days later. The recompactive effort must not begin until after the moisture has sufficiently dissipated from the recycled material and traffic has used the recycled roadway for the designated number of days. The field tester will obtain samples to determine the moisture content of the recycled material. Once the material contains 2.0 percent or less moisture, the required number of days have passed and the surface of the recycled material is 90°F or above, recompaction of the recycled surface can begin. The Resident Engineer may require additional control strips if atmospheric temperatures vary significantly throughout the day. For additional information, refer to Subsection 404.03.07, "(Cold Recycled Bituminous Surface and Premixed Bituminous Paving Material) (Construction) Spreading, Compacting, and Finishing", of the Standard Specifications.

Upon completion of compactive and recompactive efforts, the Contractor shall seal the surface, by applying an emulsified asphalt to the compacted recycled surface. The emulsified asphalt sealer applied to the surface is typically the same type of emulsified asphalt used in the recycling operation. After a significant amount of water in the emulsified asphalt dissipates, sand blotter is applied to reduce the amount of asphalt picked up by traffic. The recycled pavement must cure for a minimum number of days, as stated in Subsection 404.03.07 "(Cold Recycled Bituminous Surface and Premixed Bituminous Paving Material) (Construction) Spreading, Compacting, and Finishing", of the Standard Specifications, before it is overlaid with another plantmix material. Before placing the plantmix overlay, the recycled pavement must be recompacted with a pneumatic roller and a steel wheel roller.

After the final rolling, the inspector will use a 12-foot straightedge to check the surface of the cold-recycled pavement to verify conformance with surface tolerance requirements. Subsection 404.03.08, "(Cold Recycled Bituminous Surface and Premixed Bituminous Paving Material) (Construction) Surface Tolerances", of the Standard Specifications specifies that the surface shall not vary by more than 1/4-inch variance from the lower edge of the straightedge in any direction.

MEASUREMENT AND PAYMENT

Refer to Subsection 404.04.01, "(Cold Recycled Bituminous Surface and Premixed Bituminous Paving Material) (Method of Measurement) Measurement" and Subsection 404.05.01, "(Cold Recycled Bituminous Surface and Premixed Bituminous Paving Material) (Basis of Payment) Payment", of the Standard Specifications and Chapter 10 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

405 - TACK COAT

A tack coat is typically a light application of emulsified asphalt that creates a bond between pavement surfaces. The tack coat primarily helps to prevent development of a slip plane between an existing surface and another course to be placed on it. The Contractor applies the tack coat at an application rate as stated in the project plans or as otherwise directed by the Resident Engineer, covering the entire area uniformly. If the tack coat is applied too heavily, the tack coat no longer bonds: it becomes a lubricant, creating a slip plane on which the overlying course may creep or push. Tack coat is required on surfaces to receive paving and between all paving courses unless otherwise directed.

The bituminous material shall conform to Section 703, "Bituminous Materials", of the Standard Specifications.

BEFORE CONSTRUCTION

The tack coat is an emulsified asphalt that is diluted (mixed) with water. The project plans state the type of emulsified asphalt to be used as the tack coat. the contract documents allow the Contractor to substitute other types of emulsified asphalt for the type stated in the project plans if approved. Section 405, "Tack Coat", of the Standard Specifications, lists the types of emulsified asphalt that may be substituted. If the project plans call for the emulsified asphalt to be diluted at the rate of 70/30 (70 percent emulsified asphalt and 30 percent water by mass), then the following is an example of the dilution calculation:

(1.0 / .7) = a factor of 1.4286

5 tons of emulsified asphalt on truck x the factor of 1.4286 = 7.143 total diluted weight. Water and emulsified asphalt.

5 / 7.143 = 70.0% Oil

2.143 / 7.143 = 30.0% Water

The water is added to the emulsified asphalt in the distributor truck. A portion of water is added first, then the emulsified asphalt, and then the remaining water. When all materials are combined in the distributor truck, the materials are circulated in the truck until thoroughly mixed. Because water is added based on the weight of the emulsified asphalt, the Contractor shall provide an acceptable method of weighing diluted emulsified asphalt.

As material is delivered to the job site and before it is placed in storage tanks, the inspector will verify that the grade and type of emulsified asphalt is in accordance with the contract documents.

DURING CONSTRUCTION

When emulsified asphalt is delivered, it must arrive with three copies of a shipping notice (Bill of Lading) and a refinery material certification must be received for the delivery. For the required information contained in the shipping notice and refinery test report, refer to Section 703, "Bituminous Materials", of the Standard Specifications.

Refer to the Materials Sampling and Testing Frequencies page on the NDOT Internet site for sampling frequencies. Typically, a sample is taken for each load of emulsified asphalt delivered. The inspector marks the sample container using a marking pen, showing the sample number, type of material, contract number and date. The inspector completes and attaches NDOT Form 020-016 (Transmittal for Asphalt Samples) to the sample container.

Number each sample sequentially, beginning with the number 1. The inspector also numbers each Bill of Lading sequentially, beginning with the number 1. Record the Bill of Lading and sample number in the liquid asphalt Record of Delivery. Refer to Chapter 11 of the *Documentation Manual* for documentation details.

The Contractor shall notify the Resident Engineer when deliveries will take place so an inspector can be available to observe the delivery and sampling. The inspector observes the Contractor taking samples of the emulsified asphalt. Emulsified asphalt samples should be stored in plastic sample containers supplied by the Department. (NDOT reserves the right to require the Contractor to provide a sample of undiluted emulsified asphalt at any time.)

APPLICATION

The project plans state the theoretical application rate (gal/yd^2) for the different types of bituminous materials used. The application rate is based on the material being applied, the purpose of the material and the surface on which it is applied. The Resident Engineer adjusts the application rate based on field conditions.

The Contractor applies the emulsified asphalt using a distributor truck. (See Figure 21.) The distributor truck shall be in accordance with Subsection 405.03.01, "(Tack Coat) (Construction) Equipment", of the Standard Specifications. The distributor truck must evenly heat the material, maintaining the material at the required temperature. The distributor truck must apply the emulsified asphalt in an even and uniform pattern. (See Figure 22 for correct and incorrect spray patterns).

Figure 21: Distributor truck

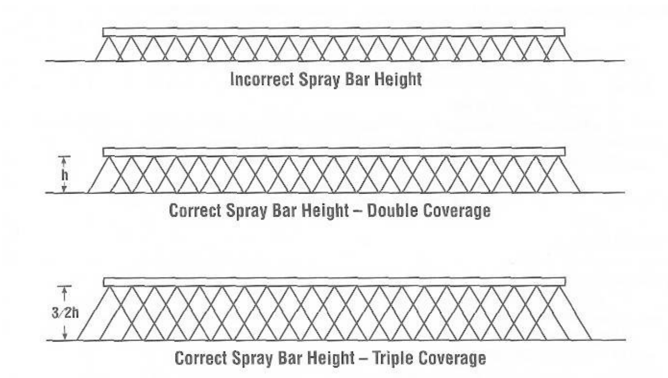

Figure 22: Distributor truck spray bar patterns

The distributor truck must not leak engine fuel, lubricants or hydraulic fluid that may contaminate the emulsified asphalt. After the emulsified asphalt has been diluted, the distributor truck is weighed using certified scales. Before applying the material to the roadway, the distributor truck operator provides the inspector with weigh tickets showing the weight of the undiluted material and the weight of the diluted material after water is added. From the weights on the weigh tickets, the inspector can determine the actual dilution rate.

To determine the amount of diluted emulsified asphalt applied to the roadway, weights are obtained before applying the diluted material (weigh-in) and after application (weigh-back). The difference between the weigh-in and the weigh-back is the amount of emulsified asphalt applied to the roadway.

If weighing the truck for a weigh-back is not feasible and the distributor truck is equipped with positive automatic in-cab controls including tachometer, pressure gages and a digital volume measuring device then the quantity of emulsified asphalt applied can be determined using these meter readings.

If weighing the truck for a weigh-back is not feasible and the distributor truck is not equipped positive automatic in cab controls, manually check the spray rate by measuring the volume of emulsion in the tank before spraying, spray, and then recheck the volume in the tank. For approval of this method of measurement, the Contractor shall check the depths on the calibration stick with the Resident Engineer prior to placement.

The surface to receive the application of emulsified asphalt must be clean, dry and free of foreign material. The inspector verifies that the surface does not contain unacceptable material such as diesel fuel, oil or other petroleum products that would degrade the effectiveness of the emulsified asphalt.

The inspector will consult with the Contractor and the distributor truck operator to clarify the limits of the application, temperature requirements, application rate, distributor truck ingress and egress, and weigh-in/weigh-back of the distributor truck. The Contractor shall limit the application area to that which can be paved with plantmix the same day. If the tacked surface is not covered with plantmix, a light application of tack coat may be applied the next day. During tack coat application, the inspector will confirm uniform application of the emulsified asphalt. The distributor truck must evenly coat the entire surface. The Contractor shall remove excess material using squeegees or brooms.

Immediately after application, the tack coat will have a dull, brown appearance. As the moisture dissipates from the tack coat, the appearance changes to shiny black and the material becomes sticky or tacky. When the water dissipates and the tack coat becomes sticky, it is said to “break.” The amount of time that a tack coat takes to break depends upon weather conditions. During the heat of the summer, the tack coat may break in minutes; but when temperatures are cooler, breaking takes longer. Do not place the plantmix over the tacked surface until the tack coat breaks. If plantmix is placed on the tack coat before it breaks, the emulsified asphalt could migrate into the mix, causing bleeding of the compacted material.

Prior to the application of the tack coat, verify that the minimum and maximum allowable spraying and mixing temperatures of emulsified asphalts meet the requirements listed in Table 1 of Subsection 406.03.04, “(Prime Coat) (Construction) Application of Bituminous Material”, of the Standard Specifications.

After the tack coat is applied, the inspector calculates the application rate (gal/yd^2), using the surface area that received the tack coat and the amount of material applied (the difference between the weigh-in and the weigh-back). To attain the total gallons applied from a weigh-back, refer to the table for average masses and volumes of emulsified asphalt in Subsection 109.01, “(Measurement and Payment) Measurement of Quantities”, of the Standard Specifications.

MEASUREMENT AND PAYMENT

Refer to Subsection 405.04.01, “(Tack Coat) (Method of Measurement) Measurement”, of the Standard Specifications, for measurement guidelines. No direct payment is made for this activity.

406 - PRIME COAT

A prime coat consists of applying a liquid asphalt material to an untreated aggregate base course. The prime coat bonds the loose aggregate particles, acts as a moisture barrier and promotes adhesion between the base and the overlying course. A prime coat is a low-viscosity liquid asphalt applied directly to the surface of a base, upon which a plantmix bituminous mat is placed. Cutback asphalt (asphalt cement diluted with petroleum products) is an asphalt commonly used for prime coats.

The bituminous material shall meet the requirements in Section 703, “Bituminous Materials”, of the Standard Specifications.

BEFORE CONSTRUCTION

Before applying a prime coat, the base course must be approved by the Resident Engineer. The base course must have the appropriate number of passing compaction tests. The base course shall also have sufficient moisture to maintain compaction and to promote penetration of the prime coat. The compacted base must be smooth and uniform, meeting the established grades and cross slopes.

The prime coat should be applied soon after acceptance of the base course to preserve the base course and to provide the longest cure time possible. For the required cure time, refer to Subsection 406.03.04, “(Prime Coat) (Construction) Application of Bituminous Material”, of the Standard Specifications. Traffic control limitations may require shorter cure times. As the cure time increases, the stickiness of the prime coat surface reduces, which reduces the potential for picking the prime coat up by paving equipment or traffic.

DURING CONSTRUCTION

APPLICATION

The project plans contain the theoretical application rate for prime coats as well as the type of material to be used. The application rate may be adjusted based on the field conditions. Typically, a sufficient amount of prime coat is applied to obtain full penetration, leaving minimum puddles on the surface.

The construction details of a prime coat are similar to those of a tack coat. Details describing the materials and application process for tack coats apply to prime coats. For additional information, refer to “405 - Tack Coat”, in this chapter. The application rate for a prime coat is typically heavier than a tack coat application rate, but the Resident Engineer determines the application rate based on the surface conditions and the amount of time that will lapse between applying the prime coat and placing a surface course. Immediately before applying prime coat, the Contractor moistens the surface to be primed. Moistening the surface improves the ability of the prime coat to penetrate the surface.

Prior to the application of the prime coat, verify that the minimum and maximum allowable spraying and mixing temperatures of cutback asphalts meet the requirements listed in Table 1 of Subsection 406.03.04, “(Prime Coat) (Construction) Application of Bituminous Material”, of the Standard Specifications.

After the prime coat is applied, the inspector calculates the application rate (gal/yd^2), using the surface area that received the prime coat and the amount of material applied (the difference between the weigh-in and the weigh-back). To obtain the total gallons applied from a weigh-back, refer to the conversion table for average masses and volumes of cutback asphalt or average masses and volumes of asphalt cement in Subsection 109.01, “(Measurement and Payment) Measurement of Quantities”, of the Standard Specifications.

After applying the prime coat, the Contractor protects the area until the material breaks. If traffic needs to use the primed area, sand blotter will be placed after the prime coat breaks, in accordance with Subsection 705.03.05, (Aggregates for Bituminous Courses) (Physical Properties and Tests) Sand Blotter”, of the Standard Specifications. If conditions allow, avoid using sand blotter. Since excess sand blotter can create a slip plane between the layers, it is removed by sweeping before paving. If sand blotter is used, the Contractor shall apply a tack coat before paving.

MEASUREMENT AND PAYMENT

Refer to Subsection 406.04.01, “(Prime Coat) (Method of Measurement) Measurement” and Subsection 406.05.01, “(Prime Coat) (Basis of Payment) Payment”, of the Standard Specifications and Chapter 11 of the *Documentation Manual* for measurement and payment guidelines and related instructions.

407 - SEAL COAT

A seal coat is an application of bituminous material that is placed on a plantmix bituminous surface or a rehabilitated roadbed to seal the surface. Seal coats provide a non-skid surface as an interim step during staged construction, or preserve and upgrade existing pavement.

Seal coats are applied in order to:

- Prevent moisture from entering the pavement.
- Reduce oxidation of the pavement.
- Rejuvenate a dry, weathered surface.
- Reduce raveling of the pavement surface.

- Retain moisture during a roadbed modification process.
- Provide a temporary surface for traffic.

Emulsified asphalts (asphalt cement diluted with water) or cutback asphalts (asphalt cement diluted with petroleum products) are asphalts commonly used for seal coats. On projects having small quantities of seal coat, emulsified asphalts may be substituted for cutback asphalt. In urban areas, air quality regulations may prohibit the use of cutback asphalt.

Emulsified asphalt (diluted) shall be proportioned and mixed according to Subsection 405.02.01, "(Tack Coat) (Materials) Bituminous Material", of the Standard Specifications.

BEFORE CONSTRUCTION

The project plans contain the application rate for seal coats as well as the type of material to be used. The Resident Engineer typically adjusts the application rate based on the field conditions.

DURING CONSTRUCTION

Details describing the materials and application process for tack coats apply to seal coats. for additional information, refer to "405 - Tack Coat", in this chapter. The application rate for a seal coat is typically heavier than a tack coat application rate, but the Resident Engineer determines this based on the surface conditions. After applying the seal coat, protect the area until the material breaks. If traffic needs to use the sealed area, apply sand blotter in conformance with Subsection 705.03.05, (Aggregates for Bituminous Courses) (Physical Properties and Tests) Sand Blotter", of the Standard Specifications, is applied after the material breaks. If conditions allow, avoid using sand blotter.

Prior to the application of the seal coat verify that the minimum and maximum allowable spraying and mixing temperatures of emulsified asphalts meet the requirements listed in Table 1 of Subsection 406.03.04, "(Prime Coat) (Construction) Application of Bituminous Material", of the Standard Specifications.

After the tack coat is applied, the inspector calculates the application rate (gal/yd^2), using the surface area that received the tack coat and the amount of material applied (the difference between the weigh-in and the weigh-back). After the prime coat is applied, the inspector calculates the application rate (gal/yd^2), using the surface area that received the prime coat and the amount of material applied (the difference between the weigh-in and the weigh-back). To obtain the total gallons applied from a weigh-back, refer to the conversion table for average masses and volumes of emulsified asphalt in Subsection 109.01, "(Measurement and Payment) Measurement of Quantities", of the Standard Specifications.

MEASUREMENT AND PAYMENT

Refer to Subsection 407.04.01, "(Seal Coat) (Method of Measurement) Measurement" and Subsection 407.05.01, "(Seal Coat) (Basis of Payment) Payment", of the Standard Specifications and Chapter 11 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

408 - SURFACE TREATMENT

A surface treatment rehabilitates, preserves, and extends the life of bituminous plantmix pavements. A common type of surface treatment is a chip seal, which keeps water from penetrating the pavement and improves skid resistance. A chip seal is performed by spraying a thin layer of asphalt, typically an emulsified asphalt, onto an existing distressed pavement, and then applying a single size aggregate. The aggregate is evenly distributed over the asphalt material and then rolled.

Variable local conditions and environmental factors influence the success of a chip seal operation. Successful chip seal operations require judgment that incorporates knowledge of materials, construction methods, and the effect of environmental factors. The experience of the Contractor, construction crew, familiarity with the local materials and suitable equipment usage improves the probability of a successful chip seal project.

Factors that affect the success of a chip seal are:

- Aggregate and emulsified asphalt spread rates.
- Surface preparation.
- Construction techniques.
- Weather.
- Materials.

AGGREGATE AND EMULSIFIED ASPHALT SPREAD RATES

Spread rates must be tailored to each project. Spread rates are determined based on source and gradation of the aggregate, the pavement surface condition and the amount of traffic. The ideal aggregate spread rate will result in a mat depth equal to the nominal size of the aggregate used. Typically, aggregate is embedded in the emulsified asphalt to 50 to 70 percent of its height after rolling. If the aggregate spread rate is too high, vehicle tires will dislodge aggregate pieces. If the aggregate spread rate is too low, sufficient coverage is not obtained and excess emulsified asphalt may flush onto the aggregate surface.

The emulsified asphalt rate is adjusted based on the road surface condition. Absorbent, weathered or flushed-surface conditions may require different application rates. Too little emulsified asphalt prevents the aggregate from embedding properly, and the aggregate will be dislodged and lost. Too much emulsified asphalt drowns the aggregate in emulsified asphalt, resulting in flushing and a reduction of skid resistance.

SURFACE PREPARATION

Before chip sealing a paved surface, the roadway surface is repaired and cleaned: potholes are filled, ruts are leveled, cracks are sealed, and broken edges are repaired.

CONSTRUCTION TECHNIQUES

Emulsified asphalt is applied to the roadway with a distributor truck equipped with spray bars. Even though the emulsified asphalt application rate is as directed by the Resident Engineer, an improperly adjusted spray bar can cause a non-uniform application or streaking of the emulsified asphalt. Streaks can result where emulsified asphalt is applied too heavily, causing bleeding. Between streaks, the emulsified asphalt can be too light, causing the aggregate to strip from the emulsified asphalt. Proper adjustments of the spray bar height, nozzle angles and spray pattern help achieve a uniform distribution.

Aggregate must be spread on the emulsified asphalt within the first few minutes after application. Teamwork among the distributor truck, chip spreader, and truck drivers is essential. If the aggregate is spread too late, it will not adequately adhere to the emulsified asphalt and stripping will result. Another critical activity is rolling, which seats the aggregate in the emulsified asphalt, enhancing a good bond. The aggregate is rolled with pneumatic tired rollers immediately after spreading. Steel wheeled rollers are not used because it will ride on the high spots, crushing the aggregate, and pass over the low spots, failing to adequately seat the aggregate.

After spreading and rolling the aggregate, light brooming removes loose aggregate. If the sweeping operation begins too soon (before the emulsified asphalt sets) it will strip away properly seated aggregate. To prevent this problem, brooming should occur after the aggregate application and after the emulsified asphalt sets, typically 1 to 3 hours after rolling for light brooming and 12 to 24 hours for heavy brooming. During hot weather, delay sweeping operations until the pavement cools, which typically occurs in the early morning. If sweeping is delayed until early morning hours, traffic control is maintained until sweeping is completed.

WEATHER

Hot, dry weather is crucial to the success of a chip seal project. It must be hot and dry for proper emulsified asphalt setting and curing. The best time for chip sealing is during warm weather months: May, June, July, August and September. Cool daytime temperatures can cause aggregate loss. Monitor weather forecasts to work around potential weather problems. When the atmospheric temperature exceeds 110°F, chip seals should not be applied because the emulsified asphalt tends to flush.

MATERIALS

Dirty aggregate is detrimental to the success of a chip seal project. Emulsified asphalt does not adhere to aggregate that is covered with fines, is too dusty, or is too wet. Dirty aggregate leads to stripping, which is dislodging of aggregate from the emulsified asphalt. The ideal solution is to use washed aggregate. The aggregate must meet the Cleanness Value requirement as stated in Subsection 705.03.04, "(Aggregates for Bituminous Courses) (Physical Properties and Tests) Screenings", of the Standard Specifications. Aggregates that do not meet the required Cleanness Value may be left in place at a cost as stated in Subsection 408.05.01, "(Surface Treatment) (Basis of Payment) Payment", of the Standard Specifications. Aggregate used for chip seals should not be too soft. Aggregates will meet the required percentage of wear found in Subsection 705.03.04 of the Standard Specifications. Soft aggregate crushes during rolling, under traffic, and breaks down rapidly after freeze-thaw cycles.

BEFORE CONSTRUCTION

REPAIRS

Pavement surface deficiencies must be repaired before applying a chip seal to the roadway. District maintenance forces typically repair roadway deficiencies before chip seals are applied. Some methods for repairing deficiencies are:

- Repairing all holes, depressions, and rutting
- Filling and sealing all cracks
- Leveling all bumps, waves, and corrugations that will impair riding quality
- Removing all excess material on patches and joints
- Cleaning the full width of the surface to be treated

Common repair activities completed before a chip seal are hotmix and coldmix patching and crack sealing. In addition to preventing water from entering the base, crack sealing reduces loss of emulsified asphalt into existing cracks. Patching levels the pavement surface and corrects areas of isolated pavement distress. The type of material used for the various repairs is important and can affect the quality and longevity of the chip seal. Patching materials and crack sealant need time to cure before placing a chip seal. Patching and crack sealing should be completed several months before the chip seal construction to allow crack sealant and paving materials to cure. As a rule, patching should be completed at least 6 months before construction and crack sealing should be applied at least 3 months before the application of chip seals.

MATERIALS

The Contractor shall submit samples of emulsified asphalt and aggregate to the Resident Engineer for testing and transmittal to the Materials Division at least 2 weeks before the chip seal operation begins.

The Contractor shall stockpile a sufficient quantity of aggregate to ensure a continuous chip seal operation. To be ready for use, the stockpiled aggregate must be tested for acceptance. Subsection 408.03.04, "(Surface Treatment) (Construction) Weather Limitations", of the Standard Specifications, contain atmospheric temperature and surface requirements that shall be verified by the inspector.

SWEEPING

Prior to placing a chip seal, the Contractor sweeps the pavement surface to remove dirt, dust or debris. In certain areas of the state, air quality regulations may require dustless sweepers to be used. Adequate sweeping provides a clean surface that allows good adhesion between the pavement surface and the emulsified asphalt. It is important that the full width of the existing surface be swept to remove all foreign material to provide a clean surface before the emulsified asphalt is applied. If the surface is swept too far in advance, it may need to be swept again on the day of construction.

Sweeping with rotary broom sweepers often creates dust. If dust poses a danger to the traveling public, a water truck may be used to reduce dust or when the roadway surface is excessively dirty. When a water truck is used, the sweeping should be completed the day before the chip seal operation begins to allow the pavement to dry.

EQUIPMENT

Before the chip seal operation begins, verify that the distributor truck is calibrated for transverse and longitudinal application rates as stated in Subsection 408.03.01, "(Surface Treatment) (Construction) Distributors", of the Standard Specifications. In addition, verify that the aggregate spreader is calibrated as stated in Subsection 408.03.02, "(Surface Treatment) (Construction) Aggregate Spreader", of the Standard Specifications.

DURING CONSTRUCTION

The field inspector or tester observes the Contractor taking samples of the emulsified asphalt from each load delivered. The emulsified asphalt is tested for viscosity before it is applied to the roadway. After the Resident Engineer accepts the emulsified asphalt and before it is applied to the roadway, temporary lane line markers are installed. After installation of the lane line markers, additional sweeping may be required to remove debris and dirt from the roadway surface. Exercise care in order to protect the lane line markers from being removed.

After the distributor truck and chip spreader are calibrated, all equipment must be in position to begin their functions. The distributor truck operator ensures that the distributor truck's spray bar is perpendicular to centerline before the emulsified asphalt application begins. The emulsified asphalt application should appear as a uniform sheet across the entire width of the spread. (See Figure 23.)

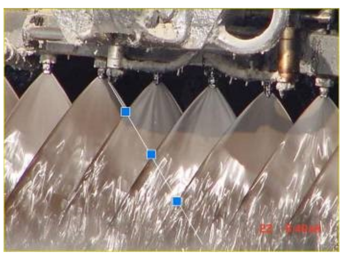

Figure 23: Emulsified asphalt spray application pattern

The inspector observes each application to verify that all nozzles are spraying correctly. Observing the emulsified asphalt distribution allows early correction of spraying problems such as a clogged nozzle, nonparallel nozzles, or improper application temperature.

Paper is placed on the roadway surface at the beginning of each spread to allow the distributor truck to attain the proper application speed as the distributor truck crosses the paper, providing a neat line and avoiding a double application of emulsified asphalt at the construction joint. In addition to the beginning of the spread, if the spreader stops for more than 3 minutes, a transverse paper joint is constructed to provide a neat line for a subsequent application of emulsified asphalt.

Regarding longitudinal joints, each day's spread must be completed to the full width of the roadway. For a two-lane roadway, a longitudinal joint is constructed by applying emulsified asphalt 6 inches wider than the aggregate spread on the first pass of the distributor truck. After half of the day's anticipated aggregate tonnage is applied, the operation returns to the starting point to begin the second pass of spreading aggregate. When emulsified asphalt is applied adjacent to the first spread, the distributor truck operator rotates the end nozzle at the longitudinal joint, effectively creating a straight edge (knife edge).

The distributor truck and the aggregate spreader shall be aligned perpendicular to the roadway before starting the spread. The emulsified asphalt is applied at the established rate. The aggregate is spread immediately after the emulsified asphalt is applied and before the emulsified asphalt begins to set. Typically, the spreader is no more than 100 yards behind the distributor truck. If the weather is hot and windy, the distance between the distributor truck and the spreader is reduced to ensure aggregate placement before the emulsified asphalt breaks. To allow for timely aggregate spreading on the sprayed emulsified asphalt, two or three loaded trucks should be in queue behind the aggregate spreader and before the rollers. Haul truck wheel paths should be staggered so that the compactive effort from the haul trucks is evenly distributed across the width of the mat. If the emulsified asphalt sets before the aggregate is spread, the spreading operation stops and corrective action is taken. In most situations, a paper joint is installed and the emulsified asphalt that has broken receives an additional application of emulsified asphalt. The aggregate spreading operation resumes after the second emulsified asphalt application. The second emulsified asphalt application rate is typically reduced to minimize bleeding or flushing of the emulsified asphalt.

A self-propelled aggregate chip spreader pulls the dump trucks through the aggregate spread area. As each dump truck is emptied, the aggregate spreader operator releases that truck, and the next truck in queue is attached to the aggregate spreader. (See Figure 24 and Figure 25.)

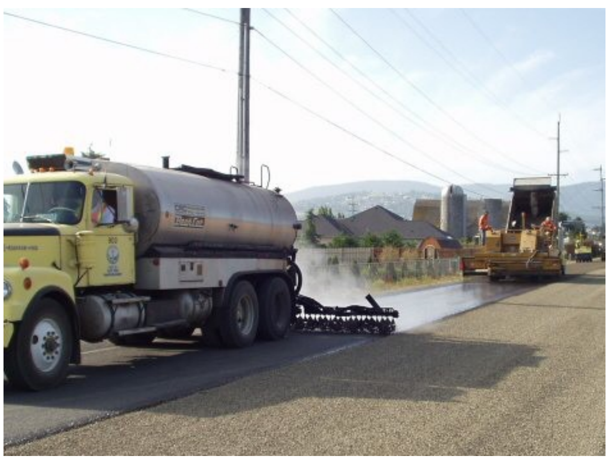

Figure 24: Emulsion distributor truck

Figure 25: Chip spreader and hauling trucks

Note that aggregate spreading greater than the specified rate can increase the risk of windshield damage because of dislodged aggregate, it is not cost effective and it requires additional sweeping efforts. Aggregate that is spread at a rate less than the specified rate creates areas of uncovered emulsified asphalt. Sparsely applied aggregate results in aggregate loss because the space between the aggregate particles does not allow the emulsified asphalt to rise high enough to hold the aggregate particles securely.

Problems that can occur during the chip seal operation include:

- Tires picking up emulsified asphalt: If aggregate is applied at the specified rate and tires pick up emulsified asphalt, then the emulsified asphalt application rate is either too high, causing the aggregate to roll over on contact with the emulsified asphalt, or the aggregate is too wet.
- Aggregate rollover: If the aggregate spreader is proceeding too fast or if the emulsified asphalt is too viscous, the aggregate may roll over, altering the uniformity of the spread.
- Minor aggregate spread deficiencies: Corrugation or missed areas can be corrected with the use of a drag broom or hand rake. Drag brooms are typically attached to the roller doing the initial rolling and assists in redistributing minor spread deficiencies. If the aggregate is uneven, non-uniform, or irregular for any reason, it should be drag-broomed or hand-raked immediately after spreading and before initial rolling.

MEASUREMENT AND PAYMENT

Refer to Subsection 408.04.01, "(Surface Treatment) (Method of Measurement) Measurement" and Subsection 408.05.01, "(Surface Treatment) (Basis of Payment) Payment", of the Standard Specifications and Chapters 10 and 11 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

409 - PORTLAND CEMENT CONCRETE PAVEMENT

Among the principal uses of Portland cement concrete for NDOT contracts are structures and pavement. The characteristics of concrete used for structures or for pavements differ in two distinct ways: strength and coarse aggregate size. Concrete used for structures has a greater compressive strength than that used for pavements. Concrete used for pavements has larger coarse aggregate particle sizes. The remaining attributes relating to materials, proportioning, mixing, and curing are substantially the same for both types of concrete. Refer to "501 - Portland Cement Concrete", in this chapter, for additional information.

When the design of the road calls for a concrete pavement, Portland cement concrete pavement (PCCP) is the top layer of the roadway structural section and the riding surface. PCCP is constructed, or placed, on a prepared roadbed. In the structural section, the PCCP layer provides the greatest load-bearing capacity per inch of thickness than any other element of the structural section. Although the initial cost of PCCP is greater than that of plantmix bituminous pavements, the useful life of PCCP is much greater than plantmix, and PCCP has lower annual maintenance costs. The cost of PCCP warrants its use principally on roadways that have high traffic loadings, such as urban interstate highways.

During construction, weather-related environmental factors could influence the quality of the PCCP. Each step of the PCCP construction process (production, transporting, placement and curing) may require modifications to reduce the effects of weather, including such factors as:

- Atmospheric and surface temperatures.
- Surface moisture.
- Humidity.
- Wind.

For additional information relating to weather and Portland cement concrete, refer to "(501 - Portland Cement Concrete) (During Construction) Weather", in this chapter.

PCCP is generally placed monolithically (in large slabs). Because concrete expands and contracts under various load conditions and with variations in temperature, cracking may occur. Joints are constructed to allow for the controlled release of stresses created by traffic loads and temperature changes. To allow the PCCP to expand or contract during hot or cold weather, longitudinal and transverse joints need to be constructed in the PCCP.

Several different types of joints are created during the construction of PCCP, including:

- Expansion joints when the PCCP is placed adjacent to existing structures, such as approach slabs.
- Contact joints, when a new segment of PCCP is placed adjacent to a previously placed segment of PCCP.
- Weakened plane joints to reduce a single large slab into smaller segmental slabs. (The weakened plane joints are saw-cut into the surface of the PCCP at regular intervals to control the location of the cracking in the PCCP.)

BEFORE CONSTRUCTION

Before PCCP is produced at a mixing plant, the Contractor shall submit a mix design to the Resident Engineer, who forwards it to the Materials Division for review and approval. Aggregates used in the PCCP must be from an approved source. Before mixture production and paving begins, the plant inspector shall obtain a copy of the approved Portland cement concrete pavement mix design.

Prior to placement of PCCP, the inspector that will be involved with the production and placement of the PCCP should thoroughly review the contract documents, focusing on:

- Concrete mix design.
- Mixing requirements.
- Placement requirements.
- Dowel bars and tie bars.

- Spreading and consolidating.
- Joints.
- Finishing.
- Curing.
- Surface tolerances.
- Protection of the surface.
- Method of measurement and payment.

MIXING

The central-mix type mixing plant, which is typically used to produce concrete for PCCP, combines and mixes the aggregate, Portland cement, water, and admixtures as required by the approved mix design. (See Figure 26.) The mixed material is then deposited into a hauling truck, which is usually a non-agitating open top truck or semi-trailer for transport to the site of placement. In some cases, a transit mix plant may be used to produce concrete for PCCP. In these cases, the individual ingredients for PCCP are deposited into a transit-mix truck, equipped with a revolving drum that combines the ingredients and completes the mixing of the concrete, then transports the material to the site of placement. In any case, material handling and storage, and operation of the mixing plant or mixer truck influence the quality of the PCCP. The plant inspector will review Section 409, “Portland Cement Concrete Pavement” and Section 501, “Portland Cement Concrete”, of the Standard Specifications, the approved mix design, proper handling and storage of materials and the operation of the plant.

Figure 26: Central-mix type concrete mixing plant

The Department requires concrete mixing plants and transit-mix trucks to be certified by the National Ready Mixed Concrete Association (NRMCA). The NRMCA is a national association of ready mixed concrete producers and plant operators. NRMCA certification of concrete production facilities provides a system for establishing that production facilities of ready-mixed concrete plants satisfactorily meet established industry standards. To receive certification, a plant is inspected by a professional engineer that is retained by the concrete producer or plant operator to assess compliance with a checklist that is provided by the NRMCA. (Certifications are valid for a period of 2 years.) The plant inspector will check that the NRMCA certification is current for the plant producing the PCCP material. The Department also requires that scales must be certified by the Nevada Bureau of Weights and Measures as specified in Section 109, “Measurement and Payment”, of the Standard Specifications.

During inspection of the production of concrete for PCCP, the plant inspector shall monitor the following items:

- Aggregates: Before mixing concrete for PCCP at the plant, the plant inspector obtains aggregate gradation test results from the NDOT field testers to verify the material is in accordance with Subsection 409.02.01 “(Portland Cement Concrete Pavement) (Materials) General”, of the Standard Specifications. The plant inspector shall also obtain moisture test results to confirm that the aggregate from the stockpile is in condition in which the aggregate particles are fully saturated but the surface appears to be dry. This is known as saturated surface dry (SSD) condition, which is the condition assumed for the mix design.

- Batch Weights: Concrete mix designs state the proportion or quantity of each component of the mix: coarse aggregate, fine aggregate, water, cement and admixtures. If the aggregates are not in SSD condition the aggregate batch weights and amount of water to be added must be adjusted to reflect the actual moisture content of the aggregate. It is the responsibility of the concrete producer or batch plant operator to obtain samples and determine the actual field moisture of the stockpiled aggregates, then adjust the batch weights accordingly. Because the actual aggregate moisture content is variable, the batch weights must be adjusted to reflect the most current moisture content. The plant inspector monitors the results of the field moisture tests obtained by the concrete producer or plant operator and the NDOT field tester to verify consistency between the tests and to ensure that the batch weights are being adjusted correctly. For additional information on adjusting batch weights, refer to “(501 - Portland Cement Concrete (During Construction) Mixing Plant”, in this chapter.

- Water: The amount of water in the mixture significantly influences the strength and durability of PCCP. Too much water reduces the durability by reducing the strength and increasing shrinkage cracks. The plant inspector monitors the amount of water added to the mix.

- Admixtures: These are chemicals typically added to a mixture to alter the physical or chemical characteristics of the PCCP. Admixtures are commonly added to the mixture at the plant through an automated dispenser. Improper or unapproved dosages of admixtures can have a detrimental effect on the quality of the concrete. The plant inspector monitors the type and amount of admixture added to each batch.

- Mixing: A plate attached to the mixer must show the manufacturer’s mixing drum capacity and speed. The plant inspector monitors the plant operation to verify that the capacity and speed do not exceed the manufacturer’s recommendations. In addition, the plant inspector observes the material emptied from the mixer, confirming that the material is well mixed with no segregation.

Field testers obtain samples of the mixed concrete from the hauling vehicle before it leaves the plant area. The testers will typically require a platform to access the hauling vehicle, obtain the sample and perform tests. The Contractor shall provide a platform for the testers to use. For more information regarding testing platform requirements, refer to Subsection 409.03.01, “(Portland Cement Concrete Pavement) (Construction) General”, of the Standard Specifications.

Communication among the plant inspector, placement inspector, and field testers is important to monitor the quality of the PCCP being produced. The Contractor may make adjustments at the plant and at the paver. Because the Contractor’s adjustment at one location can affect the PCCP quality and operations at other locations, better decisions are made when the plant inspector and placement inspector and the field testers share information.

ROADWAY

As with plantmix paving, the roadway base course must be prepared prior to placing PCCP. While the Materials Division is reviewing the mix design for approval, the Contractor prepares the roadway base course for the placement of the PCCP.

PCCP is usually placed on a plantmix (or other suitable base course surface as approved). Before PCCP is placed, the base course must be finished and in an acceptable condition. The base course is acceptable when required testing has been successfully completed, and grades and surface tolerance requirements are in accordance with the contract documents. For testing requirements, refer to Part 2 of the *Field Testing Guide*. Upon approval of the base course, a bond breaker consisting of a single application of curing compound is applied to the prepared surface and must properly cure before PCCP placement can begin.

During preparations for the placement of PCCP, the survey crew chief, the placement inspector, and the Contractor's placement supervisor should meet to discuss stakeout requirements. After the Contractor describes the method of automated grade control to be used, the survey crew chief should determine and inform the Contractor of the survey control point layout. The Contractor uses the established grade controls for the automated grade control operation.

Where joints are to be located, vehicle loading must be transferred from any individual slab to adjacent slabs for the pavement to perform as designed. These loads are transferred by dowel bars and tie bars. Dowel bars are located along transverse contact and weakened plane joints and tie bars are located along longitudinal joints.

Dowel bars are used to transfer loads across transverse contact and weakened plane joints and allow for horizontal movement between slabs as needed for expansion and contraction of the slabs. Dowel bars are plain, round, smooth bars ranging in diameter from 1-1/4 inch to 1-1/2 inch and are typically 18 inches in length. The location and alignment of dowel bars is critical. Incorrectly placed or misaligned dowel bars do not allow the pavement to transfer loads or allow the joint to move as designed.

Tie bars are used to transfer loads across longitudinal joints but do not allow horizontal movement of the slabs. While similar to dowel bars in that tie bars are designed to transfer loads between slabs, a major difference is that tie bars have smaller diameters than dowel bars, typically No. 4 (1/2-inch) or No. 5 (5/8-inch) bars and are from 24 to 30 inches in length. Tie bars have deformities or ribs protruding from the surface of the bar to help lock them into the concrete and prevent the respective slabs from separating.

The Contractor may place bars by inserting them into the concrete as it is being placed using an automatic bar inserter attached to the paver, or by placing the bars in welded wire baskets ahead of the paver and placing the concrete over the bars. Both methods require approval by the Resident Engineer before paving begins. Subsection 409.03.09, "(Portland Cement Concrete Pavement) (Construction) Joints", of the Standard Specifications, provides direction on the submittal requirements to be followed by the Contractor. The placement inspector will confirm that the Resident Engineer has approved the Contractor's bar placement method.

If the Contractor uses the wire basket method of bar placement, the baskets are placed in advance of the paver, typically 200 feet. Placing the baskets in advance of the paver allows the inspector to verify that the Contractor has installed and anchored the baskets according to the approved shop drawings. Baskets that are not securely anchored can shift or move during the paving operation, causing the bars to become misaligned. The inspector confirms the correct size bars are accurately positioned in the baskets.

Immediately before placing PCCP on the base surface, the Contractor shall moisten surfaces that will contact the mix. The surfaces should be moist enough to prevent water demand on the mix. The Contractor should not place the concrete on a base where pools of water have formed. If the surface temperature of the prepared surface is greater than 90° F, water is applied to cool the surface, which reduces the water demand on the mix. Water should be applied to the bond breaker in the form of a fine spray immediately before placement of the concrete begins.

In addition, the placement inspector will coordinate with the Contractor about the planned sequence of operations so that inspection and testing can be performed effectively and efficiently. Before concrete production begins, the placement inspector will coordinate with the field tester to ensure that required testing is scheduled. Before placement, the Resident Engineer may schedule a Pre-Pave Conference with the Contractor. Refer to the Quality Assurance Documents library on the Construction Division's SharePoint site [https://nevadadot.sharepoint.com/sites/040/QAQC%20Section/PrePour%20and%20PrePave%20Agendas] for more information. At the Pre-Pave Conference, the Contractor describes the equipment to be used for placing, spreading, and consolidating the PCCP. The placement inspector will verify that the equipment is in accordance with Subsection 409.03.01, "(Portland Cement Concrete Pavement) (Construction) Equipment", of the Standard Specifications.

DURING CONSTRUCTION

The Resident Engineer typically assigns the following in order to monitor the Contractor's paving operations:

- Plant inspector
- Field testers
- Placement inspector
- Tining and curing inspector
- Sawed joint cutting and sealing inspector

Depending on the size and complexity of the PCCP paving operation, the Resident Engineer may increase or decrease the staffing level. Regarding materials testing, materials incorporated into the PCCP are tested to determine if the material is acceptable for incorporating into the work (acceptance testing). The Resident Engineer's field testers perform acceptance testing. Some acceptance tests, however, are performed by the Materials Division, which has specialized testing equipment. Part 2 of the *Field Testing Guide* identifies acceptance tests that are performed by the Materials Division.

During construction, grade-sensing control, placement of dowel bars and tie bars, surface finishing and curing of the PCCP are significant aspects of the construction phase. For alignment and grade control, a wire line is a common technique in which a wire is set along the outer edges of the segment of PCCP being placed. Placement equipment electronically senses the wire alignment and elevation and adjusts the alignment and elevation of the PCCP being placed. When required, dowel bars are placed in the PCCP. The contract documents will show placement configurations and describe the requirements and tolerances of the dowel bar placement.

Finishing is the process of creating a uniform PCCP surface with a texture that establishes sufficient friction between the pavement surface and vehicle tires. Hand finishing is discouraged because it may bring excess paste to the surface, causing irregularities in the surface smoothness. Acceptable finishing balances a uniform surface, measured with a straightedge or profiling equipment, and texturing with a moist burlap drag and tining. Deep grooves from tining can create areas in which water can accumulate or weak ridges that can break under traffic loading. PCCP consistency is important for proper tining. Specifications require texturing the surface using a moist burlap drag before tining. The timing of texturing with the burlap drag and tining is important because PCCP that is either too soft or too hard will not achieve or retain the proper texture. 409.03.11 "(Portland Cement Concrete Pavement) (Construction) Finishing", of the Standard Specifications, prohibit tining across transverse and longitudinal joints. For tining requirements, refer to Subsection 409.03.11 of the Standard Specifications.

Instead of tining, the PCCP surface may be finished by grooving with grinding equipment that is set up to provide the required groove texture. If PCCP grooving is specified, the inspector will first verify that the pavement to be grooved meets riding tolerance specifications. Grooving should not be performed until pavement smoothness specifications have been met. The inspector will also be aware of pavement grooving time limitations. The inspector will periodically check the location, alignment, depth and spacing of the finished grooves to assess conformance with Subsection 409.03.11 of the Standard Specifications. The inspector will observe and document any damage caused by the grooving operation. The Contractor shall repair damage caused by the grooving equipment or its operation.

For proper curing of the PCCP, the Contractor applies curing compound immediately after final finishing or after free water leaves the PCCP surface. If the Contractor cannot apply the curing compound immediately, the Contractor shall apply a fog spray over the finished surface of the PCCP with water. In order to reduce the potential for shrinkage cracking, curing prevents the loss of moisture. The curing compound must completely cover the PCCP to seal the exposed pavement surface. This includes any vertical sides of the PCCP that will be exposed for any length of time. Subsection 409.03.13, "(Portland Cement Concrete Pavement) (Construction) Curing", of the Standard Specifications, require two applications of curing compound, the direction of each application being opposite to the other. The curing compound must have a white pigment, which allows the inspector to determine if uniform and complete coverage is achieved. The white pigment also helps keep the temperature of the pavement surface lower by reflecting the sunlight.

Weakened plane joints are constructed by sawing at locations designated in the project plans. A weakened plane joint is created by placing a sawcut across the PCCP surface, which weakens the structure of the PCCP at the point of the sawcut, allowing the pavement to crack at the joint created by the sawcut. The Contractor saws weakened plane joints when concrete has hardened but before random cracks develop. The Contractor shall prepare a joint sawing schedule that considers the unique conditions of the operation.

Prior to sawcutting joints, the Contractor shall mark the location of the joints on the PCCP, as detailed in the project plans. These joints must line up with the dowel bars and tie bars as specified. The Contractor shall perform sawcutting in conformance with the contract documents and the approved joint sawing schedule. The inspector observes the Contractor's joint marking and sawing operation and verifies that it in accordance with the contract documents.

Placement of PCCP is commonly done with either side-forms or a slipform paver. For details on the equipment and process requirements for each PCCP paving method, refer to Subsection 409.03.08, "(Portland Cement Concrete Pavement) (Construction) Spreading, Compacting, and Shaping", of the Standard Specifications.

SIDE-FORM PAVING

Placing PCCP within stationary side forms is called side-form paving. (See Figure 27.) The Contractor uses side-form paving when the area to be paved has irregular dimensions, small PCCP quantities, or limited working space. With side-form paving, the Contractor places and secures forms on the prepared base course. Equipment rides on the forms to spread and finish the concrete.

Figure 27: Side-form PCCP placement

When using side-form paving to place PCCP, consider the following:

- Type of finishing equipment
- Verify forms in accordance with Subsection 409.03.03, "(Portland Cement Concrete Pavement) (Construction) Setting Forms", of the Standard Specifications
- Check that the paver path is clear of debris and excess material
- Check location, elevation, cross slope, and grade of forms

- Verify that forms will not deflect during the paving and finishing operation
- Check that forms are secured, checking for movement in all directions
- Forms must be clean from debris and coated with an approved release agent
- Required resetting of misaligned forms
- Required forms to remain in place until PCCP has set sufficiently to hold the edge

SLIPFORM PAVING

With slipform paving, PCCP is placed using a self-propelled machine with attached side forms. (See Figure 28.) The machine operates on the prepared base. A wire guide controls the alignment and thickness of the PCCP placement. The slipform paver spreads, screeds, consolidates, and finishes the concrete in a single pass. For equipment requirements for slipform paving, refer to 409.03.08 "(Portland Cement Concrete Pavement) (Construction) Spreading, Compacting and Shaping", of the Standard Specifications.

Figure 28: Slipform PCCP paver

When using a slipform paver to place PCCP, the inspector will consider the following:

- Material Delivery: When PCCP is delivered to the paver, the Contractor shall ensure the material is evenly distributed in front of the paver without mounding. The paver should operate with a full and consistent head of material in front of it to prevent abrupt changes in slab thickness.
- Edge Slump: Monitor edges to confirm that slumping does not occur after the forms have passed. Edge slump of unsupported sides behind the paver is one of the major problems with slipform paving.
- Trailing Forms: Forms that extend beyond the paver are called trailing forms. Trailing forms may be used to address edge slump problems. However, using trailing forms may cause problems, because drag resistance from the form may pull down edges of the PCCP or vibration from the paver may alter the freshly placed PCCP.
- Water: Water may only be applied over the finished surface of the PCCP as a fog spray. Applying water directly to the PCCP surface can wash the surface, weaken the surface of the concrete, or result in surface scaling.
- Vibration Equipment: The Contractor uses vibration units inserted into the wet concrete to consolidate the wet concrete uniformly. Vibration equipment must comply with the requirements of 409.03.01 "(Portland Cement Concrete Pavement) (Construction) Equipment".

PROTECTION OF PAVEMENT

In areas where vehicle, pedestrian, or animal traffic can be reasonably expected, the Contractor shall protect the new concrete pavement from damage. To protect new PCCP, the Contractor may use:

- Barricades.
- Windrows.
- Proper signage.
- Fences (temporary or permanent).

In addition to protecting new PCCP from traffic, the Contractor shall also protect it from adverse weather conditions. As described in Subsection 409.03.14, "(Portland Cement Concrete Pavement) (Construction) Reinforcement", of the Standard Specifications, the PCCP must be protected from freezing, typically by placing thermal blankets on the pavement. In unique situations, heaters may be used. Protection from rain before the initial set may require covering the surface to protect it from washing of the aggregate by the rain.

RIDING TOLERANCES

Before public traffic is allowed on the PCCP, the inspector checks the pavement smoothness with a 12-foot straightedge, both longitudinally and transversely. The inspector reports the straightedge results on an Inspector Daily Report (IDR). In addition to the straightedge requirement, the Contractor shall typically perform profile measurement testing of the PCCP surface using an inertial profiler. The inertial profiler will be operated to obtain a measurement in each of the designated vehicle wheel paths and in the direction of traffic. The reading from each of the wheel paths will be combined to determine a mean roughness index for each travel lane.

The Resident Engineer assigns a person to collect, analyze, and report the measurement data received from the Contractor's inertial profiler. Copies of the measurement data from the inertial profiler shall be submitted to the Resident Engineer as soon as possible, but no later than 24 hours after the profile measurements are completed. If the profile measurement results indicate an unacceptable pavement profile, corrective action may be performed by the Contractor to meet riding tolerance requirements. This corrective action will usually involve profile grinding of the pavement surface. Excessively rough areas in the pavement surface, or areas of localized roughness, shall be marked as soon as the profile measurements are completed. With timely notification, the Contractor may be able to alter placement operations to reduce areas of localized roughness and improve the pavement smoothness prior to profile measurement. If the Contractor shall grind to meet profile requirements, the Contractor shall use care not to reduce the pavement thickness to less than what is allowed in the contract documents. The profile grinding must be completed before the average pavement thickness measurements are obtained.

When grinding is completed for PCCP there will not be a requirement to apply a seal coat to the ground surface of the PCCP.

For ride tolerance requirements for PCCP, refer to Subsection 409.03.12, "(Portland Cement Concrete Pavement) (Construction) Riding Tolerances", Subsection 402.03.03, "(Plantmix Bituminous Surfaces) (Construction) Equipment" and Subsection 402.03.05, "(Plantmix Bituminous Surfaces) (Construction) Surface Tolerances", of the Standard Specifications. One key difference in the profile equipment requirements between plantmix bituminous surface and PCCP is that a single point or spot laser will not be allowed for measurement of the PCCP due to the texture of the finished pavement surface that is constructed as part of the PCCP. A wide footprint laser that can average out the texture of the surface is required when measuring the profile of PCCP.

SAW AND SEAL JOINTS

Sawing of joints must not cause damage to existing joints. In certain cases, the joint must be sealed after completion of sawcutting. If the joint is not specified to be sealed upon completion of sawcutting, the Contractor shall maintain the joint opening and keep the joint clean until the shoulder work is complete and the contract is accepted. If a saw and seal joint is specified, a clean joint is required for the sealant to perform properly. After sawing the joint, the Contractor cleans the joint, usually with water or sandblasting. The Contractor shall recover and properly dispose of the residue from the cleaning operation. If residue remains on the walls of the joint, the sealant material will not adhere properly.

When installing a saw and seal joint, after sawing and cleaning the joint, the Contractor installs the size and type of closed cell backer rod specified in the project plans. The inspector confirms that the Contractor uses the correct diameter and type of backer rod for each width of joint. Backer rod is typically installed with a tool that places the backer rod at the required depth. After placement of the backer rod, an approved sealant will be applied to the top of the joint, completely covering the backer rod, but remaining somewhat recessed from the pavement surface.

The installation of the sealant shall comply with contract documents. The function of the joint is sensitive to the proper sealant recess depth. If the depth of the material is too shallow (too close to the surface), traffic could pull out the sealant. If the material is too deep, the joint could collect dirt and other debris that could cause spalling. In either case, incorrect installation will diminish the design life of the concrete pavement. The inspector observes the sealing operation in accordance with Section 410, “Concrete Pavement Resurfacing”, of the Special Provisions.

OPENING TO TRAFFIC

Before allowing traffic to use the new PCCP surface, the pavement must meet strength requirements, be free of debris, and have appropriate pavement markings or traffic control devices. Debris to be removed typically consists of curing compound, residual debris from joint sawing and sealing, and dust. This material, if not removed from the roadway, can create driving hazards and environmental problems. If the roadway will be opened to traffic before it meets minimum compressive strength requirements, the Resident Engineer will contact the Materials Division.

MEASUREMENT AND PAYMENT

PCCP is measured and paid by the square yard. Because of the importance of pavement thickness to strength and durability of the PCCP, Subsection 409.04.02, “(Portland Cement Concrete Pavement) (Method of Measurement) Pavement Thickness”, of the Standard Specifications, provides for reduction in payment to the Contractor when pavement thicknesses are deficient. To determine the reduction in payment, or liquidated damages, refer to Subsection 409.04.02 of the Standard Specifications.

The Resident Engineer coordinates with the Materials Division to schedule pavement thickness measurements. Pavement thickness measurements should not be obtained until after the Contractor completes required profile grinding to meet riding tolerance requirements. Pavement thickness measurements are taken at the frequency listed in Part 2 of the *Field Testing Guide*. The thickness of the pavement is measured and compared to the thickness required by the project plans. If the thickness of any individual measurement is deficient by more than 0.6 inch, secondary measurements are obtained to identify the limits of the deficiency. The area of the deficiency is called the secondary unit area, while the original area is called the primary unit area. The Materials Division summarizes the test results and distributes copies to the Resident Engineer, the District Engineer, and the Construction Division. Secondary unit areas are either removed and replaced, or left in place with no payment to the Contractor, following discussion among the Resident Engineer, the District Engineer, and the Construction Division. In the remaining primary unit area, liquidated damages are determined based on the average pavement thickness.

Refer to Subsection 409.04.01, “(Portland Cement Concrete Pavement) (Method of Measurement) Measurement” and Subsection 409.05.01, “(Portland Cement Concrete Pavement) (Basis of Payment) Payment”, of the Standard Specifications and Chapter 12 of the *Documentation Manual* for additional measurement/payment guidelines and related instructions.

410 - CONCRETE PAVEMENT RESURFACING

Concrete pavement resurfacing includes a variety of construction techniques and methods. Concrete pavement resurfacing extends the life of Portland cement concrete pavement (PCCP). The type of resurfacing or rehabilitation used in a specific situation depends on the type of distress exhibited by the pavement and the constraints presented by maintaining traffic through the work zone. When the condition of the concrete pavement is unacceptable but the base is in acceptable condition, resurfacing and rehabilitation is a cost-effective means to extend the life of the pavement.

The following are various concrete resurfacing or rehabilitation techniques:

- Rubblizing
- Cracking and seating
- Spall and joint repair
- Slab replacement
- Profile grinding
- Saw and seal joints
- Dowel bar retrofit

Depending on the pavement condition, the techniques listed above may be used independently or in combination. The Design Division prepares the contract documents in coordination with the Materials Division. If the Resident Engineer observes the roadway to be significantly different than that shown in the project plans, the Resident Engineer should describe the current condition to the District Engineer, Materials Division, and the Design Division.

BEFORE CONSTRUCTION

A unique characteristic of PCCP resurfacing and rehabilitation projects is that construction methods and field experience, strongly influence the success of the repair.

The Resident Engineer should review the field conditions to assess:

- The scope and objective of work.
- The equipment to be used and trial runs.
- The sequence of operations.
- Traffic control.
- Constraints.
- Testing requirements.
- Rehabilitation techniques.
- Concrete pavement grinding.
- Sawcutting and joint sealing.
- Random crack repair.

If the Resident Engineer determines that field conditions changed significantly to warrant modification of the repair strategy, the Resident Engineer shall contact the District Engineer, the Materials Division and the Design Division. Before the Contractor starts work, the Resident Engineer may schedule a pre-activity meeting or workshop to discuss the planned activities and other critical aspects of the work. The Resident Engineer shall develop an agenda with input from the Materials Division and the Construction Division's Quality Assurance Section.

RUBBLIZING

The intent of pulverizing the existing concrete pavement by rubblizing is to produce a structurally sound base that reduces reflective cracking by obliterating the existing pavement distresses and joints. Rubblizing produces demolished particles that are the size of large aggregate, typically smaller than 12 inches. The pulverized layer provides a foundation for the pavement overlay.

Although the rubblizing specifications contain a gradation requirement, producing small particles can reduce the structural strength of the roadway. If the subgrade is weak, the rubblizing pattern can be altered to produce larger particle sizes that maintain more of the existing concrete pavement's structural support.

Density testing cannot be performed on rubblized concrete pavement because of the large particle sizes. Therefore, the compaction process is monitored to determine the stability of the pulverized layer. After compaction, if concerns exist regarding the sufficiency of the compactive effort, a quick and effective way to determine the stability of the pulverized layer is to roll it with a loaded tandem-axle truck, such as a loaded water truck, and look for deflection of the pulverized pavement. After pulverization and compaction, a bituminous plantmix pavement is constructed on the compacted surface.

The Contractor shall perform and complete a rubblizing operation in the same construction season. If the Resident Engineer expects the work to carry into the winter months or the next construction season, the Resident Engineer will discuss with the Contractor any options that preclude leaving open, unpaved sections of pulverized concrete exposed to the elements.

CRACK AND SEAT

Crack and seat is a process that is similar to rubblizing, with the difference being the size of the pulverized concrete pavement. A crack and seat operation produces particles that are approximately 20 inches across. The intent of pulverizing the existing concrete pavement is to produce a structurally sound base that reduces reflective cracking by obliterating the existing pavement distresses and joints. The pulverized layer provides a foundation for the pavement overlay.

Concrete pavement that has been pulverized by the crack and seat process prohibits density testing. The compaction process is monitored to determine the stability of the cracked pavement. After compaction, if concerns exist regarding the sufficiency of the compactive effort, a quick and effective way to determine the stability of the cracked pavement is to roll it with a loaded tandem-axle truck, such as a loaded water truck, and look for deflection of the cracked pavement. After cracking and seating the concrete pavement, a bituminous plantmix pavement is constructed on the compacted surface.

The Contractor shall perform and complete a crack and seat operation in the same construction season. If the Resident Engineer expects the work to carry into the winter months or the next construction season, the Resident Engineer will discuss with the Contractor any options that preclude leaving open, unpaved sections of cracked concrete exposed to the elements.

SPALL REPAIR

Concrete spalling occurs when small pieces of concrete separate from the slab. Spalling typically occurs at slab joints and corners. Spall repairs can be made to existing or to new concrete pavement.

The Resident Engineer shall assess the actual pavement condition to confirm that the scope of work described in the contract documents is still appropriate. Before beginning repairs, the Contractor provides the Resident Engineer with the product information for the proposed repair material, including Safety Data Sheets (SDS). The material must be listed in the contract documents or in the Qualified Product List (QPL). If the proposed material does not conform to the contract documents, the Resident Engineer shall request and receive approval from the Materials Division before using the material.

The quantity for spall repairs is difficult to establish during design. Also, during the period between design and construction, additional spalling may take place. Because the quantity of spall repair will likely change from the amount identified in the project plans, the Resident Engineer should conduct a field review to determine if the amount of spall repair within the project limits is consistent with the design scope and budget. The Resident Engineer should discuss warranted changes with the Construction Division, District Engineer and the Design Division. The inspector marks the spalls to be repaired by the Contractor.

SLAB REPLACEMENT

At times, an isolated slab of concrete pavement may require removal and replacement. When a slab is removed, it must be removed so that it does not disturb adjacent slabs or the underlying base. Slab removal is typically done by sawcutting the perimeter of the slab, inserting lifting pins into the slab, and removing the slab by lifting. Other methods may be used for removing a slab, none of which should disturb adjacent slabs and the underlying base.

As with spall repairs, the Resident Engineer should assess the actual pavement condition to confirm that the number of slabs identified in the project plans for replacement is still appropriate. If, after a field review, the Resident Engineer determines significant quantity or scope changes are warranted, the Resident Engineer should discuss the changes with the Construction Division, District Engineer, Design Division and the Materials Division.

Before beginning slab replacement, the Contractor notifies the Resident Engineer of the proposed slab removal method. Depending on the requirements of the Special Provisions, the Contractor may be required to submit a formal plan. Before work begins, the Resident Engineer and Contractor will discuss contingencies if the slab removal operation exposes unacceptable base material. The Resident Engineer may need to consult with the Materials Division on the proposed contingency plan. Because Subsection 108.04 "(Prosecution and Progress) Limitations of Operations", of the Standard Specifications may limit work hours, a contingency plan is critical to returning traffic to the roadway by the time stated. In addition, the Contractor shall submit a concrete mix design to the Resident Engineer for review, and the Resident Engineer submits the Contractor's concrete mix design to the Materials Division for approval. The Contractor shall receive approval of the mix design before removing slabs. The inspector will mark the slabs to be replaced.

PROFILE GRINDING

When a concrete pavement exhibits minor distresses such as uneven surfaces at joints, inadequate surface drainage, or poor riding characteristics, the pavement surface may undergo profile grinding to improve the problem areas. Profile grinding may also be needed to improve skid resistance. The pavement is ground full width to re-establish an acceptable profile and cross slope as detailed in the project plans.

The Resident Engineer should meet with the Contractor to clarify the contract documents and review the equipment to be used. After the Resident Engineer is satisfied that the Contractor's equipment will achieve the desired results, the inspector will mark the area to be ground. The contract documents specify the required surface texture and surface smoothness.

SAW AND SEAL JOINTS

Concrete pavements contain joints that are created by sawing. Once sawed, the joints are sealed to keep incompressible particles and water out of the joint. Over time, seals deteriorate or break down, exposing the joint, which allows particles to enter the joint and cause cracking of the pavement. To correct this problem, joints are re-sawed and re-sealed.

If the Contractor proposes to use sealing material that is not listed on the QPL, the Contractor submits a certificate showing conformance with the contract documents to the Resident Engineer. The Resident Engineer submits the certificate to the Research Division for approval before operations commence. The Contractor shall install the joint sealer material according to the manufacturer's recommendations. The Resident Engineer may require the Contractor to have a manufacturer's representative present to verify proper installation. The Resident Engineer should discuss the saw and seal procedure with the Contractor before beginning work. In addition, the Resident Engineer and the Contractor shall discuss the traffic control plan for sawing and sealing operations to confirm compliance with the contract documents.

DURING CONSTRUCTION

RUBBLIZING

Rubblizing demolishes the existing concrete pavement. Rubblizing produces demolished particles that are the size of large aggregate, typically smaller than 12 inches. Pavement demolishing equipment must have sufficient capacity to demolish the existing pavement to full depth. Two types of machines are commonly used. One is the resonant breaker, which produces low amplitude, high frequency blows by vibrating a large steel beam. The other machine is a multi-head, guillotine-type breaker with drop hammers that provide continuous breaking up to 13 feet wide. The multi-head breaker rubblizes a full lane width in a single pass.

Although other rubblizing equipment exists, Subsection 410.03.01, "(Concrete Pavement Resurfacing) (Construction) Equipment", of the Standard Specifications prohibits certain types of equipment. The equipment proposed by the Contractor is tested to determine if it produces the desired results. The Resident Engineer designates a test strip location where the equipment is tested, as required in Subsection 410.03.02, "(Concrete Pavement Resurfacing) (Construction) Rubblizing", of the Standard Specifications. Once the equipment demonstrates that it produces the desired results, the Contractor shall use the same equipment and method of operation for the remainder of the work.

For rubblization, the approved equipment and rubblization method are used on the roadway to be rehabilitated. During the rubblizing operation, the Contractor shall protect traffic passing by the work area from flying debris created by the operation. A full depth test hole measuring 3 feet by 13 feet is excavated for each day's rubblizing operation to verify that the equipment is achieving full depth rubblization. The test hole allows the inspector to verify that the particle size is in accordance with Subsection 410.03.01 of the Standard Specifications or the size recommended by the Materials Division. Test holes are backfilled with aggregate base. After rubblizing and backfilling of test holes, the rubblized surface is compacted with vibratory steel wheel rollers and a pneumatic rubber tired roller. The compacted surface then receives a prime coat, followed by a plantmix leveling course. The leveling course is then followed by a plantmix bituminous overlay. For detailed requirements for the rubblizing operation, refer to Section 410, "Plantmix Bituminous Pavements - General", of the Standard Specifications.

CRACK AND SEAT

Crack and seat operations demolish the existing concrete pavement by producing demolished pieces that are approximately 20 inches across. Pavement demolishing equipment must have sufficient capacity to demolish the existing pavement to full depth.

Crack and seat operations typically use a guillotine-type breaker with a single drop hammer. For acceptable equipment, refer to Subsection 410.03.01, "(Concrete Pavement Resurfacing) (Construction) Equipment", of the Standard Specifications.

The equipment proposed by the Contractor is tested to determine if it produces the desired results. The Resident Engineer designates a test strip location where the equipment is tested in accordance with Subsection 410.03.03, "(Concrete Pavement Resurfacing) (Construction) Crack and Seating", of the Standard Specifications. Once the equipment demonstrates that it produces the desired results, the Contractor shall use the same equipment and method of operation for the remainder of the work.

Before the Contractor begins cracking the concrete, the pavement is flooded with water to check for existing cracks. As the pavement dries, cracks will retain moisture after the pavement surface has dried, making cracks easy to see. By identifying the extent of existing cracking, the effectiveness of the pavement breaking operation can be determined. After the pavement cracking operation, the pavement is flooded again to verify that the Contractor has achieved the required crack spacing of the pavement. If traffic will be returned to the roadway, the Contractor shall sweep the surface of the roadway to remove debris and dust. Following the cracking of the pavement, the cracked concrete is seated by operating a pneumatic roller over the surface for three complete passes. The Contractor removes loose debris from the cracks and joints, and then places a plantmix stress-relief course within 24 hours of the cleaning. This course is followed by a plantmix bituminous overlay. For more information, Refer to Section 410, "Concrete Pavement Resurfacing", of the Standard Specifications.

SPALL REPAIR

On concrete surface rehabilitation projects that include spall repair and grinding, the Contractor completes the spall repair before grinding. Specifications describe the size of the spall to be repaired. Although the size of the spalls may vary, the project plans typically show a uniform size for the repair. Loose or delaminated material is typically removed from the spall area using a lightweight jackhammer or mechanical chipping hammer. Heavy-duty jackhammers are not used because the energy can cause micro-cracking in the surrounding concrete. After removing loose material, the Contractor sandblasts the area clean.

Most spall repair products are sensitive to weather conditions. Follow all manufacturer's recommendations in order to achieve the desired results. The product manufacturer's representative must be present during placement of the material.

The manufacturer's representative determines the appropriate method of perpetuating any joints in the spall repair material. The spall repair material should be flush with the surrounding surface. Repair any surface irregularity. If grinding is included as part of the work, the spall repair may be left slightly higher than the surrounding surface to allow for grinding.

SLAB REPLACEMENT

The inspector observes the Contractor's slab removal operations to confirm that the base is not damaged. If the Contractor damages the underlying base, the base must be repaired at the Contractor's expense, using a method approved by the Resident Engineer. If the underlying base requires repair unrelated to the Contractor's operations, the base is repaired on a force account basis. The Resident Engineer consults with the Materials Division to determine an appropriate repair method.

After the excavated slab area is cleaned and inspected, the Contractor installs dowel bars or tie bars as detailed in the contract documents. After preparing the underlying base, the Contractor applies a bond breaker to the base and vertical sides, then places the new concrete pavement in the excavated area. If quick re-opening traffic lanes is critical, a high-strength, early setting concrete mixture should be considered. For construction details relating to PCCP, refer to "409 - Portland Cement Concrete Pavement", in this chapter.

PROFILE GRINDING

Concrete pavement profile grinding is combined with other concrete rehabilitation operations, such as spall and joint repair. The sequence of repair activities is important to achieve the rehabilitation objectives. Grinding takes place after spall repairs and slab replacement but before joints are sawed and sealed.

Perform profile grinding in a longitudinal direction. After the initial grind, the inspector checks the surface to confirm that the requirements of the contract documents are met. The grinder creates a corduroy-type texture with grooves on the surface. The inspector checks the initial grind using a 12-foot straightedge. The Contractor shall perpetuate the existing profile grade, cross slope, and surface drainage.

If the existing surface has deep ruts in the wheel paths, the Contractor may need to adjust the depth of the profile grinding to achieve the requirements of the contract documents. The Contractor shall be aware that the depth of the grind could cause cross slope drainage problems. To correct cross slope drainage problems, the shoulder may require grinding to taper the edge of the roadway to allow drainage.

After profile grinding, the inspector checks the pavement smoothness with a 12-foot straightedge, both longitudinally and transversely. The inspector reports the straightedge results on the Inspector Daily Report (IDR). In addition to the straightedge requirement, the Contractor will typically be required to perform profile measurement testing of the pavement surface using an inertial profiler. The inertial profiler will be operated to obtain a measurement in each of the designated vehicle wheel paths and in the direction of traffic. The reading from each of the wheel paths will be combined to determine a mean roughness index for each travel lane.

After the profile measurements are obtained, the Resident Engineer assigns a person to collect, analyze and report the measurement data received from the Contractor's inertial profiler. Copies of the measurement data from the inertial profiler shall be submitted to the Resident Engineer as soon as possible, but no later than 24 hours after the profile measurements are completed. If the profile measurement results indicate an unacceptable pavement profile, further corrective action may be performed by the Contractor to meet riding tolerance requirements.

SAW AND SEAL JOINTS

Sawing of joints must not cause damage to existing joints. A clean joint is required for the sealant to perform properly. After sawing the joint, the Contractor cleans the joint, usually with water or sandblasting. The Contractor shall recover and dispose of the residue from the cleaning operation. If residue remains on the walls of the joint, the sealant material will not adhere properly.

After sawing and cleaning the joint, the Contractor installs the size and type of backer rod specified in the contract documents for the size and width of joint. The inspector confirms that the Contractor uses the correct diameter and type of backer rod for each width of the joint. Backer rod is typically installed with a tool that places the backer rod at the required depth.

The installation must comply with the contract documents. The function of the joint is sensitive to the proper sealant recess depth. If the depth of the sealant is too shallow (too close to the surface), traffic could pull out the sealant. If the sealant is too deep, the joint could collect dirt and other debris that could cause spalling. In either case, incorrect installation will diminish the design life of the concrete pavement. The inspector observes the sealing operation to verify the installation conforms with the contract documents.

MEASUREMENT AND PAYMENT

To complete full-width grinding that complies with the contract documents, multiple passes of the grinding equipment may be needed. If the grinder passes over pavement that was previously ground, such as an overlap or regrind, no payment is made for the re-ground area. Rubblized, and crack and seat surfaces are measured and paid by the square yard. Measure the area to be demolished before pavement demolition.

Refer to Subsection 410.04.01, "(Concrete Pavement Resurfacing) (Method of Measurement) Measurement" and Subsection 410.05.01, "(Concrete Pavement Resurfacing) (Basis of Payment) Payment", of the Standard Specifications and Chapters 12 and 19 of the *Documentation Manual* for additional measurement/payment guidelines and related instructions.

418 - MICRO-SURFACING

Micro-surfacing rehabilitates, preserves and extends the life of bituminous plantmix pavements. Micro-surfacing is a thin surfacing, and can be laid at two-to-three times the thickness of the largest stone in the grading. The emulsion in the system is always polymer modified and special additives are used to create a chemical break that is largely independent of weather conditions.

Micro-surfacing can be used for the same applications as slurry seals. However, micro-surfacing uses higher quality aggregates and a fast setting and curing emulsion of higher stiffness allowing thicker layers to be placed. Thicker layers create the following extended performance characteristics and applications:

- Correction of minor surface profile irregularities
- Rut filling
- Higher durability
- Night work (or cooler temperatures)

Micro-surfacing, similar to slurry seal, is not intended as a crack treatment and will not prevent cracks in the underlying pavement from reflecting through to the surface.

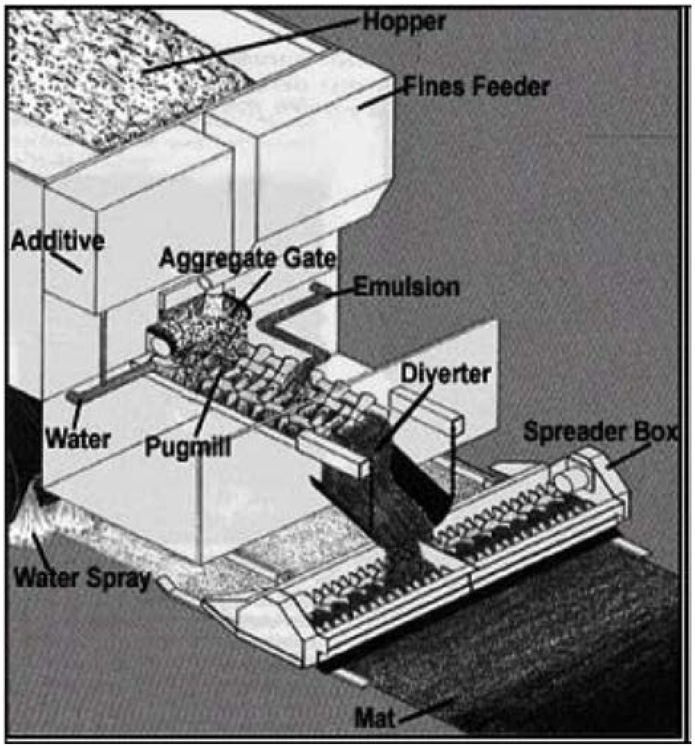

Figure 29: Schematic of a micro-surfacing machine

BEFORE CONSTRUCTION

Pavement surface deficiencies should be repaired before micro-surfacing is performed on the roadway. District maintenance forces typically repair roadway deficiencies prior to micro-surfacing. Common repair activities completed before micro-surfacing are hotmix and coldmix patching and crack sealing.

Before the work begins, the Contractor shall submit a signed mix design, meeting the requirements of Subsection 418.02.02, "(Micro-surfacing) (Materials) Mix Design", of the Standard Specifications. No micro-surfacing will be performed until the Resident Engineer has received a copy of the approved mix design.

The Contractor shall protect all manhole covers, water boxes, catch basins, and other utility structures with plastic, building felt or other material approved by the Resident Engineer.

Materials must conform to Section 106, "Control of Material", Section 703, "Bituminous Materials" and Section 705, "Aggregates for Bituminous Courses", of the Standard Specifications. The Contractor shall submit samples of emulsified bituminous material and aggregate to the Resident Engineer for testing and transmittal to the Materials Division at least 2 weeks before the start of micro-surfacing operations.

Prior to placement, the Contractor sweeps the pavement surface to remove dirt, dust or debris. (In certain areas of the state, air quality regulations may require dustless sweepers to be used.) Adequate sweeping provides a clean surface that allows good adhesion. For surface preparation guidelines, refer to Subsection 418.03.02, "(Micro-surfacing) (Construction) Preparation of Surface", of the Standard Specifications.

All equipment, tools and machines used in the application of micro-surfacing shall be maintained in satisfactory working condition at all times. When the lay-down machine has stopped, the Contractor should take this time to physically remove the buildup of asphalt and fines that are present on the primary strike-off. Each mixing unit to be used in the performance of the work shall be calibrated in the presence of the Resident Engineer. The Contractor shall follow the machine manufacturers methods of machine calibration. Ensure that the calibration and equipment conforms to Subsection 418.03.01, "(Micro-surfacing) (Construction) Equipment", of the Standard Specifications. For support and technical guidance, contact the Construction Division's Quality Assurance Section.

DURING CONSTRUCTION

The field inspector or tester observes the Contractor taking samples of the emulsified asphalt from each load delivered. Samples are then submitted to the Materials Division for testing.

The intent of rut work is to completely fill the ruts with material to correct the road profile. If ruts are underfilled, the micro-surfacing surface application will not compensate for the error and the under filled area will not have the same profile as the rest of the surface.

The Contractor shall apply the micro-surfacing mix at a constant speed. The speed should provide the appropriate production rate of dry aggregate selected by the Contractor to determine the mix unit settings. Non-uniform or excessive speed can cause the spreader box to jump (vibrate), leaving transverse ripples in the micro-surfacing. Nonuniform speed can also cause a non-uniform overlay thickness.

Throughout the day, periodically check the yield of the course being applied for compliance to the specification tolerances. Proper mix consistency should be one of the major areas of inspector concern. If mixes are too dry, streaking, lumping and roughness will be present in the mat surface. Mixes applied too wet will flow excessively and not hold straight lane lines. Excessive liquids may also cause an asphalt-rich surface with segregation.

Transverse joints with the micro-surfacing system shall be butt joints not overlap joints. The recommended method of making a good butt joint is to first cut a straight edge line into the existing mix as demonstrated here. Then the lay-down box is placed at this cut-out point perpendicular to the road. The lay-down box is then charged with fresh material and the lay-down process proceeds down the road. A hand tool is then used to dress up the transverse joint. The Contractor shall start transverse joints on paper to produce clean joints.

Constructing a longitudinal joint on highway is relatively easy as the normal process of constructing the road will ensure that the longitudinal joint application will be placed when the first application of material is well cured and stable. It simply requires the Contractor take care to minimize the overlap of material at the joint interface. A maximum overlap at a longitudinal joint should not exceed 4 inches at a typical joint.

Burlap is used to make the finished surface more uniform. The Contractor will occasionally wet the burlap. A buildup of material on the burlap can cause streaks in the surface. If streaks appear, check the burlap and have the Contractor clean it as needed. Material other than burlap may be used if it provides a surface acceptable to the Resident Engineer.

Figure 30: Spreader box and burlap

Drag marks can be repaired with a squeegee or hand tool. However, this requires a trained individual to remove the marks without leaving a poor appearance. Repaired drag marks should not look worse than the original drag marks.

There are times that the lay-down machine will not be able to reach or maneuver into an area to lay the material. In these cases, it is necessary to work the mixture by hand over these areas. Because the material is designed to cure quickly, the Contractor may require additional resources to assist in the process. The mixture must be spread and smoothed before it changes from a semi-liquid state to a coldmix state.

Visually check that the mixture is homogeneous, without lumps, balls, unmixed aggregate, segregation, excess water or excess emulsion. If a problem with the mixture is observed, inform the paving crew supervisor.

Check utility accesses, gutters and intersections. The Contractor shall remove any debris associated with the performance of the work each day.

MEASUREMENT AND PAYMENT

Refer to Subsection 418.04.01, "(Micro-surfacing) (Method of Measurement) Measurement" and Subsection 418.05.01, "(Micro-surfacing) (Basis of Payment) Payment", of the Standard Specifications and Chapters 10 and 11 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

496 - POLYMER CONCRETE

Concrete bridge decks are typically sealed to create a barrier to prevent salt and other corrosive chemicals from entering the concrete. A common method of sealing bridge decks is applying a liquid chemical, such as methacrylate, to the existing bridge deck. Another means to seal the deck is to apply a sealant, such as methacrylate, and then overlay the bridge deck with a polymer concrete or an epoxy material. Deck overlays can also be used to restore a riding surface or repair a severely cracked or delaminated bridge deck. In some situations, a bituminous pavement wearing surface may be constructed on the polymer concrete or epoxy overlay.

The most common overlay material is polymer concrete. Polymer concrete consists of graded aggregate, that is pre-bagged, and a liquid polymer resin, which acts as a binder. The typical placement depth of polymer concrete is 3/4 inch. If thicknesses exceed 1-1/2 inches, multiple lifts may be necessary because of the high temperatures generated by polymer concrete during curing.

For detailed information on the required experience of the Contractor, materials and construction details of polymer concrete, refer to Section 496, “Polymer Concrete”, of the Special Provisions.

BEFORE CONSTRUCTION

Because of the highly-specialized nature of polymer concrete, Section 496, “Polymer Concrete”, of the Special Provisions, contains requirements relating to the Contractor qualifications and experience, materials, on-site skilled technical support from the material supplier, testing of the materials, and safety and handling of the materials. Before work can begin, the Contractor shall complete all required submittals.

Before the Contractor begins operations with the materials, the Contractor shall address several safety issues. Because of the hazards associated with the materials used in polymer concrete overlays, the manufacturer’s recommendations for personal protective equipment should be followed. The Contractor shall also provide Safety Data Sheets (SDS) that are maintained on site. The inspector will review the information contained in the SDS, paying special attention to safety considerations. The Contractor shall have an on-site wash station for workers in case of chemical accidents. The Contractor shall also provide health and safety training for all personnel who will be working with the materials.

Polymer concrete is mixed on the job site either in a mechanical mixer operated manually or in a truck-mounted mixer, commonly called a volumetric mixer truck (See Figure 31 and Figure 32.)

Figure 31: Volumetric mixer truck

Figure 32: Volumetric mixer truck used to place polymer concrete

When polymer concrete is mixed manually, the aggregate is pre-bagged and delivered to the site. The manual mixing process includes adding coarse and fine aggregate, measured by the bag, with a polymer resin and a chemical hardener, measured in ounces. When a volumetric mixing vehicle is used, the equipment must bear a rating plate from the Volumetric Mixer Manufacturer Bureau (VMMB). The VMMB rating plate identifies the capacity and performance of the mixer. In a volumetric mixing vehicle, raw ingredients are stored in separate compartments on the truck and metered out for incorporation into the mix. Regardless of the units of measurement used by the vehicle—weight or volume, the quantity of polymer concrete must be consistent with the unit of measurement for payment. This may require a correlation between volume and weight of the ingredients to be incorporated into the polymer concrete.

The Contractor shall construct a trial overlay as required by the contract documents. The purpose of constructing a trial overlay is too mimic the conditions and operations that will occur during the placement of the polymer concrete overlay. The trial overlay verifies that the materials will perform as desired and that the Contractor's operations will yield acceptable results. The trial overlay must be constructed under the same conditions that would likely occur during construction. This includes atmospheric temperature and the temperature of the existing overlay surface. Also, if the polymer concrete placement will occur at night, then the trial overlay must be constructed at night. A skilled technical representative from the material supplier must be present during the trial slab placement. The technical representative adjusts the resin content as required to achieve the desired results.

The contract documents also require the Contractor to construct an overlay that meets surface tolerances. The Resident Engineer should obtain initial profile measurements of the bridge deck before the Contractor places the polymer concrete. The initial profile measurements provide a baseline in case disputes arise regarding final surface tolerance readings.

The bridge deck must be prepared before receiving a prime coat and polymer concrete overlay. Preparation includes the following:

- Identifying and repairing any areas within the bridge deck that are delaminated or require repair
- Roughening the deck to remove oil, asphalt, and dirt
- Grinding epoxy paint and deeply soiled areas
- Removing loose debris

After preparing the deck and before applying the prime coat, the inspector coordinates with the survey crew to establish a grid of deck elevations. The survey crew takes elevations again after placing the polymer concrete. The Contractor establishes the finish grade using survey information and a string line to maintain elevation. After establishing finish grades, the Contractor shall use placement equipment that will consolidate, vibrate and finish the material to the required grade.

The Resident Engineer identifies areas within the bridge deck that require repair. To identify areas of delamination, refer to test method ASTM D4580, "Standard Practice for Measuring Delaminations in Concrete Bridge Decks by Sounding." The Materials and Structures Divisions can assist with equipment and training needed to perform bridge deck delamination testing. The Contractor shall make bridge deck repairs in accordance with Subsection 502.03.15, "(Concrete Structures) (Construction) Concrete Patching and Repair", of the Standard Specifications.

In preparing the deck, the objective is to scarify the deck surface by removing the loose concrete and exposing the coarse deck aggregate, providing a clean, sound concrete surface. After the deck is cleaned, traffic is prohibited from using the deck until the placement of the polymer concrete is complete.

The Contractor may choose from a number of methods for roughening or scarifying the bridge deck:

- Shot blasting is similar to sandblasting, except that small metal beads impact the concrete surface instead of sand. Shot blasting produces a scarified surface texture and has a good production rate. Shot blasting typically requires two passes to produce the desired surface texture.
- Hydroblasting, similar to sandblasting, uses water under high pressure to impact the concrete surface. Hydroblasting produces an acceptable surface texture, but it requires a water management plan and additional time to remove the moisture from the deck. Hydroblasting may not be practical on projects that have limitations on working hours, such as night projects that must be open for traffic in the morning.
- A scabbler is a piece of equipment that uses compressed air to hammer piston-mounted bits into the concrete surface. Because a scabbler impacts the concrete surface, it can produce cracks. Small cracks are acceptable. When a scabbler is used, sandblasting is commonly required to complete the preparation of the surface.
- Typically, sandblasting is not used to prepare the deck. Sandblasting alone will not produce the required texture, and it is not allowed in most urban areas due to air quality regulations.

Some bridge decks may have waterproof membranes that contain bituminous materials. Shot blasters are ineffective because the hot metal shot melts the membrane, gumming up the shot blaster. When waterproof membranes are encountered, hydroblasting is typically effective in removing the waterproof membrane and preparing the bridge deck.

Areas that are heavily soiled and epoxy striping are removed by grinding. Because grinding can produce variable results, the inspector will closely monitor the grinding operation.

Regardless of the method used to prepare the bridge deck surface, care should be taken to ensure that the waste product from the surface preparation is properly contained and disposed of according to Subsection 107.14, "(Legal Relations and Responsibility to the Public) Disposal of Material Outside Highway Right of Way", of the Standard Specifications.

DURING CONSTRUCTION

After the bridge deck has been prepared in accordance with the contract documents, the inspector confirms that all materials to be incorporated into the work meet the requirements of the contract documents and are on site. All material certifications and tests required by the contract documents must be received and approved by the Resident Engineer before the Contractor may use the materials.

The Contractor shall isolate expansion joints to protect the joints from polymer concrete entering the joint. The Contractor has the option to sawcut joints after placement of the polymer concrete. If the Contractor elects to sawcut joints, sawcutting must occur within 4 hours of placement of the polymer concrete.

After joints are marked or isolated, the deck should be cleaned with compressed air to remove residual debris. After cleaning, a deck moisture test must be conducted. Refer to Part 2 of the *Field Testing Guide* for required tests and frequencies.

With the deck cleaned and the deck moisture content within the acceptable range required by the contract documents, the Contractor applies the prime coat, typically methacrylate. A prime coat is used to bond the polymer concrete to the bridge deck. The application of the prime coat must be uniform and it must cover the deck completely. A uniform prime coat reduces variable adhesion between the deck and the polymer concrete. Complete coverage provides a barrier between the deck and the polymer concrete. If polymer concrete contacts the concrete deck, a chemical reaction can occur, which significantly decreases the bond between the polymer concrete and the deck.

The prime coat is flooded onto the bridge deck and evenly applied using squeegees and brooms. Placement of the prime coat should be done expeditiously to reduce the potential for contamination from dust and other debris. Prime coat is also placed quickly to maintain workability and reduce the potential for uneven application. Monitor the prime coat application, checking that the Contractor corrects ponding and uneven distribution of the prime coat on the scarified bridge deck. Because the materials used for prime coat have relatively low flash point temperatures, prime coats can be hazardous. The inspector will be aware of the safety requirements contained in the SDS. If the prime coat is contaminated or unevenly applied, the inspector may reject the prime coat, in which case the Contractor cleans the surface and reapplies the prime coat. After the prime coat has set or hardened, polymer concrete placement can begin. To limit the risk of introducing contaminants that can cause debonding of the overlay, vehicle and foot traffic, equipment and materials are not allowed on the prime coat except for the Contractor's equipment.

Batching the polymer concrete takes place manually with a mechanical mixer or on a truck-mounted mixer. In either case, a skilled technical representative of the polymer concrete and prime coat supplier must be present when the initial batching begins. The Contractor shall thoroughly blend the resin before adding the aggregates to the resin. For detailed requirements, refer to Subsection 496.03.04, "(Polymer Concrete) (Construction) Concrete Placement", of the Special Provisions. The Contractor batches the polymer concrete using the appropriate mix formula based on the results of the trial overlay. The material supplier technical representative may recommend adjustments to the formula based on atmospheric and surface temperatures.

Prior to placement of the polymer concrete, calculate the approximate quantity of polymer using the bridge deck surface area, the planned thickness of the overlay, and the Contractor's mix formula. Confirm that the Contractor has enough material on the job site to complete the work. During placement of the polymer concrete, observe that the screed of the paver is adequately finishing the surface, but not over working the material. A small amount of resin coming to the surface is normal. Verify that the grade control equipment is functioning correctly. During the placement operation, the inspector monitors and documents material quantities. The polymer concrete must be placed and finished within 15 minutes, or before gelling. Any material not used within these limits must be discarded. Immediately after the Contractor finishes the material, and before it gels, the Contractor mechanically broadcasts sand onto the surface to provide a uniform application. Typically, polymer concrete begins to harden within 30 to 120 minutes after it is mixed. The polymer concrete commonly hardens completely within 4 hours of mixing. After placement, the Contractor shall protect the surface from moisture, equipment, and traffic for at least 4 hours. Pull off tests will be performed on the polymer concrete overlay to determine the bond strength of the polymer. Refer to Subsection 496.03.04, "(Polymer Concrete) (Construction) Concrete Placement", of the Special Provisions, for more information on the required tests.

SAFETY

Materials used in bridge deck sealing and overlays require special handling and safety procedures because of the chemicals used. All personnel working, handling, or transporting the materials, as well as inspectors and material testers, must attend safety training before materials arrive at the job site. Because of the volatile nature of the chemicals used in making polymer concrete, strict adherence to handling and safety procedures is required in order to avoid violent chemical reactions.

The inspector will carefully review and understand the Safety Date Sheets (SDS) that the Contractor provides. If chemicals are not shipped, handled, and combined precisely as required by the SDS and the contract documents, the combined chemicals, including chemical vapors, can cause an explosion.

MEASUREMENT AND PAYMENT

Bridge Deck Preparation and Concrete Placement is typically paid by the square yard, which includes all work associated with preparing the bridge deck surface, furnishing and placing the prime coat, and placing the polymer concrete.

The Contractor is also paid for aggregates and resins used in the polymer concrete. The method of measurement for aggregate and resin is by the pound. The Contractor is paid for the actual amount of aggregate and resin used in the polymer concrete placed. The quantity may vary significantly from the plan quantity contained in the estimate because of the profile variations on the existing bridge deck.

Refer to Subsection 496.04.01, "(Polymer Concrete) (Method of Measurement) Measurement" and Subsection 496.05.01, "(Polymer Concrete) (Basis of Payment) Payment", of the Special Provisions and Chapter 19 of the *Documentation Manual* for additional measurement/payment guidelines and related instructions.

501 - PORTLAND CEMENT CONCRETE

Concrete is a manufactured product which is a mixture of aggregates, cement and water. Additional products (admixtures) may be added to the basic concrete mixture in order to influence certain characteristics of the concrete in both its plastic state and its hardened state. For example, one admixture may slow the setting of the concrete, while another may speed up the setting. The primary advantage of concrete is its ability to adapt to virtually any form while in its plastic state and retain the shape of that form once hardened as well as its potential for high compressive strength.

During construction, the ability of these materials to behave as anticipated by the designer relies on a closely controlled mix of aggregates, cement, water and, in some cases, the addition of admixtures. The proportions of the mix are determined through the development of a concrete mix design. Development of the mix design includes careful consideration of the materials to be incorporated into the mix, the structure being created with the concrete and the environment in which that structure will serve.

By varying the amounts and types of components of the concrete mixture, the characteristics of the concrete can be modified to achieve the results required by the design. Common types of modified concrete used in Nevada are high early strength, high performance and self-consolidating.

Although concrete performs well in compression, it is comparatively much weaker when it is in tension. Reinforced steel may be used in conjunction with concrete to create a product (reinforced concrete) that is strong in both compression and tension. For more information on reinforcing steel, refer to "505 - Reinforcing Steel", in this chapter.

BEFORE CONSTRUCTION

MAJOR AND MINOR CONCRETE

Depending on the size of the concrete structure being constructed, concrete items may be classified as Concrete (Minor) or Concrete (Major). Although the physical characteristics of minor and major concrete are the same, minor concrete is likely to be used on smaller concrete structures such as culvert headwalls, short pieces of curb and gutter, small sections of sidewalk and related minor work, and major concrete is likely to be used on larger concrete structures such as bridges and box culverts.

Minor concrete has higher labor and forming costs associated with a relatively small quantity of concrete, in contrast to major concrete, which has costs distributed over a larger quantity of concrete. To account for the differences in cost to produce smaller or larger concrete quantities, the bid items Concrete (Minor) and Concrete (Major) are used on NDOT contracts. The terms “Minor” and “Major” refer only to the respective bid items and the manner of payment, not to testing, sampling and/or inspection requirements.

HIGH EARLY STRENGTH CONCRETE

As the name implies, high early strength concrete hardens faster than standard concrete. High early strength concrete is made with cement specifically designed to achieve design strength quickly.

A common use for high early strength concrete is when placing concrete on an existing roadway that must quickly be reopened to traffic. In this situation, traffic may be allowed to use the roadway as soon as 4 hours after completion of finishing, compared to 3 days or more with standard concrete.

HIGH PERFORMANCE CONCRETE

High performance concrete is a term that generally describes concrete that has an extended life expectancy because of modifications in the mix design, placement and curing. The American Concrete Institute (ACI) defines high performance concrete as concrete that meets special combinations of performance and uniformity requirements that cannot always be achieved routinely when using conventional components and normal mixing, placing, and curing practices. High performance concrete may be a high-strength concrete, but this generally is a by-product of requiring a durable concrete.

Historically, durable concrete was achieved by specifying air content, cement content and water content. With high performance concrete, durability is determined by an additional variable: permeability. Because durability characteristics are more difficult to define than strength characteristics, the contract documents typically use a combination of performance and prescriptive requirements, such as permeability and a maximum water-cement ratio.

Low permeability is desirable in a durable concrete such as high performance concrete. If the concrete cracks, it loses the benefits of low permeability and the concrete durability diminishes. To reduce cracking, the Contractor cures the concrete by supplying sufficient moisture during the curing process. One of the best methods for controlling moisture loss is the wet cure method, which is typically used for high performance concretes. Contractor quality control is important to achieve the desired results in producing and placing high performance concrete.

SELF-CONSOLIDATING CONCRETE

Self-consolidating concrete flows easily into tight and constricted spaces without segregating and without mechanical consolidation. To reduce segregation, self-consolidating concrete must be fluid, yet stable. To achieve a flowable mix, smaller, finer graded aggregates and admixtures will be used. The required level of fluidity depends greatly on the specific application. Generally, the higher the required flowability of the self-consolidating concrete mix, the higher the amount of fine material needed to produce a stable mix. In some cases, a viscosity-modifying admixture can be used instead of, or in combination with, an increased amount of fine aggregate to stabilize the concrete mixture.

Some elements of a structure built with reinforced concrete may require a large amount of reinforcing steel to be placed into a confined space. Because of the congestion created using reinforcing steel, conventional concrete may not be as easily consolidated within the forms and around the reinforcing steel. In addition, the use of mechanical consolidating tools can be constrained or physically prohibited. Self-consolidating concrete may be useful to resolve these issues.

When using self-consolidating concrete, construction of the forms should be carefully considered. Because the material constrained by the forms is more fluid than conventional concrete, the concrete may create greater pressure on the form. The Contractor shall consider the additional pressure, called liquid head, during design of the forms. In addition, form construction must result in a watertight, leakproof barrier to confine the concrete.

CONCRETE AGGREGATE

Aggregates account for 60 to 75 percent of the total volume of concrete. Concrete aggregate generally consists of two sizes of aggregate; fine aggregate (sand), and coarse aggregate (rock, stone or gravel). Fine aggregates can be natural and screened according to actual size or crushed to meet size requirements and typically range from sieve size no. 200 to 3/8 inch. Coarse aggregates can be natural and screened according to actual size or crushed to meet size requirements and range in size from sieve Size No. 4 up to 2 inches. Certain mixes will require the use of a three-aggregate blend consisting of a fine aggregate and two separate sizes of coarse aggregate. These three aggregate size blends will usually be used in major structures such as bridge decks, or Portland cement concrete paving (PCCP).

Aggregates strongly influence concrete's freshly mixed and hardened properties, proportions and economy. Consequently, aggregate selection is an important process. Although some variation in aggregate properties is expected, the following are characteristics to consider when selecting aggregate:

- Durability
- Particle shape and surface texture
- Abrasion and skid resistance
- Unit weights and voids
- Absorption

For a good quality concrete mix, aggregate should be hard, resistant to abrasion and have sufficient density to serve in the environment in which it will be placed. Concrete aggregate shall also be processed to obtain the proper sizes, shapes and cleanness.

Aggregate processing consists of crushing and/or screening to obtain proper size, shape and gradation. Gradation refers to the distribution of the aggregate particle sizes. Aggregate gradation affects the amount of aggregate used as well as cement and water requirements for a quality concrete mixture. Aggregate processing also includes cleaning the aggregate by washing or other methods to obtain the required cleanness. The cleanness of the aggregates will affect the ability of the cement particles to properly bond to the aggregate particles. If an aggregate is too dirty, the concrete will be weaker due to the lack of bond.

Once processed, the aggregates are handled and stockpiled in a way that minimizes segregation and degradation, and reduces contamination. The Contractor shall construct stockpiles that provide aggregates that meet the requirements of the approved mix design. Proper stockpile construction involves:

- Minimizing segregation. Avoiding high, cone-shaped stockpiles.
- Minimizing equipment on the aggregate stockpile because the concrete aggregate can break down, changing the gradation and introducing foreign particles.
- Separating the stockpile from other materials to avoid contamination and to maintain the integrity and gradation of the concrete aggregate.
- Monitoring the effect of weather on stockpiled aggregates. Misting during extreme heat and protecting from high wind to maintain proper moisture conditions, maintaining saturated surface dry (SSD) conditions. During cold temperatures, protecting aggregate from freezing.

As the Contractor processes concrete aggregate, the aggregate is stockpiled using methods to preserve the quality and to ensure that sufficient quantities are available to complete the planned concrete production for the day. Contractors should dedicate stockpiles to specific projects and clearly identify the location where the aggregate will be used.

CEMENT

Cement is a manufactured product that is produced by combining a series of ingredients such as lime, silica, alumina, iron and gypsum. Cement comes in a dry powdered form, where it is mixed with water and aggregates to become concrete. Cement quality may vary between manufacturers.

Several types of cement are available to the industry. Different types of cement are manufactured to meet various physical and chemical requirements. The following are the standard types of cement and their purpose:

- Type I: Type I cement is a general-purpose cement and is commonly used on construction projects. Type I cement is typically used to construct such things as buildings, bridges, pavements and precast concrete products.
- Type II: Type II cement provides moderate sulfate resistance. Type II cement is used when a concrete structure will be in contact with soils containing sulfates. Type II cement also tends to have a slower rate of set when compared to Type I cement.
- Type III: Type III cement provides a rapid setting concrete when needed. Type III cement is commonly called high early strength cement due to its tendency to produce a concrete that sets and gains strength rapidly. Type III cement is chemically similar to Type I cement except that the cement particles have been ground finer than that of Type I cement. The additional surface area of the cement allows the concrete mixture to set more rapidly.
- Type IV: Type IV cement provides a slower setting concrete that produces less heat while gaining strength. This lower heat will reduce the potential for cracks in the concrete. Type IV cement is typically used in massive structures, such as dams where there is little chance for the heat to escape.
- Type V: Type V cement provides high sulfate resistance. Type V cement is used when a concrete structure will be exposed to severe sulfate action, typically when the concrete is exposed to soils and groundwater with a high sulfate content.

Each of the standard types of cement can be modified to respond to specific environmental conditions. When a standard type of cement is modified, a letter designation will be added to the standard type designation, such as Type IA or Type IP. For example, the “A” indicates the addition of air entrainment to the cement, the “P” indicates the addition of a pozzolan to the cement.

WATER

Water plays an important role in the production of concrete. First, while the concrete mixture is in a plastic state, the water “lubricates” the particles in the mixture, helping the materials to flow and allows for more complete mixing. Next, the cement particles and water, when combined, form a gel or paste that coats and bonds with each particle of aggregate. Through a chemical reaction called hydration, this paste hardens over time.

The quality of the water has a direct effect on the quality of the concrete. The water used in concrete mixes must be clean and suitable for concrete mixes. Impurities in the water can potentially reduce strengths, delay the setting of the concrete and stain the concrete. The general rule of thumb is that if the water is suitable for drinking (potable), then it is suitable for mixing in concrete. If the quality of the water is in questions, or if it is required by Section 722, “Water”, of the Standard Specifications, a sample of water shall be sent to the materials lab in Carson City for testing. Section 722 of the Standard Specifications also indicate the actual requirements for the suitability of water for use in concrete mixes.

The strength of the concrete depends on the ratio of water to cement or cementitious materials. The water-cement ratio is simply the weight of all the mixing water in a concrete mix divided by the weight of all the cementitious materials including cement, fly ash, slag cement and/or silica fume. The quality of a concrete mix can be improved by lowering the water-cement ratio without sacrificing the workability of the fresh concrete, provided the concrete is properly placed, consolidated and cured.

ADMIXTURES

Admixtures are mineral or chemical ingredients that are added to the concrete mixture immediately before or during mixing. Admixtures are primarily used to:

- Modify the properties of fresh concrete.

- Modify the properties of hardened concrete
- Preserve the quality of concrete during mixing, transporting, placing and curing

Successful use of admixtures depends on the use of appropriate methods of batching, delivering and placing concrete.

MINERAL ADMIXTURES

Mineral admixtures, when used in conjunction with cement, produce a mixture with pozzolanic qualities. A pozzolan is defined as a material that chemically reacts with the calcium hydroxide, or free lime released from the hydration process created when cement is mixed with water. This chemical reaction produces more cementitious material. Some mineral admixtures may be cementitious on their own.

Mineral admixtures are generally used as supplementary cementitious materials (SCM) or alternative cementitious materials (ACM) to help extend the cement and potentially help to reduce the cost of concrete. These mineral admixtures are generally less expensive than cement, and have properties similar to cement. Mineral admixtures are typically blended with cement or added to the concrete mix along with the cement during batching.

Calcined clay, calcined shale and metakaolin are examples of naturally occurring mineral admixtures. These products shall be mined and processed for use in concrete mixtures. These products are not commonly used on NDOT contracts.

Fly ash, slag and silica fume are examples of mineral admixtures and are actual by-products of industrial processes. The following mineral admixtures may be used as a partial replacement for cement and, in many cases, may also modify the concrete mix as follows:

- Fly ash
  - Enhances workability
  - Reduces bleed water
  - Reduces slump loss
  - Increases long-term strength
  - Reduces permeability
  - Increases durability
  - Reduces the potential for sulfate attack
  - Reduces the heat of hydration
  - Reduces the potential for alkali-silica reactivity
- Slag (Ground Granulated Blast Furnace Slag)
  - Increases workability, finishability and pumpability
  - Increases compressive and flexural strength
  - Reduces permeability
  - Increases resistance to chloride intrusion and corrosion
  - Mitigates moderate to severe sulfate attack
  - Reduces the potential for alkali-silica reactivity

  - Reduces thermal stress in mass concrete through lower heat generation

- Silica Fume
  - Reduces permeability
  - Increases the resistance of concrete to chloride penetration
  - Potentially produces very high compressive strength results

CHEMICAL ADMIXTURES

Chemical admixtures are generally manufactured products that are produced with the purpose of changing a specific characteristic of the concrete in its fresh and/or hardened state.

The following are general classes of chemical admixtures:

- Air-entraining: Air-entraining admixtures are used to introduce microscopic air bubbles into the concrete. Air entrainment is used principally to improve resistance to freezing when exposed to water and deicing chemicals. The microscopic air bubbles relieve internal pressure on the concrete by providing tiny chambers for the expansion of water when it freezes. Air-entraining agents can also improve the workability and durability of concrete.

- Water-reducing: Water-reducing admixtures usually reduce the required water content for a concrete mixture by about 5 to 10 percent. Consequently, concrete containing a water-reducing admixture needs less water to reach a required slump than untreated concrete. The treated concrete can have a lower water-cement ratio, which increases the strength of the concrete without increasing the amount of cement.

- Retarding: Retarding admixtures, which slow the setting rate of concrete, are used to counteract the accelerating effect of hot weather on concrete setting. Retarding admixtures allow a longer period between concrete production and placement. Retarders may also be used when a longer set time is required. Retarders keep concrete workable during placement and delay the initial set of concrete.

- Accelerating: Accelerating admixtures increase the rate of early strength development, allowing finishing operations to begin sooner. Accelerating admixtures are especially useful for modifying the properties of concrete in cold weather, allowing required chemical reactions to take place so the concrete can harden. Accelerating admixtures do not prevent freezing of the concrete.

- Plasticizers (superplasticizers): Plasticizers, also known as superplasticizers or high-range water reducers (HRWR), reduce water content by 12 to 30 percent. Superplasticizers are added to concrete with a low-to-normal slump and water-cement ratio to make high-slump, flowing concrete. Flowing concrete is a highly fluid but workable concrete that can be placed with little vibration or consolidation. The effect of superplasticizers lasts approximately 30 to 60 minutes, depending on the dosage rate, handling and weather conditions. After the effect of the superplasticizer wears off, workability of the concrete decreases rapidly. Because superplasticizers have a short effective life, superplasticizers are usually added to concrete at the job site.

All other varieties of admixtures fall into the specialty category whose functions include corrosion inhibition, shrinkage reduction, alkali-silica reactivity reduction, workability enhancement, bonding, damp proofing, coloring and viscosity modification.

Corrosion-inhibiting admixtures are used to slow corrosion of reinforcing steel in concrete. Corrosion inhibitors can be used for concrete structures, such as marine facilities, bridges and parking garages that will be exposed to high concentrations of chloride. Other specialty admixtures include shrinkage-reducing admixtures and alkali-silica reactivity inhibitors. The shrinkage reducers are used to control drying shrinkage and minimize cracking, while alkali-silica reactivity inhibitors aid in controlling durability problems associated with alkali-silica reactivity. Workability enhancers, such as viscosity modifying admixtures, are used in self-consolidating concrete to increase flowability and decrease aggregate segregation.

Most chemical admixtures are supplied in ready-to-use liquid form and can be added to the concrete at either the plant or at the job site. Certain admixtures, such as pigments, expansive agents and pumping aids, are used in extremely small amounts and may be added to a batch by hand using pre-measured containers.

The following factors determine the effectiveness of an admixture:

- Type and amount of cement
- Water content
- Aggregate characteristics
- Mixing time
- Timing of admixture introduction into concrete mix
- Time between addition of admixture and placement of concrete
- Slump
- Concrete temperatures
- Atmospheric temperature
- The manner in which admixture is introduced to the mix

Because some admixtures can be incompatible with each other, an analysis of the properties and effects of all the combined admixtures may be required prior to approval of a mix design. If the Contractor wishes to use an admixture that is different than what is on an approved mix design, the submittal of a new mix design may be required to allow for analysis of the characteristics of the newly proposed admixture.

ADMIXTURE ALTERNATIVES

Sometimes, effects similar to those achieved through the addition of admixtures can be achieved by simply altering the basic concrete mixture. These alterations can include but are not limited to changes such as:

- Reducing the water-cement ratio.
- Adding additional cement.
- Using a different type of cement.
- Changing the aggregate.
- Changing the aggregate gradation.

These changes would need to be submitted as a mix design before they can be employed in a concrete mix for NDOT contracts. If the Contractor wishes to alter the ingredients or proportions of a currently approved mix design, a new mix design may be required. Contact the Materials Division for guidance in this area.

PROPORTIONING

Careful proportioning and mixing of concrete ingredients produces a strong and durable concrete. A concrete mixture with insufficient paste to fill all the voids between the aggregates is difficult to place and produces rough, honeycombed surfaces and porous concrete. A concrete mixture with excess cement paste is easy to place and produces a smooth surface, but it is susceptible to increased shrinkage cracking and spalling.

A properly designed concrete mixture possesses the desired workability for the fresh concrete and the required durability and strength for the hardened concrete. Typically, the absolute volume of a mix is made up of between 7 to 15 percent cement, 60 to 75 percent aggregate, and 14 to 21 percent water. Entrained air in many concrete mixes may also take up another 4 to 8 percent of the volume.

Concrete ingredients are proportioned to make the most economical use of available materials to produce concrete of the required workability, durability and strength. Because the mixture must meet multiple objectives, increasing one ingredient may achieve one objective, but detract from another. Achieving optimum concrete proportions requires balancing the characteristics of each component and the physical and chemical characteristics of the components in combination. Initial proportioning of component material (mix design) is based on the theoretical characteristics of the components. The final proportions are typically established by adjustment in the field and must remain consistent with the approved mix design. Field adjustments are generally limited to adjusting the aggregate batch weights and amount of water to be used in the concrete mix, based on the amount of moisture in the aggregate stockpiles as determined by sampling the aggregates prior to the production of the concrete. By determining the weight of the actual moisture in the aggregates and comparing to the weight of the aggregates in a saturated surface dry condition, the amount of excess, or free water, can be determined. The amount of mixing water to be added to the concrete mix will need to be reduced by the amount of free water on the aggregate.

High-quality concrete can be produced by lowering the water-cement ratio without sacrificing the workability of fresh concrete. Generally, using less water produces a higher quality concrete, provided the concrete is properly placed, consolidated and cured.

Aggregates from different sources may produce significant differences in concrete strength even though the amounts of water and cement remain constant. Cement quality may vary between manufacturers. Although components of the mix are variable, variability of the aggregates influence concrete strength more than changes in the quality of the cement.

After the components are combined into a concrete mix, a factor that is commonly used to evaluate and monitor the concrete mixing process is the water-cement ratio.

The water-cement ratio helps to monitor the appropriate amount of water in the concrete mixture. It is a design criterion that influences the final properties of concrete by measuring the weight of water to the weight of cementitious materials in the mixture. It provides control over two opposing, yet desirable, properties: strength and workability. The advantages of a low water-cement ratio are:

- Increased strength.
- Lower permeability.
- Increased resistance to weathering.
- Reduced shrinkage cracking tendencies.

The less water used, the better quality of concrete, provided it can be consolidated properly. A mixture with a high water-cement ratio will be more workable than a mixture with a low water-cement ratio. A less workable mixture (low water-cement ratio) results in a stronger concrete. A water-cement ratio is chosen to give the best result for a given situation. This is not an entirely free choice because the water-cement ratio should be at least 0.25 to complete the hydration reaction. Typical values of water-cement ratios are between 0.35 and 0.45 because they give a good amount of workability without sacrificing a lot of strength. The water-cement ratio can be determined by using the weight in pounds of each material used in the concrete mix and calculating the water-cement (w/c) ratio by the following equation:

$$w/c = \text{water} / (\text{cement} + \text{cement substitutes} + \text{mineral admixtures})$$

The water used is determined by the water measured into the batch plus any free water on the wet aggregate.

On NDOT contracts, the Contractor develops a concrete mix design and submits it to the Resident Engineer, who reviews and submits it to the Materials Division for final approval. The Materials Division sends a memorandum to the Resident Engineer stating the acceptance or rejection of the mix design. The Resident Engineer notifies the Contractor of the acceptance or rejection of the mix design.

Producing a concrete mixture requires balancing several objectives and managing materials to produce the desired outcome. Aggregates, cement, water and admixtures are combined to produce a concrete mix that achieves the design objective. Not only are the materials and the proportioning of the materials important, the mixing plant and its operation can affect the quality and durability of the concrete.

DURING CONSTRUCTION

MIXING PLANT

The Contractor is responsible for the plant and its operations. Although the Contractor is responsible for the operation of the plant, an inspector will be present during the production of concrete. The inspector observes and monitors the plant operation to verify that the mixing plant is in accordance with Subsection 501.03.06 “(Portland Cement Concrete) (Construction) Mixing”, of the Standard Specifications, and that components of the concrete mixture are consistent with the approved mix design.

The Department requires concrete mixing plants and transit mixing trucks to be certified by the National Ready Mixed Concrete Association (NRMCA). The NRMCA is a national association of ready-mixed concrete producers and plant operators. NRMCA certification of concrete production facilities provides a system for establishing that production facilities of ready-mixed concrete plants are satisfactory. To receive certification, a plant is inspected to assess compliance with an industry checklist. Certifications are valid for a period of 2 years. The inspector will check that the NRMCA certification is current for the plant producing the concrete. The requirement for this certification can be found in Subsection 106.07, “(Control of Materials) Plant Inspection”, of the Standard Specifications.

The Department requires the scales on the mixing plant to be inspected and certified by the Nevada Department of Agriculture, Division of Measurement Standards, Bureau of Weights and Measures. The mixing plant scales shall be inspected and certified annually, or any time the mixing plant is moved and set up in a new location. The Resident Engineer may also request that the scales be checked as necessary. The requirement for the scale certification can be found in Subsection 109.01, “Measurement and Payment (Measurement of Quantities)”, of the Standard Specifications.

Concrete is produced using several different methods, and the characteristics of each method are as follows:

- Transit-Mixed: Raw ingredients are loaded directly in the transit mixer truck. The drum of the mixer truck is turned at mixing speed (6-18 rpm) while the materials are loaded. Once loaded, the concrete is mixed for 70 to 100 revolutions at mixing speed before the truck leaves the plant. Upon completion of the mixing, the drum of the mixer truck is turned at a slow speed (2-6 rpm) during transit to the placement site.
- Shrink-Mixed: Raw ingredients are partially mixed in a plant mixer and then discharged into the drum of a transit mixing truck to complete the mixing. Central mixing plants are typically used to shrink mix, or partially mix the concrete. When shrink-mixed concrete is being produced, the transit-mix truck receiving the shrink-mixed load will still be required to complete a minimum of 70 to 100 revolutions at mixing speed before the truck leaves the mixing plant.
- Central-Mixed: Raw ingredients are completely mixed in a plant mounted mixer drum before being discharged into a hauling truck. The hauling truck, either a dump truck or transit mix truck, is used primarily to transport the mix.
- Volumetric-Mixed: Raw ingredients are stored separately in a truck-mounted, volumetric mixing unit. These mobile mixing units can supply freshly mixed concrete in relatively precise quantities for small-volume placements. The unit consists of a truck with bins of sand, coarse aggregate, cement, water and admixtures. The Construction Division must approve the use of volumetric mixing units.

Of these mixing methods, the central-mixed method provides the fastest production time and better control of materials. In addition, when transit mixing trucks are used for mixing purposes, the consistency of the concrete mixture can be variable because each truck and operator can have different mixing characteristics and capabilities. Regardless of the type of mixing process, the inspector should be familiar with the plant and its operation before concrete production begins. In doing so, the inspector can effectively monitor the quality and quantity of the materials and mix.

Before concrete is produced each day, the Contractor shall obtain a sample of the concrete aggregates and determine the moisture content in order to adjust the batch weights of those aggregates to correct for the actual moisture content. The test results are reviewed to verify the results of the moisture tests. Field testers or the plant inspector will conduct moisture tests to verify the results of the Contractor's moisture tests and report any discrepancy.

Concrete mix designs state the proportion or quantity of each component of the mix: Coarse aggregate, fine aggregate, water, cement and admixtures. The proportion of materials is based on an aggregate moisture condition in which the aggregate is in a saturated surface dry (SSD) condition, which is the condition assumed for the mix design. The aggregate batch weights must be adjusted to reflect the condition of the actual moisture content of the aggregate in the field. Batch weights can be adjusted by calculating the actual moisture content of the aggregate and comparing the result to the calculated absorbed moisture content of the aggregate at SSD, then adding the difference to the design batch weight of the aggregate.

The concrete mix batch weights produced at the mixing plants are based on SSD conditions. Although the mixing plants are computerized, inspectors will calculate adjusted batch weights for aggregates based on the Department's test results.

After completion of calculating the adjusted batch weights for aggregate, the inspector will calculate the maximum amount of water that can be added to the mix. The amount of water that may be added to the mix at the plant is the difference between the maximum allowable water established in the mix design and the free water available from the moisture in the aggregates. Aggregate moisture greater than the SSD moisture is free moisture. This free moisture will end up being incorporated into the mixing water. By using the mix design and the daily moisture content test results, the inspector can calculate the maximum allowable mixing water that can be added to the mix at the batch plant.

EXAMPLE

Absorbed water in aggregate per cubic yard *(from mix design)*:

Absorbed water in aggregate = 87 pounds per cubic yard

Convert pounds to gallons:

87 / 8.33 *(lbs. / gallon)* = 10.44 (10) gallons per cubic yard *(absorbed)*

Maximum mixing water allowed based on the amount of absorbed water in aggregate as determined from the mix design and assuming aggregates are in SSD condition *(from mix design)*:

Maximum mixing water allowed = 275 pounds per cubic yard

Convert pounds to gallons:

275 / 8.33 *(lbs. / gallon)* = 33.01 (33) gallons (maximum mixing water allowed)

Actual water in aggregate per cubic yard: *(from field moisture tests):*

Actual water in aggregate = 190 pounds

Convert pounds to gallons:

190 / 8.33 = 22.81 (23) gallons *(actual)*

Amount of excess *(free water)* per cubic yard based on actual conditions:

Free water = 23 gallons (actual) - 10 gallons (absorbed) = 13 gallons *(free water)*

Maximum water that can be added at the plant per cubic yard based on actual conditions:

33 gallons *(maximum mixing water allowed)* - 13 gallons *(free water)* = 20 gallons *(maximum water added at plant)*

Maximum water added at plant based on the total cubic yards of concrete:

The mixing plant is batching a total of 8 cubic yards of concrete.

20 gallons *(maximum water added at plant)* x 8 cubic yards = 160 gallons

A maximum of 160 gallons of water can be added at the plant for this load.

After calculating the maximum allowable water, the mixing plant inspector will note this information on NDOT Form 040-025 (Transit-Mix Concrete Delivery Form). The inspector will also note the actual water added at the plant, admixtures, and additional information relating to the plant operation. If used, the form is prepared for each load and given to the delivery truck driver, who gives it to the inspector at the site of placement. The inspector will confirm that the total water does not exceed the maximum mixing water allowed as noted on the form. If NDOT Form 040-025 is not used, the inspector will check the delivery ticket that is provided by the mixing plant to verify accuracy and confirm that the total mixing water does not exceed the maximum mixing water allowed as determined in the previous example.

WEATHER

Weather conditions during concrete placement can constrain and affect the quality and durability of the concrete. Weather conditions during placement and curing can also affect the quality of concrete, even though weather may not be extreme.

To reduce the effects of weather during concrete placement, the inspector should be aware of the following:

- Pre-wetting surfaces that will be in contact with freshly placed concrete to reduce water loss from concrete
- Limiting transit time to reduce the potential of stiffening of the mixture, typically within 90 minutes of introducing mixing water to the cement and aggregates
- Limiting concrete temperatures to less than 90°F during placement to maintain workability and to reduce water demand
- Placing curing seal as soon as possible after finishing to reduce evaporation
- Limiting finishing time to reduce migration of water to the surface, leading to additional evaporation
- During finishing, adding of water to the surface by fogging or misting should be minimal; application of water by sprinkling is not allowed because it leads to inconsistencies in the mixture which can lead to scaling or cracking.
- Monitoring concrete surface temperature to determine if corrective measures are needed to offset the effects of weather.

Cold weather, hot weather and windy conditions can all affect the quality of concrete. During the spring and fall seasons, temperature differentials can be significant and require special attention. Coordination between the Resident Engineer, inspector and Contractor ensures that the Contractor's planning for weather conditions provides sufficient protection of the concrete during placement and curing. At the time of concrete placement, the Contractor shall closely monitor the weather forecast and the temperature of the concrete. Having sufficient materials available before placement begins increases the options available for protecting the concrete. Wind accelerates the loss of moisture from newly placed concrete. Constructing windbreaks to protect fresh concrete reduces the effect of wind.

COLD WEATHER

Cold weather concreting is common throughout Nevada, even in the southern Nevada climate. Every cold weather application must be considered carefully to accommodate unique situations. The American Concrete Institute defines cold-weather concreting as "a period when for more than 3 successive days the average daily air temperature drops below 40°F and stays below 50°F for more than half of any 24-hour period." Such temperature conditions can lead to problems with concrete freezing before it hardens or delayed cure time due to reduced heat of hydration.

During cold weather, the primary objectives of concrete placement are to:

- Prevent concrete from freezing.
- Ensure that the concrete reaches sufficient strength for loading or form removal.
- Maintain normal curing conditions.
- Limit rapid temperature changes.

During cold weather, humidity can be lower than it is during hot weather. The lower humidity can cause greater moisture loss than during hot weather. Therefore, the Contractor shall protect concrete from moisture loss during cold weather concrete placement and curing.

During cold weather, the placement and curing of the concrete requires close observation by the inspector. Before the Contractor places concrete in cold weather, the inspector checks that the temperature of surfaces in contact with the concrete are above freezing and that the Contractor has removed snow, ice and frost. Materials to be embedded in the concrete, such as reinforcing steel, should have temperatures above 40°F. The temperature differential between the coldest or warmest part of the surface and the delivered concrete must be less than 30°F. When concrete is placed on steel structures, the Contractor may heat the underside of the structure to reduce the temperature differential. The Contractor should never place concrete on a frozen surface. To protect the surface from freezing before concrete placement, the surface can be covered with insulated blankets a few days before concrete placement.

Concrete's exposure to cold weather will extend the time required for it to gain strength. Concrete temperature must be maintained at a minimum of 50°F for the first 3 days after placement and a minimum of 40°F for the next 4 days. Concrete should not be allowed to freeze during the curing period.

As concrete cures, it produces heat. Some concrete may need protection to reduce the heat from escaping while it cures; more severe temperatures may require supplemental methods of maintaining heat, such as heaters. The Contractor should not apply heat directly to the concrete surface. Efforts should be directed toward heating the air, not the surface. Monitoring concrete temperature during cold weather requires a recording thermometer, and/or temperature datalogger as described in Nevada Test Method No. T440.

When a Concrete Quality Control Plan (CQCP) is required in accordance with Subsection 501.02.01, "(Portland Cement Concrete) (Materials) General" of the Special Provisions, the plan shall consider the following:

- Maintain specified temperatures throughout the entire operation. Fresh concrete has temperature requirements as well as the hardened concrete.
- Protect individual components used in concrete from the adverse effects of cold weather.
- Protect aggregate stockpiles from freezing, so that frozen aggregate is not introduced into the mix. Use insulating blankets and steam to keep aggregate from freezing.
- Warm reinforcing steel and beams before placing concrete to preclude differential temperatures in the concrete.
- Heat mixing water, either at the plant or in the trucks. Take care to use water that is not too hot.
- Typically, do not heat cement; merely protect it from the elements.
- Follow the manufacturer's recommended temperature ranges, as liquid admixtures are susceptible to degradation from extreme temperatures.
- Use insulating blankets to protect underlying base materials and the forms from freezing.
- Use insulating blankets to protect freshly placed concrete from cold weather.

HOT WEATHER

When mixing, transporting and placing concrete, it is important to understand the effects of hot weather, low humidity, solar radiation and wind on concrete properties and construction operations. Hot weather can result in rapid moisture loss on the surface of recently placed concrete, resulting in plastic shrinkage cracking and accelerated setting time. Hot weather can also speed up cement hydration and create the potential for cracking in large concrete structures. Although hot weather-related problems usually occur in the summer, the combination of low humidity and high winds can also lead to rapid moisture loss, even during winter months, particularly in arid climates. Generally, high humidity reduces the effects of high temperatures.

In hot weather, the following conditions can cause problems during concrete mixing or placement:

- Water demand
- Rate of slump loss, which increases the tendency to add water at the job site
- Rate of setting, resulting in difficult handling, finishing, and the risk of cold joint

Improper curing during hot weather can cause the following problems with the concrete:

- Decreased strength
- Increased rate of evaporation, causing shrinkage and thermal cracking
- Decreased durability from cracking
- Increased permeability
- Increased potential for reinforcing steel corrosion due to increased cracking

The Contractor can take a variety of precautions to reduce the effects of hot weather on concrete. The precautions used for a specific situation depend on the conditions when the concrete is placed. According to the American Concrete Institute, if the temperature at the time of concrete placement will exceed 77°F, precautions must be taken to address the effects of hot weather. When a Concrete Quality Control Plan (CQCP) is required in accordance with Subsection 501.02.01, "(Portland Cement Concrete) (Materials) General" of the Special Provisions, the plan shall consider the following:

- Maintain specified temperatures throughout the operation. Both fresh concrete and hardened concrete have temperature requirements.
- Reduce the delivery time.
- Moisten subgrade, steel reinforcement and forms before placing concrete.
- Erect temporary wind breaks to limit wind velocities and sunshades to reduce concrete surface temperatures.
- Cool the components of the concrete to reduce its initial temperature. Follow these temperature-reducing guidelines:
  - Reducing the aggregate temperature 2 degrees reduces the concrete temperature 1 degree.
  - Reducing the water temperature 4 degrees reduces the concrete temperature 1 degree.
  - Reducing the cement temperature 8 degrees reduces the concrete temperature 1 degree.
- Substitute ice for a portion of the water in the concrete to lower the temperature. When substituting ice for a portion of the water, account for the ice in the mix. (For every pound of ice, add 1 pound of water.)
- Use a concrete consistency that allows rapid placement and consolidation.
- Apply water to the outside of transit truck drums, being careful to keep water from entering the drum.
- Use water-chilling systems internal to the freshly placed concrete for large concrete placements.
- Protect the concrete surface during placement with plastic sheeting or evaporation retarders to maintain the initial moisture in the concrete.
- Provide sufficient labor to minimize the time required to place and finish the concrete, as hot weather conditions substantially shorten the time for the concrete to harden.

- Fog or mist the area above the concrete placement to raise the relative humidity and reduce the evaporation rate. Care must be taken not to allow accumulation of water on the concrete surface.
- Provide appropriate curing methods as soon as possible.
- Adjust the time of concrete placement during the day to take advantage of cooler temperatures, such as early morning or nighttime placement.

CURING

Curing is the process of controlling the concrete moisture content and temperature while the chemical reaction between cement and water (hydration), which started during mixing, continues and the concrete begins to harden. Proper curing is essential to quality concrete. Curing influences the properties of hardened concrete, such as durability, strength, permeability and resistance to abrasion, freezing, thawing and deicer chemicals. Proper curing is critical on large concrete surface areas exposed to the atmosphere. Improper curing can significantly reduce the strength of concrete.

Curing the concrete aids the chemical reaction called hydration. Although most freshly mixed concrete contains more water than required for complete hydration, any appreciable loss of water by evaporation can delay or prevent hydration. If temperatures are favorable (50°F to 75°F), hydration is relatively rapid the first few days after concrete is placed. Retaining water during the first 48 hours is important to the hydration process. Good curing prevents or reduces evaporation. The environmental conditions at the placement site shall be monitored during the placement and curing periods and the resulting data is recorded on NDOT Form 040-024 (Concrete Evaporation Rate and Cure Monitoring).

Using the forms as a method of curing is an acceptable practice. The forms help to maintain temperatures and control evaporation. For this method to be truly effective, the forms will need to remain in place for at least 7 days. For concrete exposed to the atmosphere, the following are the most common methods of curing:

- Curing Compound Method: This curing method consists of applying a liquid chemical to the surface of the wet concrete, forming a membrane that retains moisture in the concrete. Curing compounds shall be applied immediately after completion of the finishing of the concrete surface. Where curing compound has been applied, efforts should be made to protect the surface by minimizing foot traffic that could damage the membrane. Any damage to the curing compound shall be repaired immediately.
- Curing compounds are typically white pigmented. Some curing compounds may contain a dissipating dye (usually red) that makes it easier to see during application if the concrete surface is completely covered with the curing compound. This is especially useful when spraying the curing compound in two applications. White pigmented curing compounds have the added benefit of light reflectivity, which helps keep the concrete cool, thereby improving the hydration process. White-pigmented curing compounds are used on concrete pavements where reflectivity aids in cooling the large surface areas exposed to the atmosphere.
- Waterproof Membrane Method: This method consists of placing a sheet or sheets of absorbent fabric such as burlap bonded with a polyethylene sheeting over the newly placed and finished concrete surface to keep the concrete moist. This waterproof membrane shall be pre-wetted prior to placement on the concrete surface and shall be kept in place and maintained for at least 7 days.
- Wet cure method: This method, called the Bridge Deck Curing method in Subsection 501.03.08, "(Portland Cement Concrete) (Construction) Curing", of the Standard Specifications, consists of placing burlap, soaker hoses and polyethylene sheeting, then applying water through the soaker hoses to the concrete surface, keeping the burlap and concrete surface moist for the duration of the curing period. Bridge decks and approach slabs, which typically use high performance concrete, require a wet cure of at least 10 days. The burlap should be pre-wetted and placed directly on the concrete surface. The soaker hose should be placed on top of the burlap and the polyethylene sheeting should completely cover the burlap and soaker hose to reduce the potential for evaporation.

  Upon completion of the 10-day wet cure, the polyethylene sheeting, soaker hoses and burlap shall be removed from the concrete surface and a bridge deck curing compound is applied while the surface is still moist.

Regardless of the curing method, the concrete may require supplemental heating or cooling to maintain favorable curing temperatures.

The reactions between cement and water are accompanied by escaping heat. A part of this heat escapes through the surface of the concrete mass, but some heat is retained, creating a rise in the internal concrete temperature. Excessive internal temperatures may reduce the concrete strength and create internal stresses that cause cracks. In large concrete masses that may be part of major bridge structures, internal cooling may be necessary to control increasing temperatures in the concrete. Chilled water, circulated through a network of pipes embedded in the concrete, controls the temperature and cools the concrete mass.

Figure 33: Cooling system for a mass concrete footing

Figure 34: Component cooling pipes (red tubes) embedded in footing

MEASUREMENT AND PAYMENT

No method of measurement or basis of payment is made for Portland cement concrete. Refer to the following for measurement/payment guidelines and related instructions:

- Subsection 409.04.01, "(Portland Cement Concrete Pavement) (Method of Measurement) Measurement", of the Standard Specifications
- Subsection 409.05.01, "(Portland Cement Concrete Pavement) (Basis of Payment) Payment", of the Standard Specifications
- Subsection 502.04.01, "(Concrete Structures) (Method of Measurement) Measurement", of the Standard Specifications
- Subsection 502.05.01, "(Concrete Structures) (Basis of Payment) Payment", of the Standard Specifications
- Subsection 503.04.01, "(Prestressed Concrete and Precast Members) (Method of Measurement) Measurement", of the Standard Specifications

- Subsection 503.05.01, "(Prestressed Concrete and Precast Members) (Basis of Payment) Payment", of the Standard Specifications
- Subsection 504.04.01, "(Lightweight Concrete for Structures) (Method of Measurement) Measurement", of the Standard Specifications
- Subsection 504.05.01, "(Lightweight Concrete for Structures) (Basis of Payment) Payment", of the Standard Specifications
- Subsection 509.04.01, "(Drilled Shaft Foundations) (Method of Measurement) Measurement", of the Standard Specifications
- Subsection 509.05.01, "(Drilled Shaft Foundations) (Basis of Payment) Payment", of the Standard Specifications
- Subsection 601.04.01, "(Pipe Culverts - General) (Method of Measurement) Measurement", of the Standard Specifications
- Subsection 601.05.01, "(Pipe Culverts - General) (Basis of Payment) Payment", of the Standard Specifications
- Subsection 609.04.01, "(Inlets and Manholes) (Method of Measurement) Measurement", of the Standard Specifications
- Subsection 609.05.01, "(Inlets and Manholes) (Basis of Payment) Payment", of the Standard Specifications
- Subsection 611.04.01, "(Concrete Slope Paving) (Method of Measurement) Measurement", of the Standard Specifications
- Subsection 611.05.01, "(Concrete Slope Paving) (Basis of Payment) Payment", of the Standard Specifications
- Subsection 613.04.01, "(Concrete Curbs, Gutters, and Sidewalks) (Method of Measurement) Measurement", of the Standard Specifications
- Subsection 613.05.01, "(Concrete Curbs, Gutters, and Sidewalks) (Basis of Payment) Payment", of the Standard Specifications
- Chapter 12 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

502 - CONCRETE STRUCTURES

Structures include bridges, grade separations, structure approach slabs, culverts, headwalls, drainage inlets and retaining walls. Structures can be constructed with concrete or steel girders. Even structures with steel girders contain a number of components that are made with concrete (See Figure 35.)

A major structure, such as a bridge, consists of the following components:

- Piles
- Footing
- Pier columns
- Pier cap
- Abutments
- Girders and diaphragms

- Bridge deck
- Parapet (bridge rail)
- Approach slab

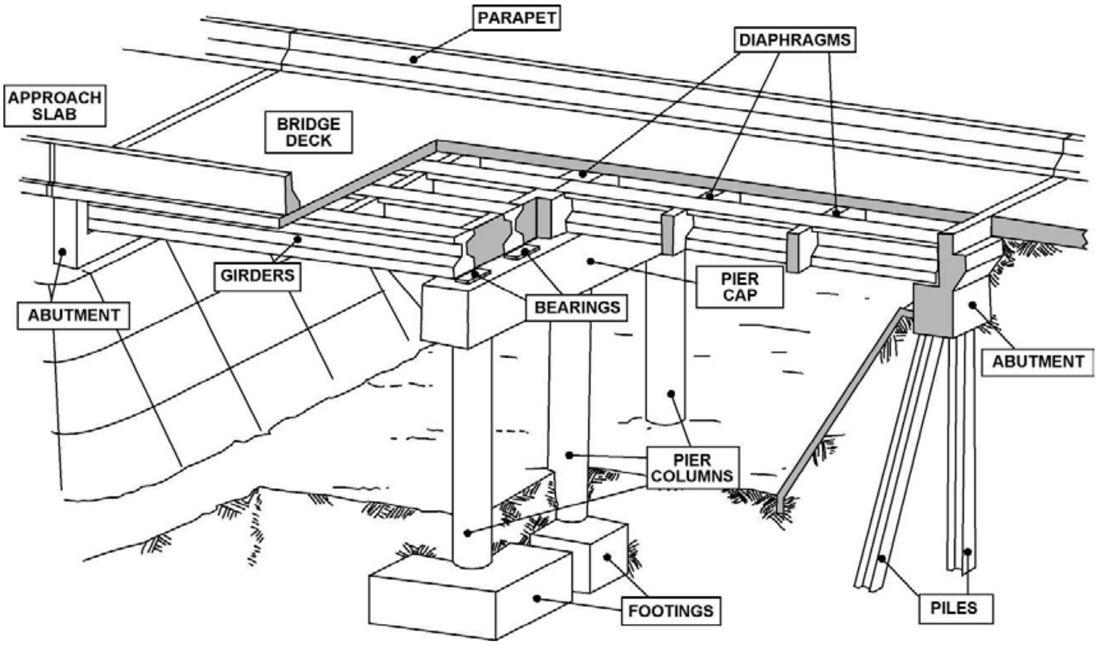

Figure 35: Typical bridge components

The basic purpose of a bridge is to carry traffic across an obstacle or depression. The vehicles travel on the bridge deck, which is part of the superstructure. The superstructure is supported by abutments at the ends of the bridge and columns between the abutments, which are part of the substructure. Columns and abutments are supported by foundations, or footings, which rest on the soil. Some columns and abutments rest on deep foundations such as driven piles or drilled shafts. On the sides of the bridge deck are parapets or bridge rails that keep vehicles from straying off the bridge.

The Department designs and constructs several types of bridges. The selection of the bridge type depends on the following criteria:

- Ability to maintain traffic during construction
- Construction time constraints
- Availability of construction materials
- Cost of construction materials
- Roadway geometry constraints
- Design complexity related to roadway geometry
- Environmental constraints
- Hydraulic constraints
- Subsurface characteristics

- Aesthetics
- Cost to maintain

Most NDOT bridges are constructed using concrete or structural steel girders. (See Figure 36.)

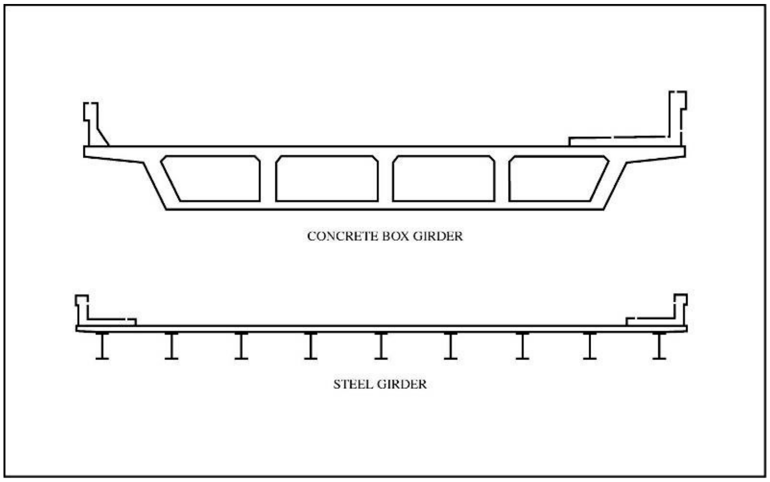

Figure 36: Common NDOT bridge types

Although timber structures still exist in rural areas where traffic volumes are low, new construction typically consists of cast-in-place concrete box girders (see Figure 37), precast concrete girders (see Figure 38) and structural steel girders (see Figure 39). Cast-in-place concrete box girder bridges are the most common type of bridge in Nevada.

Figure 37: Cast-in-place concrete box girder bridge

Figure 38: Segmental precast concrete box girder bridge under construction

Figure 39: Structural steel bridge

Many of the construction details required for concrete bridges apply to steel bridges. The difference between concrete bridges and steel bridges is that the superstructure of a steel bridge is made of steel.

Bridge construction begins with foundations constructed on prepared soil or aggregate base. A basic foundation is a large block of concrete (footing) that sits on the soil. If the soil does not have sufficient strength to support the design loads, a footing with more surface area is used, spreading the load over a larger area (a spread footing). When the native soil does not have sufficient strength to support a spread footing, deep foundations are constructed to support the footing. Deep foundations are steel or concrete columns, called piles, placed in the ground. Deep foundations support loads through friction between the surface of the pile and the surrounding soil and, in some cases, through end bearing in which the bottom of a pile rests on a load bearing stratum.

Columns and abutments are constructed on footings. The superstructure is constructed on the columns and on the abutment. Depending on the design, the superstructure may rest on the columns or be connected to them. Concrete structural members may be cast-in-place (concrete is placed in forms at the job site) or precast (concrete is placed in forms offsite, then transported to the job site). For cast-in-place concrete superstructures, a temporary framework supports the forms, equipment, people and concrete when the superstructure is being built. This temporary framework is called falsework. Following construction of the superstructure, the bridge deck is constructed, followed by the parapets. After the concrete has reached a sufficient strength and other requirements (e.g., post-tensioning) are completed, the falsework and forms are removed.

Construction of major bridge structures are complex and require constant coordination and communication among the Resident Engineer, inspector, testers, survey crew, bridge designer and the Contractor. Because of the complexity associated with constructing a bridge, poor materials or inferior construction methods can significantly impact quality and the safety. Therefore, the Resident Engineer, inspector, testers and survey crew must thoroughly understand the bridge construction details to verify that the Contractor completes work consistent with the contract documents. Unique situations may involve railroads, other utilities, environmental factors, or new construction techniques. Early coordination between the Contractor, Resident Engineer, Structures Division and third parties increases the understanding of all parties and provides greater efficiencies during construction.

SAFETY

During the construction of structures, everyone on the job site must be alert to movement of materials and equipment in order to avoid placing themselves in unsafe situations and reduce the chances of being struck by a moving vehicle, backing transit truck, construction equipment, or the traveling public.

A worker may be required to perform duties that require protection against falls. For construction projects, the Federal Occupational Safety and Health Administration (OSHA) requires fall protection if a worker is at risk of falling 6 feet or more. However, regardless of the fall distance, fall protection is required when working over dangerous equipment, machinery or traffic. If NDOT personnel will be working in a situation where fall protection is required, a fall protection harness will be necessary and proper training to use that harness is required. Fall protection training should be requested through the Safety and Loss Control Division before the harness is used.

The Contractor is required by the Standard Specifications and by OSHA to develop a safety plan. The Contractor shall submit a safety plan to the Resident Engineer for review and comment. NDOT employees must follow NDOT safety policies. To minimize exposure to a variety of hazards, NDOT safety policies provide direction on personal protective equipment (PPE), such as gloves, foot and eye protection, protective hearing devices, hard hats and respirators. The Contractor may also require NDOT employees to comply with the Contractor's safety plan.

When constructing structures, reinforcing steel is present throughout the structure job site. Reinforcing steel presents situations that require the full attention when walking on reinforcing steel to guard against twisted ankles and sprains. Vertical reinforcing steel can also create safety problems. The Contractor shall cap exposed ends of reinforcing steel bars, whether horizontal or vertical with blunt, protective caps that can protect a person who may fall on the steel. The requirement to place protective caps on the exposed ends of the reinforcing steel is mandated by OSHA in 29 CFR 1926 Subpart Q (§1926.701).

BEFORE CONSTRUCTION

An inspector will thoroughly understand the contract documents relating to construction of bridges or other structures. The contract documents will describe specific limitations or requirements associated with environmental permits or agreements with third parties, such as railroads or utilities. In addition, the inspector will coordinate with the Contractor about the planned sequence of operations so that inspection and testing can be performed effectively and efficiently. An important part of communication and coordination is the Concrete Quality Control Plan (CQCP) that the contract documents may require the Contractor to prepare on projects with major concrete structures. When required in accordance with Subsection 501.02.01, "(Portland Cement Concrete) (Materials) General", of the Special Provisions, the Contractor shall designate a Concrete Quality Control Manager who shall be responsible to prepare and submit a Concrete Quality Control Plan (CQCP) that addresses the following items:

- Concrete production
- Quality control testing
- Transport
- Placement
- Finishing
- Curing
- Contingency plans for equipment breakdown or inclement weather

Because the CQCP responds to the unique requirements of each project, the Resident Engineer must verify that the Contractor's plan conforms to the specific requirements of the project. It is acceptable for a Contractor to submit a CQCP for an entire project, and then submit a supplemental plan that includes details for concrete placement at specific structures. After the Contractor prepares a CQCP, the Resident Engineer reviews and approves it. During the review, the Resident Engineer may consult with the Construction Division, the Structures Division and the Materials Division. If review comments require modification to the plan, the Resident Engineer provides the comments to the Contractor who revises the plan and resubmits it for approval. The Resident Engineer must approve the plan before the Contractor can place any concrete. The Construction Field Crew will review the contents of the approved Concrete Quality Control Plan. The Contractor's Concrete Quality Control Supervisor will also be responsible for the implementation and oversight of the Concrete Quality Control Plan. Since the CQCP is unique to each project, the inspector will refer to the Special Provisions for that specific contract to determine which specific items are required in the CQCP.

For concrete structures, the Contractor shall perform engineering and surveying for various elements of the work:

- Engineering: The Contractor engineers the form design, falsework and other construction details relating to the means and methods that the Contractor elects to use in the construction of the structure. Any engineering performed by the

Contractor shall be stamped or certified. The Contractor's approved engineered drawings become the basis for the inspector to verify that the work is constructed as planned. Inspectors are provided with the most current approved working (shop) drawings and any contract modifications in order to perform their duties effectively. Refer to "(Other Contract Administration Functions) Submittals", in Chapter 2 of the *Construction Manual*, for additional details.

- Surveying: The Contractor performs the surveying needed to construct all parts of the bridge. The inspector confirms that the Contractor completes the required surveying needed to construct the work. In addition, the survey crew verifies the accuracy of the Contractor's surveying.

Falsework is the temporary structure that the Contractor builds to support forms for the structure being constructed. The Contractor shall submit engineered drawings for falsework. The Contractor shall also include falsework erection and demolition plans. The Resident Engineer reviews the falsework drawings to determine if the drawings are complete and conform to the contract documents. If the Resident Engineer finds the submitted drawings acceptable, the drawings are submitted to the Structures Division for review and approval. If the structure will cross a railroad, sufficient time should be allowed for review by the railroad company.

Following an initial review, the Contractor may be required to revise the drawings or to submit additional information. Once approved, the Contractor shall erect the falsework in conformance with the approved drawings. Deviation from the approved falsework drawings is not allowed without prior approval from the Structures Division. The inspector observes the construction of the falsework to verify conformance with the approved drawings.

During the Resident Engineer's review of the Contractor's submitted drawings, consider the following:

- Confirm that the Contractor's falsework drawings conform to the contract documents, and that the drawings incorporate structure-specific details.
- Determine if a falsework erection or a demolition plan is needed, and that a traffic control plan has been incorporated.
- Verify that the falsework drawings include details to prevent falling debris and to protect pedestrians and motorists.
- Verify that the falsework drawings include details that would prevent water from dripping on pedestrians and motorists during deck curing.

When inspecting falsework:

- Confirm that soil compaction test results for falsework support elements conform to density required in the Contractor's approved submittal.
- Observe the Contractor's installation of tattle-tales. Tattle-tales are devices used to monitor falsework settlement and movement. Confirm tattle-tale readings are taken prior to concrete placement.
- Verify that the Contractor follows the approved safety plan and provides fall protection and other personal protective equipment during falsework installation.
- Confirm that the Contractor's Engineer of Record for the falsework reviews the falsework system in person and provides written certification that the falsework system has been assembled according to the approved falsework drawings and approved revisions

All elements of bridge construction must strictly conform to the plan details, including reinforcing steel, steel spacing, steel clearances and concrete dimensions. Do not substitute or modify the plan details without prior approval from the Resident Engineer and the Structures Division. Even apparent minor modifications can significantly alter a structure's performance or behavior. For example, using reinforcing steel of a larger diameter than specified or increasing concrete dimensions can increase the rigidity and loading of the structure, conflicting with the structural designer's assumptions.

A Pre-Pour Conference is required before concrete placement of any major structure. Required attendees include representatives from key NDOT divisions (Construction Division, the Structures Division and the Materials Division), the

Contractor, concrete material suppliers and other appropriate invitees of the Resident Engineer. Discussions at the Pre-Pour Conference include key aspects of the concrete placement activities, such as mixing, finishing, curing and traffic safety. The Pre-Pour and Pre-Pave Agendas can be found in the Quality Assurance Documents library on the Construction Division's SharePoint site [https://nevadadot.sharepoint.com/sites/040/QAQC%20Section/PrePour%20and%20PrePave%20Agendas].

Before concrete placement, the Contractor and inspectors make final preparations at the concrete mixing plant and at the structure site. Each location, mixing plant and structure site, typically has an inspector who monitors materials and operations. For more information on mixing plant inspection, refer to "(501 - Portland Cement Concrete) (During Construction) Mixing Plant".

As with the plant inspector, the inspector at the structure must review the contract documents to monitor the work and materials effectively. Before concrete arrives at the structure, the forms and reinforcing steel must be inspected. The testers will review the concrete mix design and the materials specifications related to the concrete structure that is being built.

Forms can be made of many types of materials, depending upon the type of construction, methods of placement and, in many cases, economics. Wood is the most common form material. Plywood is used extensively for forms. Lumber with knots, splits, warps and other defects that may affect the concrete surface is not allowed. Lumber used in forming should have adequate strength and rigidity, as well as surface smoothness where required. Corrugated metal and prefabricated metal can also be used for forms. Fiber forms, shaped as circular tubes, may be used for constructing small columns of limited height.

Bracing prevents forms from moving or becoming misaligned when they are supporting concrete, people, or equipment. If forms move or become misaligned, they must be corrected. Form oil or other approved coating is applied before the forms are placed. The Contractor shall be careful not to get the coating on reinforcing steel. Coating on the reinforcing steel, which reduces the bonding between the steel and the concrete. The coating allows the forms to be removed without damaging the concrete.

The following are some guidelines for dimensional tolerances for inspecting formwork:

- Variation from plumb or batter in the lines and surfaces of columns, piers, abutment and girder walls:
  - In any 10-foot length or less: 3/8 inch
  - Maximum for the entire length: 1 inch
- Variation in cross-sectional dimensions of columns, piers, girders and thickness of walls and slabs:
  - +1/2 inch
  - -1/4 inch
- Girder alignments (deviation from a line parallel to center line of girder measured between diaphragms):
  - 1/2 inch up to 40-foot lengths
  - 3/4 inch up to 60-foot lengths
  - 1 inch greater than 60-foot lengths
- Variations from the level of the grades indicated on the drawings in slabs, beams, horizontal grooves and railings:
  - Exposed, in 10 feet: 1/2 inch
  - Backfilled, in 10 feet: 1 inch

- Variations in footing dimensions:
  - Greater than specified: No limit (does not apply to reinforcing steel placement)
  - Less than specified: 5 percent of specified thickness up to a maximum of 1 inch
- Variations of precast members:
  - Tolerances for precast members are in Subsection 503.03.10, "(Prestressed Concrete and Precast Members) (Construction) General", of the Standard Specifications

Once the forms are in place, the Contractor places the reinforcing steel. Before placement of the reinforcing steel, the Contractor supplies samples and certificates of compliance for the reinforcing steel. Reinforcing steel details in the project plans describe reinforcing steel size (diameter), length, shape and configuration. If the Contractor wants to deviate from the details contained in the project plans, they must submit shop drawings or bending diagrams to the Resident Engineer for review and approval. If reinforcing steel diagrams have been accepted, the inspector will have the current shop drawings to verify that proper reinforcing steel is placed at the prescribed locations in the structure. If the structure incorporates prestressing, refer to "503 - Prestressed Concrete and Precast Members", in this chapter.

During placement of the reinforcing steel, the inspector will monitor clearances between adjacent reinforcements and between reinforcing steel and forms. It is important that bars are placed and held in position as shown in the project plans. Improper positioning of reinforcing bars can affect the strength of any concrete structure. For allowable tolerances for reinforcing steel placement and for sampling requirements, refer to "503 - Prestressed Concrete and Precast Members", in this chapter. On horizontal flat surfaces, such as bridge decks, the reinforcing steel is supported by a variety of supports, such as wire frames (chairs) or precast concrete blocks (dobies). A layer of reinforcing steel is often called a mat. It is important for the inspector to verify whether the longitudinal bars are to be placed on top of the transverse bars or the transverse bars are to be placed on top of the longitudinal bars in a mat. Within a mat, as a reinforcing steel bar, crosses over another, the bars are tied together with tie wire. For the number of bar intersections that must be tied, depending on the spacing between adjacent bars, refer to Subsection 505.03.04, "(Reinforcing Steel) (Construction) Placing and Fastening", of the Standard Specifications. For additional details or guidance on the placement of post-tension ducts, refer to 505 - Reinforcing Steel" or "503 - Prestressed Concrete and Precast Members", in this chapter.

With forms and reinforcing steel in place, the inspector confirms that the equipment and tools that will be used in the placement, consolidation and finishing operations are on site and in good working order. On most parts of a structure, forms cover concrete surfaces that will be exposed. In these cases, the primary equipment is a vibrator used to consolidate the concrete. In the case of a bridge deck, the large surface area is exposed throughout the placement, consolidation and finishing operations. To accomplish the operation efficiently, a self-propelled mechanical paving machine is used for bridge decks. The paving machine requires substantial setup and preparation. Once setup is complete, the machine is operated without concrete to confirm it will produce the required grade and depth. The inspector observes the trial run and measures the distance between the bottom of the screed and the top reinforcing steel in the deck (top clearance) and the bottom of the screed and the form (deck thickness).

Figure 40: Bridge deck paving machine

The key to a successful concrete placement and finishing operation is careful preparation. By thoroughly inspecting materials, forms, reinforcing steel and equipment, the bridge is prepared to receive concrete.

DURING CONSTRUCTION

The placement inspector, through coordination with the Contractor, estimates the projected quantity of concrete to be placed and the duration of the daily placement operation. By anticipating the quantity of concrete and duration of placement, the placement inspector can better coordinate activities associated with the operation. Before the concrete plant begins production, the placement inspector will coordinate with the mixing plant inspector and the field testers to confirm their availability and advise of the scheduled starting times and estimated quantity of concrete that is needed at the site of placement.

Because transit-mix trucks cannot always access the specific location of the placement, the following alternative placement methods are available:

- Unloading the transit-mix truck into a pumping truck, which pumps the concrete to the forms for placement.
- Loading the concrete into a concrete bucket. The bucket is hoisted by a crane and moved to the placement location, where the concrete is released into place.
- Using a portable conveyor belt system.

Regardless of the placement method, the concrete cannot free fall more than 4 feet. Typically, a steel pipe or tremie is used to comply with this requirement.

Because there are time limitations on the mixing and delivery of concrete, the inspector will know the limits for the type of mixing and delivery method used for the concrete. For example, the time limitation for transit-mix delivery is 90 minutes from the time water is introduced to the mix until the mix is discharged. In contrast, for concrete mixed at a central plant and transported using non-agitating hauling equipment, the time limitation is 45 minutes from the time water is introduced to the mix until the mix is discharged. Time limits may be extended with the addition of retarding admixtures. However, the effects of the admixture on the concrete must be considered during the mix design process. Admixtures cannot be used without the approval of the Materials Division.

As the first concrete delivery truck arrives, the placement inspector receives NDOT Form 040-025 (Transit Mix Concrete Delivery) or batch plant delivery ticket and completes the appropriate sections of the delivery form or delivery ticket. The inspector will visually inspect the mix for consistency. At this point, an initial slump test is typically performed to confirm that the slump is within the required range for the mix design. If the Contractor elects to increase the slump, the inspector will review the mix design requirements. If a water reducer has been added to the concrete mixture at the mixing plant, the Contractor may make only one attempt to adjust the slump using a high-range water reducing admixture or superplasticizer that is listed on the approved mix design. The Contractor shall ensure that the maximum slump will not be exceeded with the addition of the approved admixture. If a water reducing admixture has been added to the mix either at the mixing plant or at the site of placement, the addition of water will not be allowed once the delivery truck departs the mixing plant.

The air content of the mix may also be adjusted at the site of placement by making one attempt using an air-entraining admixture that is listed on the approved mix design.

If an admixture is added at the site of placement, the drum of the mixer truck must be revolved 45 times at mixing speed to produce a homogenous mix. Additional revolutions must be at agitation speed. For the requirements relating to the addition of admixtures, refer to Subsection 501.03.06, "(Portland Cement Concrete) (Construction) Mixing", of the Standard Specifications. The inspector will observe the admixtures being added at the job site and confirm that the required mixing takes place.

When concrete mix is delivered by non-agitating hauling trucks instead of transit-mix trucks, water and admixtures are added only at the mixing plant because hauling trucks are not equipped for mixing.

Immediately before the concrete is placed in the forms, all surfaces contacting the concrete shall be sprayed with water. Moistening the surfaces reduces the tendency of water being drawn out of the wet concrete, which negatively affects the hydration process. When the concrete is placed in the forms, the inspector will observe any movement or deflection of the forms or reinforcing steel.

Because an entire major concrete structural element may not be able to be completed with a single concrete placement operation, construction joints are placed in designated locations at the end of the placement operation. The project plans typically designate locations for planned construction joints and/or identify locations where construction joints are prohibited. With approval from the Structures Division, the Resident Engineer may allow the Contractor to place construction joints at other locations. Proper planning of the placement operation must address the planned joint locations. The Resident Engineer must thoroughly understand the project plans to confirm that the Contractor is placing construction joints at the proper locations. Clear communication between the Resident Engineer and the placement inspector is vital to ensure that a construction joint is placed in the proper designated location.

Emergencies, such as equipment breakdowns or delivery complications, may require the placement of a construction joint at unplanned locations. Structures have a variety of stresses throughout all elements. In areas where stresses can be high, the quality and durability of the concrete must also be high. Construction joints are prohibited in areas that require high-strength concrete. If the concrete stops at a point at which a joint is prohibited, the Contractor may need to remove concrete to construct the joint in an acceptable location.

Construction joints are prohibited in:

- Locations identified in the project plans as "no splice" areas for reinforcing steel.
- Locations identified in the project plans as "no construction joint" areas.
- Longitudinal joints (parallel to girders) at mid-points between girders or directly over girders.
- Locations identified as negative moment areas, located on either side of piers. (See areas denoted with "-" in Figure 41.)

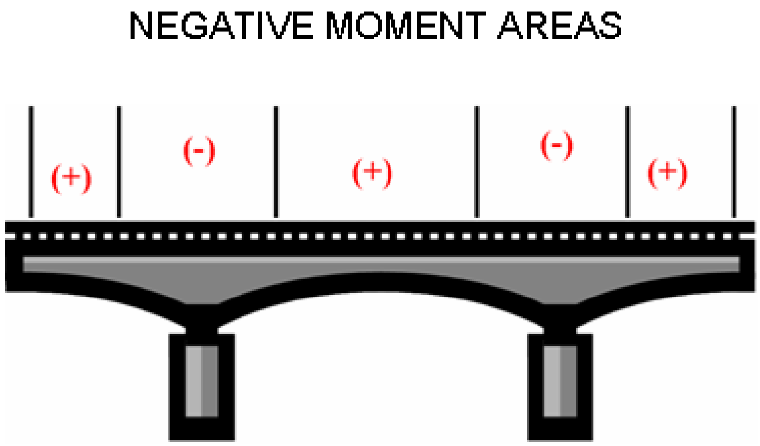

Figure 41: Negative moment areas

The surface of the construction joint should be struck off and made straight, but should remain unfinished. The rough surface provides improved interlock between the hardened concrete and the newly placed concrete. In some cases, a keyway is required in a construction joint. This keyway will provide a tongue and groove interlock between the respective sides of the construction joint. When the daily concrete placement operation is complete, and joints are constructed, the curing process begins.

Surfaces exposed to the atmosphere shall be cured properly to enhance the hydration process, as described in “501 - Portland Cement Concrete”, in this chapter. The Contractor shall monitor the curing process, the temperature of the concrete and the adequacy of the wet curing. The inspector will verify that the Contractor is monitoring the wet cure operation and that excess water is being contained. Excess water can create environmental problems, interference with traffic and problems with freezing. For bridge decks, after sufficient curing, the deck surface is tested to determine smoothness and rideability. Grinding, in accordance with Subsection 409.03.12, “(Portland Cement Concrete Pavement) (Construction) Riding Tolerances”, of the Standard Specifications, is required on areas of the bridge deck that are not in accordance with Subsection 502.03.16, “(Concrete Structures) (Construction) Finish of Horizontal Surfaces”, of the Standard Specifications. Generally, grinding is not permitted until after a 14-day cure and the concrete has reached its specified 28-day compressive strength.

Forms can be removed when the concrete has hardened sufficiently to prevent spalling or chipping during form removal. The proper time to remove forms depends on the atmospheric temperatures and humidity.

The condition of the concrete should be observed when forms are being removed. If the inspector discovers that the removal of the forms is causing damage to the concrete, they should immediately notify the foreman in charge of the work and request that the removal of the forms stop until an alternate method of removal that will not damage the concrete is determined. The inspector will then notify the Resident Engineer and request further direction. After removal of the forms, a curing compound is applied to the exposed concrete if the specified curing time has not been reached. Forms shall be removed from columns before concrete is placed for the superstructure. Removing the column forms first allows the inspector to determine the condition of the concrete in the columns before the weight of the structure is placed on the columns. Bridges that utilize pre-stressed or post-tensioned beams or girders must be stressed before falsework or other support is removed. For additional information, refer to “503 - Prestressed Concrete and Precast Members”, in this chapter.

The inspector observes the workmanship and quality of the materials as soon as the forms are removed, because this is the best time to detect any faults in the structure. If any defects are discovered upon removal of the forms, they should be documented thoroughly by the inspector and the Resident Engineer should be informed at once. All defects in exposed concrete must be corrected soon after the forms are removed. Surface areas damaged during form removal must be repaired in conformance with approved procedures. If a defect is deemed by the Resident Engineer to be significant in nature or a major defect, the Contractor shall submit a plan for repair of the defect. This repair plan will be prepared by an engineer who is registered as a Civil or Structural Engineer in the State of Nevada. Once the repair plan has been submitted to the Resident Engineer, it will be evaluated. Once the repair plan has been approved, the Contractor can begin the repair process as detailed in the approved repair plan. The Contractor shall remove and replace unconsolidated concrete with appropriate concrete patching material as approved as soon as possible.

MEASUREMENT AND PAYMENT

Refer to Subsection 502.04.01, "(Concrete Structures) (Method of Measurement) Measurement" and Subsection 502.05.01, "(Concrete Structures) (Basis of Payment) Payment", of the Standard Specifications and Chapters 13 and 14 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

503 - PRESTRESSED CONCRETE AND PRECAST MEMBERS

Prestressing is a technique for providing additional reinforcement to a concrete structure, utilizing steel strands threaded through conduits or ducts contained in the completed concrete in conjunction with reinforcing steel. The steel strands are tightened, or tensioned, producing stresses in the beam or girder that counteract those created during the lifecycle of the structure.

Prestressing concrete takes advantage of the concrete's compressive strength and overcomes its weakness in tensile strength. Bridges that utilize prestressed concrete can have longer spans than would be practical using only reinforcing bars to reinforce the concrete. Prestressing tendons (generally of high tensile steel cable or rods) are used to provide a clamping load. Each tendon consists of multiple steel strands. The clamping load produces a compressive stress in the structure that offsets tensile stresses that would otherwise exist when the concrete is loaded. On NDOT contracts, prestressing is typically accomplished in two ways, pre-tensioning and post-tensioning.

With pre-tensioning, concrete is cast around tensioned tendons. The cured concrete adheres and bonds to the bars. When the tension is released from the tendons, the tension is transferred to the concrete as compression by static friction. This method requires substantial anchoring points between which the tendon is stretched. The tendons are usually in a straight line. The bond between the tendons and the concrete protects the tendons from corrosion and provides for direct transfer of tension. Pre-tensioned elements are typically prefabricated in a plant and transported to the job site. Because pre-tensioned elements fabricated at a factory require transport, the size of the members is limited. Pre-tensioned elements may be beams, girders, foundation piles, pier caps and columns.

With post-tensioning, concrete is cast around plastic, steel, or aluminum ducts. The alignment of the ducts follows the areas where tension would occur in the concrete element. Concrete is cast around the ducts. The stressing tendons are fished through the ducts either before or after the concrete is cast. After the concrete has gained sufficient strength, hydraulic jacks, which react against the concrete member, tension the tendons. When the tendons have been stressed to the load specified by the design, the tendons are wedged in position, transferring stress to the concrete. The duct is then grouted to protect the tendons from corrosion and to transfer the load to the structure. Post-tensioning is used to construct a variety of bridge types.

BEFORE CONSTRUCTION

Representatives of the Structures Division inspect prestressing that is performed at an off-site factory or yard. For prestressing that is performed on-site, the inspector's responsibilities before the stressing operation are those as described in "502 - Concrete Structures", in this chapter.

PRE-TENSIONED STRUCTURES

The Structures Division reviews and approves pre-tensioned girder shop drawings after they are submitted to the Resident Engineer. Girder construction can begin as soon as the shop drawings are approved. Typically, the Structures Division's Non-destructive Testing Section inspects the pre-tensioned girders. Depending on workload, service providers or the Resident Engineer's inspector may be required to perform inspection. The Non-destructive Testing Section can, upon request, provide the necessary training on inspection. Because of the specialized nature of pre-tensioned girders, the Resident Engineer coordinates with the Construction Division and the Non-destructive Testing Section for inspection of the pre-tensioned girders a minimum of 2 weeks in advance.

During construction of the girders, the Non-destructive Testing Section inspector will observe the fabrication of girders to verify the girders are constructed in conformance with the approved shop drawings. The girders must be properly sized, the reinforcing steel must be placed correctly, strands must be placed in the proper locations, and the girders must be cured and handled in conformance with Section 503, "Prestressed Concrete and Precast Members", of the Standard Specifications.

During the fabrication of pre-tensioned girders, a field tester will sample and test the concrete materials to verify conformance to contract documents and the approved mix design. Field testers assigned to the work must have the required Nevada Concrete Qualification Program (NCQP) or American Concrete Institute (ACI) certification in order to test the concrete. for additional information on field tester qualification requirements, refer to "(Quality Control) Qualifications", in Chapter 4 of the *Construction Manual*.

POST-TENSIONED STRUCTURES

The Structures Division reviews and approves post-tensioning shop drawings after they are submitted to the Resident Engineer. The post-tensioning shop drawings typically include the following details:

- Stressing duct locations
- Post-tensioning anchorages and system components
- Number of stressing strands per duct
- Post-tensioning force
- Grouting procedures
- De-tensioning procedures (to be used if de-tensioning is required)
- Acceptable strand losses per tendon, duct and the structure
- Information on the calibrated pressure gauge and hydraulic ram to be used for post-tensioning operations

Accurate placement of the ducts is important so that the structure performs as designed. When the Contractor places the ducts, the inspector will verify that the ducts are placed within 1/4 inch of the location shown on the approved post-tensioning shop drawings.

The stressing tendons, or strands, are delivered to the job site before the stressing operation begins. The Materials Division must test samples of the strands before the material is incorporated into the work. Each spool containing strands has a fabrication number (heat number). The inspector will obtain certificates of compliance and document the heat number of each spool delivered to the job site and verify that each spool is tested as needed and approved by the Materials Division. Each spool must be visually inspected to confirm that it is not damaged. Ducts must be clean of foreign material and debris, which is typically done by blowing air through the duct. The Resident Engineer's inspector will observe that post-tension ducts are properly located as detailed on the approved shop drawings and that system-specific reinforcing steel is properly placed. Before the ducts are enclosed by girder formwork, the inspector will verify that the ducts are not damaged. The primary responsibility of the Resident Engineer's inspector at the structure is to ensure that the structure, forms and all pertinent materials have been approved for use and have been installed according to the project plans and approved shop drawings so that the Structures Division prestressing inspector can oversee the stressing operation.

Typically, the Structures Division's Non-destructive Testing Section inspects and monitors the post-tension process. Depending on workload, consultants or the Resident Engineer's inspector may be required to perform inspection and testing. In these instances, the Non-destructive Testing Section provides training on inspection and testing. When the Resident Engineer's inspector performs the inspection and testing, the Non-destructive Testing Section may still be present during portions of the work. Because of the specialized nature of pre-tensioned girders, the Resident Engineer coordinates with the Construction Division and the Non-destructive Testing Section for inspection of the pre-tensioned girders a minimum of 2 weeks in advance.

During the post-tensioning activities, the inspector samples and tests the materials in accordance with the contract documents and the approved mix design. The inspector also observes that the post-tensioning activities conform to the approved shop drawings: the reinforcing steel is placed correctly, strands are placed in the proper locations, and the post-tensioning, concrete placement and curing all conform to the contract documents.

DURING CONSTRUCTION

The Structures Division's Non-destructive Testing Section inspector is supported by the Resident Engineer's inspector during the stressing operation. The Resident Engineer's inspector observes the loading of the strands into the ducts. As strands are loaded, the inspector documents the spool number and heat number of the strand loaded into each duct. On most prestressing work, strands are loaded into the ducts after concrete is cast around the ducts. The Contractor may, however, load the strands into the ducts first, and then cast the concrete. If the Contractor loads the strands first, the Contractor shall protect the strands in accordance with Subsection 503.03.02, "(Prestressed Concrete and Precast Members) (Construction) Protection of Materials", of the Standard Specifications. The protection of the strands may include the application of an approved rust inhibitor. Typically, a rust inhibitor is not used if stressing is planned to occur within 10 days after placement, unless inclement weather is anticipated. In either situation, the strands are not tensioned until the concrete reaches its specified strength. With the ducts loaded with strands, the Contractor stresses the tendons in the sequence detailed in the approved shop drawings. After all tendons are stressed, each duct is grouted. Because of the hazards associated with working around stressing equipment and activities, be constantly aware of hazards and areas that are designated as off-limits by the stressing Contractor and adhere to safety measures.

MEASUREMENT AND PAYMENT

Refer to Subsection 503.04.01, "(Prestressed Concrete and Precast Members) (Method of Measurement) Measurement" and Subsection 503.05.01, "(Prestressed Concrete and Precast Members) (Basis of Payment) Payment", of the Standard Specifications and Chapters 13 and 14 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

504 - LIGHTWEIGHT CONCRETE FOR STRUCTURES

Because of its lower in-place density versus regular concrete, lightweight concrete can be used to help reduce the overall mass of certain components of a concrete structure such as a bridge deck. This product can be produced by using lighter weight aggregates that are simply aggregates with a lower density in pounds per cubic feet when compared to regular concrete aggregates. This can result in a concrete product with a potential reduction in density of about 30 pounds per cubic foot. The lighter mass of this type of concrete will allow the designer to reduce the size of some of the support elements of the structure, possibly resulting in a more economical design that can match the strength, permeability and durability requirements of regular weight concrete.

BEFORE CONSTRUCTION

Because lighter weight aggregates will tend to be more porous and absorption values will typically be much higher than regular aggregates, ensure that the aggregates have been fully saturated with water prior to batching. Adding water to the piles for several hours prior to batch time will help with this requirement. If the aggregates are not fully saturated at the time of batching, they will continue to absorb water after batching, effectively robbing the concrete of mixing water and causing a reduction in slump. Moisture tests are important to determine the amount of water that has been incorporated into the aggregates and to determine if any free moisture is available in order to deduct it from the batch amount. The plant inspector shall review a copy of the mix design for lightweight concrete. Some of the batch amounts may be different than what is familiar to the inspector. The inspector will also review the list of any approved admixtures and the prescribed amount of each.

DURING CONSTRUCTION

Even if lightweight concrete will be used in a structure, Section 501, "Portland Cement Concrete" and Section 502, "Concrete Structures", of the Standard Specifications will still apply with certain exceptions. For more information, refer to Section 504, "Lightweight Concrete for Structures", of the Standard Specifications. Some notable differences between lightweight concrete and regular concrete will be the maximum water/cement ratio, batching and discharge procedures. The maximum water/cement ratio will range from .49 to .53.

The batching procedure for lightweight concrete requires that 75 percent of the total mixing water and the admixtures are introduced to the mixer and mixed for at least 45 seconds before the aggregates are introduced. As cement is introduced into a truck mixer, the drum of the mixer will need to be slowed down. As soon as all the ingredients are in the drum of the mixer, the drum will need to be increased to mixing speed. The mixing time or number of revolutions at mixing speed will generally be increased for lightweight concrete mixtures as well. For specific loading and mixing requirements, refer to Section 504, "Lightweight Concrete for Structures", of the Standard Specifications.

Just prior to discharge of the lightweight concrete mix, the drum of the mixer will be increased to mixing speed for at least 60 seconds to ensure adequate remixing of the concrete.

When lightweight concrete is being placed using a pump, extra effort is required in order to ensure smooth, consistent concrete flow and prevent the pump from plugging during placement. Some things that will help maintain quality lightweight concrete will include using pump lines no smaller than 5 inches in diameter, keeping the pump lines as straight as possible with a minimal number of elbows and connectors and, limiting free fall of the concrete mix at any point from the mixer truck to the point of discharge.

The pump operator should also be aware that the aggregates in lightweight concrete will tend to be more porous than regular concrete aggregates. Because of this, the lightweight concrete mixture should be pumped with as little pressure as practical. Excessive pressure when pumping lightweight concrete will result in loss of slump and reduced pumpability.

MEASUREMENT AND PAYMENT

Refer to Subsection 504.04.01, "(Lightweight Concrete for Structures) (Method of Measurement) Measurement" and Subsection 504.05.01, "(Lightweight Concrete for Structures) (Basis of Payment) Payment", of the Standard Specifications and Chapters 13 and 14 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

505 - REINFORCING STEEL

Reinforcing steel is used on concrete structures to enhance the quality of the concrete. While the compressive strength of concrete (i.e., resistance to pressing the concrete together) tends to be very high, the tensile strength of concrete (i.e., resistance to pulling the concrete apart) is relatively low. Reinforcing steel is added to concrete to give it additional tensile strength. As a result, reinforced concrete is produced.

Important characteristics of reinforced concrete include the strength of the steel used, size or diameter of the steel and the location of the steel within the concrete.

Reinforcing bars are made of steel that has been milled into rods with cross-hatchings (deformations) that help concrete bond with the reinforcing steel (rebar). When exposed to deicing salts and other chemicals, rebar can corrode, leading to possible accelerated deterioration of the structure. To protect the steel from corrosive elements, reinforcing steel is coated with epoxy. Epoxy coated rebar is required for applications where corrosion protection is necessary.

Reinforcing steel is classified by several characteristics. The principal ones are grade (strength of the steel) and diameter of the bar. Common grades of reinforcing steel are as follows:

- Grade 40: Minimum strength 40,000 pounds per square inch (psi)
- Grade 60: Minimum strength 60,000 psi
- Grade 75: Minimum strength 75,000 psi

Reinforcing steel used in NDOT structures must comply with American Association of State Highway and Transportation Officials (AASHTO) M31 (Grade 60) or American Society for Testing and Materials (ASTM) standards (A706). The project plans specify the type of steel to be used.

For reinforcing steel bars up to 1 inch in diameter, the size designation is based on the cross-sectional diameter of the bar, measured in eighths of an inch. Refer to the table in Subsection 505.04.01, "(Reinforcing Steel) (Method of Measurement) Measurement", of the Standard Specifications, when doing calculations for payment.

Steel bars also have markings that identify producing mill, bar size, steel type and grade. Some manufacturers will add unique deformations to the bar to aid in identification of the producing mill and bar characteristics. (Although some mills still use metric bar size markings, many are in the process of changing back to English units as casting dies are replaced.) Compare the bar markings to the certificates of compliance or mill test reports to determine origin, heat number, grade and type of steel in the bar. For assistance with bar identification, contact the Construction Division's Quality Assurance Section.

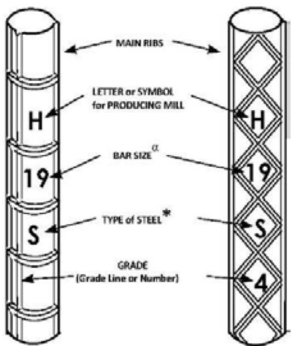

Figure 42: Reinforcing bar markings

Reinforcing steel has deformations, or ridges, that bind it mechanically to the concrete with friction. Even with these deformations, reinforcing steel can still be pulled out of the concrete under high stresses. To prevent this type of failure, reinforcing steel is either deeply embedded into adjacent structural members, or is bent and hooked to lock it around the concrete and other reinforcing steel.

Each structure has unique bent bar requirements. The bent bar requirements are detailed in the project plans. The bent bar diagrams identify the type of steel, bar size and the dimensions of the reinforcing steel.

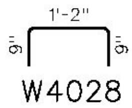

Figure 43: Example rebar bending designation

When referring to the bent bar diagram (refer to Figure 43), the identifying designation of the bar is W4028. The characters in the designation describe the following:

- W: The bar will be placed in the wingwall
- 4: Size of the bar (# 4 bar)
- 028: Length of bar, measured in feet and inches (2 feet, 8 inches)

NOTE: If the bar is epoxy coated, the designation would contain the letter E after the length (W4028E).

Figure 43 shows a bar with a total length of 2 feet 8 inches long and is bent in two locations, resulting in three separate lengths: two at 9 inches each and one at 1 foot, 2 inches. When referring to bent bar diagrams, the sum of all the individual lengths of the bar should equal the total length of the bar as called out in the project plans.

Reinforcing bar identification should also be cross-referenced with the project plans' Bill of Materials, which breaks each bar down into location in structure, size, length and number of bars needed for each element of the structure.

At times, reinforcing steel must be joined to create a continuous length of reinforcement. Joining one piece to another is called splicing. Reinforcing steel splices allow loads to be transmitted continuously along the total length of the joined reinforcing steel. The three methods of splicing are lap splices, mechanical splices and welded splices. The Contractor shall obtain approval for any changes to splice type and/or location if it is not specifically detailed in the project plans.

Lap splices are the most commonly used splice and are typically used for smaller-diameter horizontal and vertical reinforcing steel. Lap splices are limited to bar size #11 and smaller. A lap involves two pieces of rebar overlapped to create a continuous line of rebar. The length of the lap varies depending on a number of factors, including the concrete strength, the rebar grade, size and spacing. The project plans, and in some instances the Standard Plans, will indicate the required lap length based on the diameter of the reinforcing steel. If details do not indicate a lap length, the inspector or Resident Engineer will contact the Structures Division to determine the required lap lengths for that specific item in the structure.

Welded splices are typically used to splice two pieces of reinforcing steel with large diameters. The two pieces are welded end-to-end, called butt-welded. Unless specifically shown in the project plans, the use of welded splices must be approved by the Structures Division. Use of welded splices requires a submittal of welder's qualifications and welding procedures. The inspector will contact the Structures Division's Non-destructive Testing Section for further guidance regarding the welder or welding process and to request an inspection.

Mechanical splices are typically used when space limitations prevent a lap splice or for larger-diameter horizontal and vertical reinforcing steel. Mechanical splices are proprietary and supplied by a number of manufacturers. A common type of mechanical splice is a threaded coupler in which two pieces of rebar are threaded and screwed into the coupler. Unless specified in the project plans, the use of mechanical splices must be approved by the Structures Division.

BEFORE CONSTRUCTION

In preparation for construction, the inspector will observe the delivery and storage of reinforcing steel. When reinforcing steel is delivered to the job site, the inspector will obtain certificates of compliance for each heat, or production run, represented by the delivery. The certification and the certificate of materials origin contain information that determines whether the steel complies with Buy America requirements. As part of the submittal process, the Contractor shall submit a completed NDOT Form 020-095 (Certificate of Materials Origin (CoMO)), available in the Forms library on the Materials

Division's SharePoint site [https://nevadadot.sharepoint.com/sites/020/FormServerTemplates/]. (Refer to Subsection 106.12, "(Control of Materials) Buy America", of the Standard Specifications, for more information.) Epoxy coated reinforcing steel also requires certificates of compliance from the coating manufacturer. In storage, the reinforcing steel should be protected from corrosive elements, including water, soil and any other contaminants. Reinforcing steel is typically stored on wooden blocks, called dunnage, keeping the steel off the ground. Epoxy coated reinforcing steel shall be covered to protect it from damaging ultraviolet (UV) light and moisture if it will be stored for more than 2 months.

Depending on the steel's exposure to the elements, rust may form on the steel. A small amount of loose, powdery rust is not detrimental. While some rust is not necessarily detrimental on non-epoxy coated bars, excessive rust may warrant cleaning of the reinforcing steel or rejection of the reinforcing steel if the cross-sectional area is reduced because of the rust.

Rust on epoxy coated bars is not allowed and epoxy coated bars with rust on them is an indicator of a damaged coating. These bars should be cleaned of rust and the epoxy coating should be repaired. Patching material is usually sent with a shipment of epoxy coated reinforcing steel. Refer to Subsection 505.03.02, "(Prestressed Concrete and Precast Members) (Construction) Protection of Materials", of the Standard Specifications, for further information on limits of damage and patching of epoxy coated reinforcing steel bars.

For further guidance, contact the Resident Engineer and, if necessary, the Construction Division's Quality Assurance Section.

DURING CONSTRUCTION

Inspecting reinforcing steel requires attention to the condition of the reinforcing steel and placement. The steel shall be clean and free of foreign material and other debris, including grease and oil. Bonded rust or mill scale can remain on the steel, provided the rust does not create cross-sectional loss. Most loose rust will be removed by the handling of the steel during placement.

Figure 44: Reinforcing steel showing minor amounts of rust

Cutting and bending bars affects the quality of the steel. Because heat alters the tempering of the steel, making it weak or brittle, heat should not be used to cut or bend steel. The Contractor shall use an abrasive saw to cut reinforcing steel. All bends in reinforcing steel bars are required to be cold bends unless otherwise permitted. If steel is bent at the job site, the Contractor shall submit field bending procedures for review and approval by the Resident Engineer and the Structures Division.

Before placement of reinforcing steel, the Contractor shall supply two samples of each bar size, per manufacturer, per project, per year. If the Resident Engineer feels that the quality of reinforcing steel is questionable, the Resident Engineer may require the Contractor to supply samples for each heat, or production run, delivered to the job site. The steel samples are transmitted to the Materials Division using NDOT Form 020-018 (Transmittal for Test Samples and Certifications), which is available in the Forms library on the on the Construction Division's SharePoint site [https://nevadadot.sharepoint.com/sites/040/FormServerTemplates/Forms/]. (Refer to the *Field Testing Guide* for information required on the transmittal.) Certificates of compliance allow the Contractor to incorporate the steel into the work, pending acceptable test results from the Materials Division.

The Contractor shall place the specified size and grade of reinforcing steel as detailed in the project plans, including spacing with adjacent steel and clearance from forms and the quantity of bars. The Resident Engineer and the Structures Division shall approve all substitutions or other modifications to reinforcing steel. Even apparent minor modifications can significantly alter the performance or behavior of the structure. (For example, using reinforcing steel of a larger diameter than specified in the project plans can increase the rigidity and loading of the structure.)

The following are some guidelines for dimensional tolerances for the placement of reinforcing steel in various elements of a concrete structure:

- General: The reinforcement shall be placed within 1/4 inch of the location shown in the project plans unless the tolerance is otherwise specified.
- Footings: Horizontal reinforcing steel shall be placed within 1/2 inch vertically of the bottom clearance shown in the project plans. The side form clearance shall be within 1 inch of the clearance shown in the project plans. In any case for footings, reinforcing bars shall not deviate more than 1 inch from the location shown in the project plans.
- Dowel Bars – Columns and Walls: Dowels shall be placed within 1/2 inch of the position shown in the project plans. The side form clearance for any dowel shall be within 1/4 inch of the clearance shown in the project plans.
- Columns: Vertical reinforcing steel shall be placed within 1/2 inch of the position shown in the project plans. Column ties shall be placed within 1 inch of the position shown in the project plans for a specific tie, with no accumulation of tolerances caused by the spacing between ties. Side form clearances for any tie shall be within 1/4 inch of the clearance shown in the project plans.
- Walls: Reinforcing steel shall be placed within 1 inch of the position shown in the project plans for any one bar, with no accumulation of tolerances caused by the spacing between bars. The side form clearance for any bar shall be within 1/4 inch of the clearance shown in the project plans. Bar spacing may be shifted out of tolerance where necessary to clear a fixture. If is necessary for bars to be shifted, the quantity of bars to be shifted in the affected area will be designated in the project plans. The remaining bars that are not affected by the shift shall be placed within 1 inch of the position shown in the project plans.
- Beams and Caps: Longitudinal reinforcing steel shall be placed within 1/2 inch of the bottom and top vertical clearances shown in the project plans for all layers of reinforcing steel. The side form clearances shall be within 1/2 inch of the clearance shown in the project plans. Stirrups shall be spaced and tied within 1 inch of the position shown in the project plans, with no accumulation of tolerances caused by the spacing between stirrups.
- Deck Slabs: Top and bottom horizontal reinforcing steel shall be placed within 1/4 inch of the top and bottom vertical clearances shown in the project plans. Horizontal spacing and side form clearances shall be within 1/2 inch of the dimension shown in the project plans. Curb, sidewalk and barrier reinforcing steel shall be placed within 1/2 inch of the locations shown in the project plans.
- Prestressing Reinforcing Steel: In the event of a conflict between the reinforcing steel and the post-tensioning duct, the position of the post-tensioning duct shall prevail with the reinforcing steel adjusted locally as approved. Refer to Section 503, “Prestressed Concrete and Precast Members”, of the Standard Specifications, and contract-specific tensioning details for additional tolerances for placement of prestressing reinforcing steel.

The Contractor maintains clearance between reinforcing steel and forms by using spacers separating the steel from the inside face of the form. Spacers can be made of concrete blocks (dobies) or manufactured supports (chairs).

Figure 45: Typical reinforcing steel spacers and supports

During the placement of steel by the Contractor, the inspector checks that splices are located and constructed in accordance with the contract documents.

When lapping reinforcing steel for a splice, the Contractor uses tie wire to connect the two pieces of steel together firmly. When rebar intersects another piece of rebar, connect the pieces using tie wire. Subsection 505.03.04, "(Reinforcing Steel) (Construction) Placing and Fastening", of the Standard Specifications, contains the requirements relating to the amount of intersections to be tied. Regardless of the required amount of intersections, the rebar mat shall be sufficiently stable to withstand activity associated with concrete placement, such as movement of workers and concrete being placed. To reduce the amount of deflection in the reinforcing steel, the Contractor shall place bar supports sufficient in number and strength to carry all anticipated loads until the concrete is placed and finished. Refer to Subsection 505.03.04 of the Standard Specifications for additional requirements for support spacing.

When handling and placing epoxy-coated reinforcing steel, every effort should be made to preserve the integrity of the coating. The Contractor and the inspector shall ensure that the bars are handled, placed, tied and supported properly. Specially coated tie wire, supports and concrete vibrators are required when using epoxy coated rebar.

MEASUREMENT AND PAYMENT

Refer to Subsection 505.04.01, "(Reinforcing Steel) (Method of Measurement) Measurement" and Subsection 505.05.01, "(Reinforcing Steel) (Basis of Payment) Payment", of the Standard Specifications and Chapters 13 and 14 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

506 - STEEL STRUCTURES

Concrete and steel structures are similar in that both structures have concrete footings, columns, abutments and decks. The major difference is that the superstructure is constructed with structural steel, based on design and economic considerations.

For steel structures, the Structures Division's Non-destructive Testing inspector oversees:

- Fabrication of the steel at the manufacturing facility.
- Placement of the steel at the job site.
- Field painting of the girders.

Because the structural steel material, length and configuration are unique for each bridge project, the steel elements are assembled at a fabrication plant. During the fabrication process, the inspector is on-site to monitor the fabrication and testing activities. When complete, the structural members are transported to the job site. At the site, an inspector will be present during the erection process, when the steel girders are erected and connected to adjoining members.

Depending on the bridge construction and erection conditions, the Contractor may have additional requirements, as stated in the contract documents. A common requirement is an erection plan, which can be a separate plan or included as part of the shop drawings. The Resident Engineer and inspectors must have a thorough knowledge and understanding of the requirements stated in the contract documents.

BEFORE CONSTRUCTION

Because of the specialized nature of structural steel shop drawings, the Structures Division or designer of record communicates directly with the steel fabricator as necessary to resolve issues or concerns during the shop drawing review. The Resident Engineer receives copies of all correspondence, and the Structures Division sends copies of the approved shop drawings to the Resident Engineer.

Structural steel shop drawings detail all elements of steel girder fabrication, including:

- Material specifications.
- Dimensions and sizes of plates and shapes.
- Number and location of shear studs (for field installation).
- Cross frame/diaphragm details.
- Stiffener and connection plate details.
- Weld designations.
- Welded shop splice/bolted field splice details.
- Bolted connection details.
- Camber of girders.
- Painting details.
- Procedures for shop handling and assembly.

DURING CONSTRUCTION

The level of detail in the shop drawings ensures that the steel members are fabricated and erected in accordance with the contract documents. After the Structures Division approves the shop drawings, the Contractor shall fabricate and erect the steel members in conformance with the approved drawings. Deviation from the approved shop drawings and erection plan is not permitted without prior approval from the Structures Division. The inspector observes the erection of the steel to verify conformance with the approved erection plan.

During steel erection, the inspector will:

- Confirm that the Resident Engineer has approved the Contractor's traffic control plan if steel is erected near traffic.
- Confirm in advance that the Contractor has surveyed the elevations of the substructure and that the Resident Engineer's survey crew has verified the survey.
- Check the elevation of the temporary supports and the falsework relative to the required cambers.
- Check that the falsework is constructed in accordance with the approved shop drawings and that it is monitored daily by the Contractor for tightness of bolts, wedges and cables.

- Check the surface that will support the beam to confirm that:
    - Bearing elevation and orientation are correct.
    - Anchors are set accurately as detailed.
    - Expansion bearings are properly placed for ambient air temperature.
- Check that the structural steel stored at the job site is supported above the ground on skids, platforms, or other supports and properly drained and protected from corrosion.
- Verify that the Contractor follows the approved safety plan and provides fall protection and other personal protective equipment during steel placement.
- Check that temporary bracing or blocking is in place during erection and remains in place until the structure is fully erected and connections are complete.

All elements of steel erection must strictly conform to the erection plan, including steel placement, splices and field connections, and bracing and diaphragms. Do not substitute or modify the plan details without prior approval from the Resident Engineer. Minor modifications can affect the stability and performance of the structure.

Stay-in-place deck form systems are commonly used to form the bottom of the deck slab between steel girders. Connection details for stay-in-place deck form systems, overhang jacks (used to form the deck overhang beyond the exterior girder), safety railing and any other construction items that may be attached to the steel girders must be included in the shop drawings.

The Resident Engineer shall consult with the Structures Division regarding any proposed field modifications. Welding, heating or cutting of structural steel items on the job site are prohibited without the approval of the Structures Division.

MEASUREMENT AND PAYMENT

During fabrication inspection, representatives from the Structures Division's Non-destructive Testing Section will document the progress of the work and the materials used for partial payments. This information is transmitted to the Resident Engineer for inclusion in progress payments.

Refer to Subsection 506.04.01, "(Steel Structures) (Method of Measurement) Measurement" and Subsection 506.05.01, "(Steel Structures) (Basis of Payment) Payment", of the Standard Specifications and Chapters 13 and 14 of the *Documentation Manual* for additional measurement/payment guidelines and related instructions.

508 - DRIVEN PILES

A driven pile is a form of deep foundation that is typically used to support a bridge or other structure when a standard or spread footing will not be satisfactory to support that structure. A pile can provide greater support as a result of the friction of the soils against the sides of the pile, the end bearing of the pile on a solid foundation, or a combination of both skin friction and end bearing. A driven pile may consist of a steel sheet pile, concrete-filled steel pipe, steel H-pile, prestressed concrete, timber, or a combination of materials. Prestressed concrete and timber piles are no longer being used for NDOT contracts. The Department typically uses concrete-filled steel pipe piles. Piles are made of preformed material having a predetermined shape and size that are installed by impact hammering or vibrating into the ground. (See Figure 46.)

Figure 46: Pile driving operation

BEFORE CONSTRUCTION

Before piles are driven, the Contractor shall stake-out the location of structure footing and the location of the piles. The Contractor shall submit a pile installation plan, a complete listing of equipment to be used in the pile driving operation, including the type of pile driving hammer, and a wave equation analysis to the Resident Engineer. A geotechnical engineer, hired by the Contractor, is responsible for conducting the wave equation analysis. This analysis incorporates design information from the project plans, the NDOT geotechnical report, and information pertaining to the Contractor's proposed equipment. The wave equation analysis uses data and assumptions to develop a graph that relates theoretical blow counts and driving load resistance. A blow count is the number of blows that the hammer delivers to the pile to move the pile a given distance, typically 1 foot. The wave-equation graph estimates the blow counts required to achieve the driving load resistance shown in the project plans. The wave equation analysis can also help predict pile stresses and delivered hammer energy. The Resident Engineer will review the submittals for completeness, and if the submittals are sufficient, forwards them to the Materials Division's Geotechnical Section for review and approval. The Geotechnical Section must approve the submitted pile installation plan, equipment list, and wave equation analysis as well as any changes to the approved pile installation plan.

As piles are delivered to the job site, the inspector monitors delivery and storage. If steel piles are used, the inspector obtains the certificate of compliance for each production run, including mill test reports and verification of the steel meeting Buy America requirements. The inspector compares the contract documents with the information contained in the certificate. Piles should be inspected to verify they are not damaged or flawed. The inspector will monitor the unloading of piles to verify piles are unloaded using the appropriate number of pick-up points and locations. (Pick-up points are selected to prevent bending.) Typically, the pile length requires a minimum of two pick-up points, at the 1/3 and 2/3 points of the pile length. The Contractor shall place piles on blocks, called dunnage, to prevent them from sagging and to protect them from corrosive elements, including water and soil. Place dunnage so that the piles do not sag.

Piles are usually shipped without the driving tip or shoe attached. The pile driving tips or shoes will usually be delivered separately from the piles. Certificates of compliance, mill test reports and verification of Buy America requirements are required for the pile tips or shoes. The inspector will inspect the pile tips or shoes carefully to ensure they match the details in the project plans. If the pile tips or shoes vary from the project plans in any way, the Resident Engineer and the Structures Division should be notified as soon as the discovery is made. The approved tips or shoes shall be attached to the pile in the field by a certified welder according to the requirements of Subsection 506.03.16, "(Steel Structures) (Construction) Welding", of the Standard Specifications. The Resident Engineer will notify the Structures Division when the tips are being attached to the piles in the event the Structures Division should wish to send a representative from its Non-Destructive Testing Section to inspect the attachment of the pile tips or shoes. If a representative from the non-destructive testing section is not present during welding, the field inspector will check with the on-site welder to verify certifications as required in Subsection 506.03.16 of the Standard Specifications.

The inspector will review the plan details related to pile driving, identify key elements of the pile installation plan and identify key inspection elements of Section 508, "Driven Piles", of the Standard Specifications. Two key elements of a pile installation are splice details and tip elevations. Because a pile length cannot be exactly determined before driving, piles can be spliced to achieve the length needed to develop the driving load resistance shown in the project plans. (The contract documents include splice details.) A pile's tip is the leading end of the pile as it is driven into the ground. Do not include the pile tip or shoe in this measurement.

The project plans specify the minimum tip elevation and the design tip elevation. The minimum tip elevation is the minimum depth that the pile tip must be driven. The design tip elevation is the depth at which the driving load resistance is expected. Based on the data developed during the dynamic load testing, a tip elevation is established to reflect actual conditions. The tip elevation established during the dynamic load testing may differ from the project plans, but it shall not be less than the minimum tip elevation.

DURING CONSTRUCTION

Coordination and communication ensures pile driving progresses efficiently and without delays. The Materials Division's Geotechnical Section staff plays a key role in pile driving. Because piles are the foundation on which the structure is supported, deviations from the contract documents may have significant impacts. The Resident Engineer will contact the Geotechnical Section when clarification of the contract documents is needed or when work or materials require approval. The Resident Engineer must keep the Geotechnical Section informed of the pile driving progress. If required, communicate daily with the Geotechnical Section to keep them adequately informed.

The inspector has a key role during the pile driving operation. The inspector observes the pile driving operation, records relevant information, and documents the pile driving activities. The inspector does not direct the Contractor's pile driving activities, but if the inspector observes a potential for non-conformance, the inspector notifies the Contractor and the Resident Engineer. Notifying the Contractor of the potential for non-conformance allows the Contractor to take corrective action and avoid having non-conforming work. Timely communications between the inspector and the Contractor can eliminate delays to the Contractor's operations.

The piles shall be marked in 1-foot increments before they are lifted from the ground and driven. The markings shall be of a durable material that will not rub off during handling of the pile. The inspector will then use the markings to monitor and document the length of pile driven into the ground. Pile driving can begin by either placing the pile tip directly on the ground or by driving the pile into a pre-drilled pilot hole. Refer to the contract documents to confirm that pre-drilled pilot holes are allowed. Once the pile is placed under the pile driving hammer, and before driving begins, the inspector confirms that the pile is in the right location and at the proper angle to the ground. During pile driving, as the tip reaches the proper depth, the inspector verifies that the pile has reached the driving load resistance shown in the project plans.

A driven pile reaches its proper depth when the bottom tip of the pile is driven to an elevation designated as the design tip elevation as shown in the project plans, the required blow count has been met, and the capacity of the pile is sufficient. Upon approval from the Resident Engineer, who consults with the Geotechnical Section, the pile may be accepted when the bottom tip of the pile reaches an elevation designated as the minimum tip elevation, the required blow count has been met and the capacity of the pile is sufficient.

The pile capacity is the amount of vertical and lateral force that a pile is designed to resist for different loadings, such as scour and seismic events. The required blow counts needed to achieve the driving load resistance shown in the project plans is estimated initially by the wave equation analysis.

A dynamic load test is required during pile driving operations as detailed in Subsection 508.03.06, "(Driven Piles) (Construction) High-Strain Dynamic Testing", of the Standard Specifications. During driving of the first pile in a group, the Contractor's geotechnical consultant performs a dynamic load test, which occurs as the pile is being driven, and validates or verifies the Contractor's wave equation analysis and pile installation plan. In addition to validating and verifying the wave equation analysis and pile installation plan, the dynamic load test accomplishes the following:

- Verifies the driving load resistance and capacity of the pile
- Determines the ease or difficulty in penetrating through soil layers
- Evaluates the performance of the Contractor's proposed pile driving system
- Determines the pile lengths required for production piles
- Establishes the driving criteria (number of blows per foot required to obtain design driving load resistance) for production pile driving

A pile group consists of all the piles driven for a part of the foundation, such as an abutment, pier or some other element.

The inspector closely observes the pile driving operation and records the number of blows per foot, for each foot the pile is driven. When the tip of the pile reaches the design tip elevation, the required number of blows per foot is obtained, and the capacity of the pile is sufficient, the inspector immediately informs the Contractor that the driving requirements have been met. If the design tip cannot be reached but the pile can be driven to at least minimum tip elevation, the required number of blows per foot is obtained, and the capacity of the pile is sufficient, the inspector will notify the Resident Engineer, who will consult the Materials Division's Geotechnical Section to determine if driving can stop. The Resident Engineer will notify the Contractor and the inspector of the decision as soon as possible.

After all piles in a group are driven and approval is given by the Resident Engineer, the pile is cut-off to the designated elevation. After successfully driving a pile, the Contractor proceeds to the next pile. The next pile to be driven should not be adjacent to the last pile driven, but should be spaced some distance away in the pile grouping. Inspectors should review Section 508, "Driven Piles", of the Standard Specifications, for specific restrictions and limitations on pile driving.

When several piles are driven adjacent to each other consecutively, pore water pressure could build up in the underlying soil layers to the point that the pile would not drive any further, creating a condition called false refusal. To alleviate false refusal, the Contractor stops the pile driving in the area, and resumes the driving later (usually the next day), after allowing the pore water pressure to dissipate. In contrast to false refusal, practical refusal occurs when the pile has reached either design tip, minimum tip or somewhere in between, and cannot be driven any deeper without exceeding the target maximum number of blows per foot which, if driving could continue at the higher blow count, would possibly cause damage to the pile. For additional requirements, refer to Subsection 508.03.04, "(Driven Piles) (Construction) Driving Piles", of the Standard Specifications.

If a pile does not attain the specified driving load resistance when driven to the design tip elevation or the dynamic load test tip elevation, the Contractor shall stop driving the pile and allow the pile to stand undisturbed for a period of time. This period (set period). During the set period, soil resistance typically increases. The inspector will consult with the Resident Engineer to determine the required length of the set period. When driving resumes, if the target blow count is still not achieved during restriking, a splice may be required to increase the pile length. When splicing is required on a pile, refer to the contract documents for requirements.

The Contractor surveys the elevation of the top of the pile, referenced to a fixed datum, after installation and periodically thereafter, as adjacent piles are driven. The purpose of the survey is to monitor the elevations of the pile tops. Driving a pile can cause upward movement of adjacent piles (pile heave). If piles heave more than 1/4 inch, the Contractor shall re-drive the heaved pile. To ensure accuracy, the Construction Field Crew should frequently check the Contractors survey results to ensure accuracy.

During the pile driving operation, the inspector will be close enough to the hammer and pile to observe the operation and to count the blows per foot, while maintaining a safe distance from the work. Because the area around the pile driving operation can be hazardous due to the exhaust of the hammer, the overhead danger of the crane and the pile, and the noise of the operation, wear appropriate safety gear, such as a hard hat and hearing protection. The inspector will constantly be aware of the pile driving activities and have a route to escape if necessary.

During the pile driving operation, the inspector will complete NDOT forms 040-059 (Continuous Pile Driving Record) and 040-058 (Foundation Piling Driving Record) These forms record key information such as the time it takes to drive a pile, specific elevations, hammer stroke, and the number of blows to drive the pile a foot, for every foot the pile is driven. The inspector can and should enter as much of the form data as possible before the driving operations begin so they can pay full attention to the pile driving operation.

In addition to the pile driving forms, the inspector completes the Inspector Daily Report (IDR), which documents the following:

- Name of the Contractor's foreman or supervisor
- Pile driving activities
- Relevant communications
- Progress of operations
- Equipment and materials used in the work

There are typically two types of hammers used for driving piles on NDOT contracts: diesel hammers and vibratory hammers.

A diesel hammer, more specifically called a single-acting open-end diesel hammer uses a small amount of fuel oil to lift a piston contained within an open-ended cylinder. Once the piston reaches the top of its stroke, gravity pulls the piston back down resulting in an impact near the top of the pile head. As the impact occurs, the fuel oil is ignited and the piston is forced up again. This process continues until either the fuel is cut off or the force of the impact is no longer enough to ignite the fuel oil. A device consisting of a man-made material and referred to as a hammer cushion is used to reduce the damaging effects of the piston impacting the bottom of the cylinder. The hammer cushion shall be checked for wear before driving gets underway and after every 100 hours of driving.

A vibratory hammer rests on the top of the pile, vibrating the pile and temporarily negating the friction between the pile and the soil. The pile sinks into the subsoil under its own weight and the weight of the vibrator. Vibratory hammers are most typically used for driving sheet piles, which are used for scour protection, river diversions and some types of retaining walls. For further information on hammer, and pile types along with the requirements for the driving of piles, refer to Section 508, "Driven Piles", of the Standard Specifications.

Once the driving of a pile is completed, the inspector will inspect the interior of the piles to determine the condition of the piles. A small mirror will serve the inspector to reflect sunlight into the pile and check for damage. There should not be any standing water inside the pile and the inspector should be able to see the inside of the pile tip (if one is attached). If water is present in the pile or the bottom of the pile is not visible from the top, then damage is indicated. If pile damage is suspected, notify the Contractor and the Resident Engineer as soon as the discovery is made. The Resident Engineer will then contact the Geotechnical Section for further guidance. Further inspection may include the deployment of a downhole video camera to further inspect the interior of the pile and identify any potential defects. If it is determined that a defect exists, the Contractor shall submit a plan to remedy the defective pile.

If the inspection performed upon completion of pile driving reveals no defects, the top of the pile should be covered to keep water and debris from falling into the pile before it is filled with reinforcing steel and concrete. Upon approval, a reinforcing steel cage may then be lowered into the pile. The Contractor shall provide a satisfactory means of supporting the reinforcing steel cage from the top so that it does not settle (float) during placement of the concrete.

Certificates of compliance, mill test reports and verification of buy America requirements are required for the reinforcing steel. Before the reinforcing steel cage is installed, the inspector will inspect it to ensure the pitch of the spiral reinforcement matches the details and that all the reinforcing steel is of the size and length specified in the project plans. The inspector will also check that the reinforcing steel cage is tied properly. The reinforcing steel should not be installed into a pile until all the piles in a group have been driven, inspected, and approved in case a pile needs to be re-driven due to pile heave.

After the reinforcing steel has been installed into the pile and the installation is approved, concrete may be placed into the pile. The inspector will need ensure that the concrete for the pile is produced according to the approved concrete mix design. The concrete used for driven piles is usually a Class D concrete which is produced without any air entrainment. The air-entrainment is not necessary because the concrete in the pile will be entirely encased in the steel shell of the pile and the top of the concrete in the pile will in turn be encased in the concrete used for the pile cap.

MEASUREMENT AND PAYMENT

Refer to Subsection 508.04.01, "(Driven Piles) (Method of Measurement) Measurement" and Subsection 508.05.01, "(Driven Piles) (Basis of Payment) Payment", of the Standard Specifications and Chapter 13 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

509 - DRILLED SHAFT FOUNDATIONS

While drilled shaft foundations provide support similar to driven piles, the construction of drilled shafts differs significantly from driven piles. With drilled shafts the shafts are drilled or excavated; reinforcing steel cages are placed in the shaft excavation; and, concrete is placed in the shaft excavation, encasing the steel. Because drilled shafts can have a greater diameter than driven piles, drilled shaft foundations are used when a bridge or structure requires greater support or when using driven piles is impractical. Drilled shaft piles are also referred to as cast-in-drilled-hole (CIDH) piles, in the contract documents. (See Figure 47.)

Figure 47: Construction of a drilled shaft foundation with installation of a reinforcing steel cage

There are generally three methods used for the construction of a drilled shaft foundation. The chosen method of construction will be largely dependent on the anticipated and/or encountered geologic conditions:

DRY CONSTRUCTION METHOD

The dry construction method is generally the easiest method to perform as the work consists of drilling the shaft, cleaning the bottom of the shaft excavation, installing the reinforcing steel cage and placing the concrete.

WET CONSTRUCTION METHOD

The wet construction method is more complicated than the dry method and as a result, will be subject to additional requirements. In addition to the work prescribed under the dry method, the Contractor shall produce and maintain a slurry mixture that will be placed into the shaft excavation during drilling to maintain the stability of the sides of the shaft. This slurry will remain in constant circulation throughout the shaft excavation until the concrete displaces it from beneath. The Contractor shall monitor the slurry for certain characteristics during drilling and all the way through completion of the concrete when the slurry has been completely discharged from the shaft. As the slurry is being discharged, it will be contained and disposed of properly. For further requirements on disposal, refer to Subsection 107.14, "(Legal Relations and Responsibility to the Public) Disposal of Material Outside Highway Right of Way", of the Standard Specifications.

CASING CONSTRUCTION METHOD

The casing construction method is the most involved method of shaft construction as it requires all the procedures listed in the dry method (and in many cases the wet methods) of construction and requires the installation of a steel casing to a prescribed depth in order to maintain the stability of the shaft excavation. Then, as the concrete is being placed, the casing is extracted from the shaft excavation while keeping the bottom of the casing below the level of concrete. Extraction of the casing without displacing the reinforcing steel or interrupting the concrete placement, all while facilitating the circulation of the slurry mixture, results in a significant amount of congestion in the airspace directly above the drilled shaft. This operation is often further complicated when the casing is required to be removed in segments. The support for the reinforcing steel and the tremie for the concrete placement will need to be released briefly to facilitate removal of an individual casing segment from the area above the shaft. This procedure is carefully performed to prevent settling of the reinforcing steel cage and/or breaching of the concrete in the shaft beneath the slurry. With some effort, this procedure can be successful. The actual procedure should be discussed in depth at a pre-activity meeting prior to the beginning of drilled shaft construction.

Service providers are retained by the Department to perform integrity testing using crosshole sonic logging (CSL) or another approved method of integrity testing on drilled shaft foundations. Integrity testing assesses the quality of the concrete placed in drilled shaft foundations. CSL testing is the most commonly used method of integrity testing. CSL testing requirements are described in Subsection 509.03.14, "(Drilled Shaft Foundations) (Construction) Integrity Testing", of the Standard Specifications. Typically, in order to perform CSL testing, the installation of 2-inch diameter tubes in the concrete foundation is required. The tubes are secured to the inside of the foundation's reinforcing steel cage at regular spacing around the diameter of the cage before the cage is placed in the shaft excavation. After the concrete is placed and cured, the service provider performs CSL testing. CSL testing uses sonic waves with a transmitter in one tube and receiver in another tube. The velocity of the signal from the transmitter to the receiver determines the integrity of the concrete in the space between each tube. The transmitter and receiver are moved from tube to tube to establish a pattern of raypaths that give an overall picture around the diameter of the shaft as well as across the shaft. The number of possible raypaths increases with the diameter of the shaft and resulting number of tubes that are installed. Refer to the project plans to determine the actual number of tubes to be installed for the shaft being constructed.

BEFORE CONSTRUCTION

Before beginning work, the inspector and field testers will review the contract documents. Concrete used for drilled shaft foundations has special requirements detailed in Subsection 509.02.01, "(Drilled Shaft Foundations) (Materials) General", of the Standard Specifications. This specialized concrete, self consolidating concrete, has unique flowability characteristics that make it different from regular concrete. The Contractor shall submit a mix design to the Resident Engineer for approval by the Materials Division.

The Contractor performing the construction of the drilled shafts must be pre-qualified to perform drilled shaft construction and must provide a drilled shaft plan to perform the work specified. The Contractor submits their qualifications and drilled shaft installation plan before beginning the drilled shaft work. The Resident Engineer reviews the submittals for completeness, and then forwards them to the Materials Division for review and approval. For more information, refer to Subsection 509.01.02, "(Drilled Shaft Foundations) (Description) Qualifications of Drilled Shaft Contractors", and Subsection 509.01.03, "(Drilled Shaft Foundations) (Description) Submittals", of the Standard Specifications.

The approved drilled shaft installation plan that describes the key personnel, equipment, and proposed operations. The plan also includes safety and fall protection provisions. The inspector shall receive and review a copy of the approved drilled shaft installation plan.

The Contractor shall stakeout of the structure footing and excavates to grade before the shaft locations are staked out. Each pile is assigned a unique identifier, usually as part of the construction plan submittals. A drawing that shows pile locations and designations is prepared as a reference document. The inspector or survey crew chief will frequently check the Contractor's survey markings for accuracy.

DURING CONSTRUCTION

Regardless of the method of drilled shaft construction employed, each method will begin with the location and drilling or excavation of the shaft.

DRY CONSTRUCTION METHOD

If the drilled shaft is constructed using the dry construction method, the drilling will continue until the shaft reaches the design tip elevation. When the design tip elevation is reached, the bottom of the shaft is cleaned of any loose debris or accumulated ground water if present and the shaft is prepared for the installation of the reinforcing steel. If more than 1 foot of water accumulates in the bottom of the shaft over a 1-hour period, the wet method of drilled shaft construction is required.

WET CONSTRUCTION METHOD

If the drilled shaft is constructed using the wet method, the slurry mixture is introduced into the shaft excavation as soon as the drilling is underway or the wet condition is encountered. The slurry will be continuously circulated in the shaft excavation throughout the drilling process. The slurry mixture is run through a series of pumps and tanks that will allow the suspended particles to settle out of the slurry mixture as it is being circulated. Once the shaft is excavated to the design tip elevation, the bottom of the shaft is cleaned of any loose sediment or debris and the shaft is prepared for the installation of the reinforcing steel. The Contractor continues to circulate the slurry mixture even after the drilling operation is completed.

CASING CONSTRUCTION METHOD

If the drilled shaft is constructed using the casing method, the casing is lowered or driven into the excavation along with the drilling operation. The drill works inside the casing to cut and remove the soils in the shaft. Some types of casing installation use a machine, called an oscillator that twists segments of casing into the ground at the location of the drilled shaft. Once a segment of casing is installed, a device, called a clamshell is lowered into the casing and is used to extract the soil from within. After the clamshell reaches the bottom of the casing, another segment of casing is installed and driven. With either drilling or the clamshell, the process of driving the casing and extraction of the soil continues until the casing reaches the specified depth or the design tip elevation. Once the design tip elevation is reached, any loose debris are cleaned from the bottom of the shaft and the shaft is prepared for the installation of the reinforcing steel. If a slurry mixture is required for the casing method, the slurry is introduced according to the approved submittal or as directed and continuously circulated during the entire excavation period and through the completion of concrete placement.

During the drilling or excavation of the shaft, the inspector will continuously monitor the drilling or excavation and recording on NDOT Form 040-060 (Drilled Shaft Inspection Report) all times involved with drilling or excavation, the soil type, condition, color, depths at which each type of soil is encountered, ease of drilling or excavation, and any other pertinent observations.

Reinforcing steel is assembled into a cage that is lowered into the shaft excavation. The inspector will verify the appropriate sizes and number of reinforcing steel bars that are used and that the construction of the cage conforms to the contract documents, including the number and placement of longitudinal bars. Subsection 509.03.11, "(Drilled Shaft Foundations) (Construction) Reinforcing Steel Cage Construction and Placement", of the Standard Specifications require that the Contractor shall tie every other reinforcing steel intersection, with double tied and double wrapped wires. When the cage is complete, the inspector will evaluate the construction of the cage to confirm that the cage will not deform when placed in the shaft excavation. Additional reinforcement may be required to stiffen the cage and prevent it from twisting or bending during lifting and placement of the completed cage. These internal stiffeners shall be removed after the cage is place if they interfere in any way with the insertion of the concrete placement tube, or tremie, or in any way interfere with the placement of concrete into the drilled shaft. If Crosshole sonic logging (CSL) tubes are required, the inspector will ensure that the tubes are installed according to the project plans and Subsection 509.03.14, "(Drilled Shaft Foundations) (Construction) Integrity Testing", of the Standard Specifications. These tubes should not be bent or damaged in any way during assembly, lifting, or placement of the reinforcing steel cage. In some cases, the Materials Division's Geotechnical Section may require the installation of additional devices that will be used to monitor or test characteristics of the drilled shaft upon its completion. The inspector will check the project plans to determine the location of any other devices to be attached to the reinforcing steel cage, such as added monitoring or testing equipment, spacers or rollers, or any other devices, prior to its placement into the shaft.

Before placement of reinforcing steel in the shaft excavation, the inspector will identify each cage to verify that the proper cage is placed in the correct shaft excavation. The reinforcing steel cage shall be lowered into the shaft excavation within 30 minutes of cleaning the bottom of the shaft excavation. The cage is supported in the shaft excavation until the concrete is completely placed. (During the placement, the cage cannot touch the bottom of the shaft.) Verify the elevation of the top of the cage, allowing for the appropriate cover between the steel and the top of the footing so that the ultimate elevation of the concrete is consistent with the project plans.

With the cage properly placed in the shaft excavation, the inspector ensures that material has not been dislodged from the sides of the shaft excavation. If any material is dislodged, the Contractor shall remove the material before placing concrete. Report any dislodged material and the measures taken to remove it on NDOT Form 040-060. Before concrete is placed, the Contractor fills the crosshole sonic log tubes with water, which helps to equalize the pressure in the tube with the pressure from the concrete.

With the shaft excavation and reinforcing steel cage inspected and approved, the inspector observes the concrete placement. Concrete placement must begin within 1 hour of cleaning the bottom of the shaft excavation. Using a tremie, or tube, the concrete must be placed concrete continuously from the bottom elevation to the top of the drilled shaft, and continue after the shaft excavation is filled until quality concrete is observed at the top of the shaft excavation. The discharge end of the tremie or tube is maintained at a depth of at least 5 feet in the fluid concrete throughout the placement operation. If placing concrete in the shaft according to the wet method or casing method with slurry, the head of concrete must remain below the slurry in the shaft as it is deposited into the shaft, effectively displacing the slurry from beneath as the concrete is placed into the shaft excavation. During placement of concrete, the slump flow is closely monitored. For additional requirements, refer to Subsection 509.02.01, "(Drilled Shaft Foundations) (Materials) General", of the Standard Specifications. After the concrete is placed, cure the exposed concrete surface. Refer to Part 2 of the *Field Testing Guide* for sampling and testing requirements.

Upon completion of a drilled shaft, work shall not begin on an adjacent shaft and no earthwork should be performed within 10 feet of the drilled shaft until at least 24 hours have passed. Work may begin on a shaft that is not adjacent to the recently completed shaft prior to the expiration of the 24-hour period, provided the work will not cause disturbance to the new shaft.

Integrity testing using the crosshole sonic logging tubes will be performed within 3 days of the completion of concrete placement for the shaft. Representatives from the Materials Division's Geotechnical Section, or service providers retained by the Department, perform the crosshole sonic log testing. The frequency of the testing is based on the size and type of the drilled shaft. The Resident Engineer will coordinate the integrity testing through the Materials Division. If any shaft has unacceptable crosshole sonic log test results, the Contractor shall submit a plan for corrective action.

The inspector will complete NDOT Form 040-060 for each drilled shaft. This form provides a written record of activities, observations, and progress made during the construction of drilled shaft piles. During placement of concrete into the drilled shaft, the inspector will also use the Drilled Shaft Concrete Volumes worksheet and information provided by the Contractor to monitor concrete volumes in drilled shaft foundations. This worksheet is part of NDOT Form 040-060 and can be found on the back of the form. Contact the Construction Division's Quality Assurance Section for further guidance on filling out NDOT form 040-060.

MEASUREMENT AND PAYMENT

Refer to Subsection 509.04.01, "(Drilled Shaft Foundations) (Method of Measurement) Measurement" and Subsection 509.05.01, "(Drilled Shaft Foundations) (Basis of Payment) Payment", of the Standard Specifications and Chapter 13 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

601 - PIPE CULVERTS: GENERAL

Proper drainage affects a roadway's service life. In addition to providing for existing natural drainage channels, a roadway drainage system collects and disposes of surface runoff. Runoff that is collected from the roadway is carried to natural drainage channels or existing drainage systems within the right of way. In areas with groundwater that may affect the roadway structural section, groundwater drainage systems are incorporated into the design.

During the design phase, drainage systems are designed to accommodate existing drainage channels and roadway runoff. In urban areas, surface drainage is conveyed underground through a storm drain system. A storm drain system is a network of drop inlets, catch basins, pipes and box culverts. Because drainage flows by gravity, culvert grades and elevations must be closely controlled and monitored in storm drain systems. Conditions can change from the time when the design was completed until the start of construction. The Resident Engineer will evaluate the adequacy of the designed drainage systems in relation to current field conditions and carefully review the contract documents, giving special attention to environmental and right-of-way provisions. The contract documents reflect the environmental, right-of-way, and other NDOT commitments made before work begins.

To identify areas where drainage may be a concern, the Resident Engineer should observe drainage flows during storms. Observing the flow characteristics of the stormwater runoff allows the Resident Engineer to assess the adequacy of existing and proposed drainage improvements. The Department periodically constructs drainage facilities for other governmental entities. Because drainage facilities on a project are part of a larger, more complex drainage system, the Design Division's Hydraulics Section plays an active role in decisions affecting drainage facilities. The Resident Engineer will discuss any concerns or proposed changes for approval with the Design Division Hydraulics Section.

Culverts used in roadway projects are constructed of several types of materials, such as concrete, steel and plastic. (See Figure 48, Figure 49, Figure 50 and Figure 51.) Common types of culverts used on NDOT contracts are nonreinforced and reinforced concrete pipe, corrugated metal pipe, plastic pipe and metal arch pipe. Culverts may have a variety of treatments at the ends of the culvert. Examples include end sections, headwalls, manholes, drop inlets or riprap basins.

Figure 48: Reinforced concrete pipe

Figure 49: Corrugated metal pipe

Figure 50: Plastic pipe

Figure 51: Metal arch pipe

Construction and installation of culverts include excavation of trenches. Trench excavation may require shoring or sloping back of the trench walls to reduce the risk of the trench collapsing. If the excavation exceeds 4 feet in depth, shoring is required or the sides of the trench shall be sloped back to the angle of repose. Confirm that required shoring or sloping has been completed before entering a trench. If the trench dimensions require shoring or sloping back the trench walls for safety, the inspector will monitor the Contractor's operations to verify that activities comply with the approved safety plan. The Contractor shall comply with the approved safety and trenching plan and Occupational Safety and Health Administration (OSHA) regulations.

BEFORE CONSTRUCTION

One of the first items of work relating to drainage is staking the culverts and other drainage improvements by the survey crew. Refer to the project plans and Chapter 14 of the *Documentation Manual* for more information.

The objectives of any drainage improvement are to perpetuate existing drainage conditions and to accommodate modified flows resulting from the roadway project. Typically, the flow line grade and alignment of a culvert should be the same as the channel that it replaces. To meet the objective of perpetuating an existing drainage channel, the grade of a culvert may be changed, extended, shortened or realigned.

Based on information in the project plans, and modifications required due to field conditions, the survey crew will stake the culverts. If the survey stakeout results in changes to pipe lengths, the Resident Engineer will inform the Contractor of the modified pipe length quantities for each culvert.

If field conditions require modifying a culvert, the following flow characteristics should be considered:

- A steep grade tends to allow debris and sediments to pass easily through the culvert, but it can increase abrasion along the flow line and increase erosion potential at the outlet.
- A flat grade tends to allow sediment to deposit in the culvert.
- The transition between an inlet channel and a culvert should be smooth without constricting the flow.
- Disturbance of vegetation and riprap may increase erosion around the culvert.
- The channel at the outlet of the culvert is susceptible to damage, even under normal flow.
- Modifying culvert inlets or outlets may require additional channel protection. Protection may extend upstream or downstream. Adjustments to the flow line require approval of the Design Division's Hydraulics Section.

Before culvert installation begins, the inspector will review the contract documents for the location, type and size of culverts, and the bedding required. Verify that the pipe bedding and backfill materials have been source accepted.

When inspecting culverts, consider the following:

- Upon delivery of material, verify receipt of proper material certifications. Inspect pipe material for cracks, defects and damage that may have occurred during shipping.
- Obtain samples, if required, as indicated in Part 2 of the *Field Testing Guide*.
- Check pipes for:
    - Proper class, type, and size.
    - Proper thickness, gauge, and schedule.
    - Proper coating and lining.
    - Proper lengths of sections.
- Review the safety requirements for trenching operations and confined space entry.
- Do not enter manholes, inlets, vaults, trenches or other confined spaces without taking the proper safety precautions.
- Check that manholes, inlets and pipes are properly staked.
- Verify that staked locations and elevations are appropriate for existing field conditions.
- For pipe extensions, verify that the end of the existing pipe is in such condition that the extension can be firmly connected. If end of the existing pipe is damaged, a length of that pipe may need to be cut off to get to a point where the extension can be firmly connected. If a segment of the existing pipe must be cut off, the length that was cut off shall be added to the length of the extension.

- Verify that the Contractor has taken steps to determine the exact location of all underground utilities and has resolved all utility conflicts before doing work that may damage such facilities.

As with all elements of a construction contract, safety is a Department priority. Construction and installation of culverts includes excavation of trenches that may require shoring or sloping back the trench walls to reduce the risk of trench collapses. Culvert installations frequently include movement of materials such as concrete and metal pipes being hoisted. The Resident Engineer and crew should review the Contractor's safety plan related to trenching and excavations and review its requirements. Discuss any concerns or questions about the Contractor's safety plan with the Contractor's safety officer.

DURING CONSTRUCTION

Installation of culverts includes excavation of material to construct the trench, preparation of the trench, placement of bedding material, placement of culvert and backfilling. If a culvert is located in an embankment, the embankment is constructed and then the trenching operation is performed.

TRENCHING

If the trench dimensions require shoring or laying back the trench walls for safety, the inspector will monitor the Contractor's operations to verify that activities comply with the approved safety plan. During the excavation operations, the inspector will frequently check the survey grade stakes. The inspector will discuss any discrepancies with the survey crew. The inspector will also review the requirements of the contract documents for excavating culverts. The inspector will check the excavation for correct depth, width and alignment. Verify that the bottom of the trench has been properly graded and compacted. Obtain compaction test results from the tester to verify that the required compaction is achieved prior to pipe installation. For additional information, refer to "206 - Structure Excavation", in this chapter.

BEDDING

The quality of the bedding directly affects the load supporting capacity of a culvert pipe. Bedding material for culverts must conform to the requirements of contract documents. The inspector will check the type and depth of bedding in accordance with the contract documents. Culvert installation begins at the downstream end unless otherwise specified in the contract documents. When installing culvert pipe, check that the entire length of pipe rests in contact with the bedding material at the proper flow line. Frequently check the alignment and elevation, and be exact in checking grade and alignment for sewer pipes. Because sewer pipes are commonly gravity flow and have a low flow rate, they will have specific elevation and grade requirements.

LAYING PIPE

Culvert pipe joints must be placed in conformance with the contract documents. Typically, the direction of joint laps is placed so that the bell or grooved end of concrete pipe or the outside laps of metal or plastic pipe are placed in the upstream direction. Placing the joints in this position improves the water tightness of the joint. Check that joints are properly sealed or banded and snug. Verify that joints are grouted where required. Any holes in the pipe material that were used for lifting shall be plugged by an approved method. The inspector will check in-place pipe for damage before backfilling and before accepting the work, and will confirm that any damage to coating or lining is properly repaired.

BACKFILL

The material around and above the pipe and the manner in which it is placed and compacted influences the culvert's ability to perform as designed and to achieve its design life. In general, the greater the compaction of the backfill under the haunches and along the sides of the pipe, the less the pipe will deform under load. Consistent and uniform compaction reduces settlement. (Settlement of the backfill can result in an increased transfer of embankment load onto the pipe.) Increasing loading of the pipe could deform the pipe, which weakens the pipe and causes separation of the pipe joints.

For these reasons, the backfill or embankment material adjacent to the pipe should contain material free from large rocks and lumps, and contain sufficient fines so it compacts to a relatively impervious mass. It shall be compacted to a density and width in accordance with Subsection 206.03.01, "(Structure Excavation) (Construction) General", of the Standard

Specifications. Care must be taken to obtain proper compaction under the haunches of the pipe and to place and compact the backfill uniformly on both sides of the culvert. Firm support must be obtained. Over-tamping of the haunches can cause the pipe to lift out of position. To ensure the pipe to performs as designed, backfilling is performed in accordance with Subsection 207.03.03, "(Backfill) (Construction) Placing and Compacting at Culverts", of the Standard Specifications. For additional information, refer to "207 - Backfill", in this chapter.

The inspector verifies that the backfill material is placed and fully compacted in lifts of the required thickness. This operation shall be performed equally and simultaneously on both sides of the pipe. The area under the haunches of the pipe is critical during the backfilling and compaction operation. (See Figure 52.)

Figure 52: Pipe backfill

Note that the required compaction must be obtained prior to placing successive lifts. Observe the operation to confirm that the compaction method does not cause pipe damage or displacement. The inspector will request compaction testing whenever the Contractor's compaction methods change or appear inadequate.

The construction method of the embankment around and above the culvert largely affects the load that will be imposed on a culvert pipe. The Standard Plans show the maximum fill height allowed over various sizes and types of pipe. Equipment is not permitted to operate across the culvert until the embankment has been constructed to a safe minimum depth above the culvert, typically 2 feet. Concrete headwalls should be constructed as soon as the embankment is constructed to the height of the headwall so the ends of the culvert are protected during storms.

PIPE JACKING

Pipe jacking is a technique for installing underground pipelines and culverts, usually concrete pipes, by jacking, or pushing, pipes through the ground. Pipes can be jacked with little or no surface disruption. For large diameter pipes, excavation takes place as the leading edge of the pipe is pushed through the ground.

To install a pipeline using this technique, construct jacking pits at the beginning and ending points. The dimension and construction of a jacking pit depends on the equipment selected by the Contractor.

A thrust wall is constructed to provide a support against which to jack. High-pressure hydraulic jacks provide the force required for jacking concrete pipes. The ram diameter and stroke of the jack may vary according to a Contractor's technique. To ensure that the jacking forces are distributed around the circumference of a pipe being jacked, a thrust ring is used based on the number of jacks being used. The jacks are interconnected hydraulically to ensure that the thrust from each is the same. The number of jacks used may vary because of the pipe size, the strength of the jacking pipes, the length to be installed and the anticipated frictional resistance.

During the jacking operation, the pipe may veer off-line. (The Contractor shall monitor the pipe alignment.) Check the roadway surface for signs of upheaval or failure, and/or require immediate corrective action. When the contract documents designate jacking, proposed alternative methods require written approval by the Resident Engineer in coordination with the Design Division's Hydraulics Section.

Upon completion of the work, the inspector performs a final inspection on the pipe and checks for:

- Debris or obstructions.
- Cracks exceeding specified widths and/or depths.
- Properly sealed joints (especially around manholes).
- Pipe invert free of sags or high points.
- Pipe ends or stubs properly plugged.
- Connections and hookups properly made.
- Catch basins, inlets, and drains connected properly.
- Manhole frame and covers properly installed.
- Patching and crack repairs completed.

MEASUREMENT AND PAYMENT

Refer to Subsection 601.04.01, "(Pipe Culverts - General) (Method of Measurement) Measurement" and Subsection 601.05.01, "(Pipe Culverts - General) (Basis of Payment) Payment", of the Standard Specifications and Chapter 14 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

603 - REINFORCED CONCRETE PIPE

NOTE: "601 - Pipe Culverts: General"*, in this chapter, addresses pipe culverts as it applies to reinforced concrete pipe. The guidelines in this section clarify the installation of reinforced concrete pipe.*

Reinforced concrete pipe may have circular or elliptical cross-sections. The contract documents will specify the type of reinforced concrete pipe. When non-reinforced concrete pipe is specified, follow the guidelines for reinforced concrete pipe.

The following are the basic shapes of reinforced concrete pipe joints:

- Modified tongue and groove
- Tongue and groove
- Bell and spigot

In general, use a rubber gasket for sealing concrete surfaces with opposing shoulders on both ends, such as the bell and spigot and the modified tongue and groove joints. Use preformed flexible joint sealants or mortar joints where lesser joint performance is required, or where the product shape dictates the type of seal. Joints using flexible sealants typically perform as a soil-tight system unless the project plans identify and alternate joint design.

BEFORE CONSTRUCTION

Before work begins, review the following guidelines:

- At the Contractor's option and expense, the Contractor can use pipe that exceeds specified strength requirements.
- Inspect the pipe for damage. Minor hairline cracks and chips are not reasons for rejecting the pipe. However, the following problems are unacceptable:
  - Pipe with cracks through the wall
  - Exposed reinforcing steel
  - Damaged bells, spigots, or joint grooves
- Monitor the Contractor's method of handling pipe to confirm that the pipe is not damaged.
- Before structure excavation, the Contractor constructs embankments according to the contract documents. Before the Contractor installs pipe, the inspector determines the acceptability of excavations and any required bedding. For pipes with bell ends, confirm that the excavation and bedding uniformly support the pipe.
- For elliptical pipe, the top of the pipe must be marked.
- Store rubber gaskets in a cool place away from sunlight. If lubrication is required before installation, the Contractor shall follow the manufacturer's instructions.
- Before using joint mortar, the mortar aggregate must be approved.
- Ensure that reinforced concrete pipe is fabricated by a certified manufacturer.

DURING CONSTRUCTION

During reinforced concrete pipe installation, the inspector will:

- Confirm that pipe of the specified size, type, and class is installed at the proper locations.
- Observe that pipes are placed with belled ends upstream. Where possible, lay pipes from lower to higher elevations. Laying pipe from the downstream end facilitates tight joints, particularly on steep grades. When extending an existing pipe downstream, the new pipe can be placed beginning at the existing pipe, continuing downstream, or beginning downstream and connecting at the existing pipe with a special connecting structure.
- When a section of pipe is placed, verify that the pipe elevation and alignment conforms to the project plans.
- Ensure that joints have smooth, uniform interior surfaces. Unless otherwise required, joints must be sealed completely with mortar, rubber gaskets, resilient materials or liquid sealing materials. Reject gaskets that have cracks or splits.
- Before the Contractor places the backfill, confirm that lift holes are plugged.
- Use mortar within 30 minutes after adding water.
- Refer to "207 - Backfill", in this chapter, for additional guidance on backfill.
- Water cannot contact the interior of the pipeline until joints containing mortar have aged 24 hours.
- Require backfilling in a manner that will not damage joints.

- For siphons and pressure pipes, perform hydrostatic testing in accordance with Subsection 603.03.04, "(Reinforced Concrete Pipe) (Construction) Siphons and Pressure Pipe", of the Standard Specifications before backfilling. Repair all leaks and other defects. If the pipe sweats but no flow develops, repair is not needed.
- Require minimum cover for construction loads, as shown in the contract documents.
- Protect pipes from damage during construction operations.
- Do not permit the pipe to be dropped onto the bedding to consolidate and mold the bedding. (This is commonly called battering, which is not allowed because of the potential to damage the pipe.)
- After the pipes have been installed and before the work is complete, verify that the pipes are clean and free of dirt and other debris.

MEASUREMENT AND PAYMENT

Reinforced concrete pipe is manufactured in standard lengths. The length of pipe measured for payment is the total length necessary to be placed before cutting, if cutting is necessary. If culvert end sections are incorporated into the work, structure excavation and backfill associated with the end sections are not paid, but included in the cost of the end section.

Refer to Subsection 603.04.01, "(Reinforced Concrete Pipe) (Method of Measurement) Measurement" and Subsection 603.05.01, "(Reinforced Concrete Pipe) (Basis of Payment) Payment", of the Standard Specifications and Chapter 14 of the *Documentation Manual* for additional measurement/payment guidelines and related instructions.

604 - CORRUGATED METAL PIPE AND METAL ARCH PIPE

NOTE: "601 - Pipe Culverts: General"*, in this chapter, addresses pipe culverts as it applies to reinforced concrete pipe. The guidelines in this section clarify the installation of corrugated metal pipe and metal arch pipe.*

Corrugated metal pipe and metal arch pipe may have circular or near-circular cross-sections. The contract documents will specify the type of corrugated metal pipe and metal arch pipe. When using slotted corrugated pipe to allow surface drainage to enter the pipe, install it flush with the top of dense-grade pavement before placing the open-graded surface.

BEFORE CONSTRUCTION

Before work begins, the inspector will:

- Inspect the pipe for damage. Damaged corrugated metal pipe should not be incorporated into the work.
- Monitor the Contractor's method of handling pipe to confirm that the pipe is not damaged.
- Before structure excavation, the Contractor constructs embankments in accordance with the contract documents. Before the Contractor installs pipe, determine the acceptability of excavations and any required bedding.
- If rubber gaskets are used, verify that the Contractor stores the gaskets in a cool place away from sunlight.
- Verify information on the pipe matches the information on the certifications.

DURING CONSTRUCTION

During corrugated metal pipe installation, the inspector will:

- Confirm that pipe of the specified size, type, and class is installed at the proper locations.
- Where possible, lay pipes from lower to higher elevations. Laying pipe from the downstream end facilitates tight joints, particularly on steep grades. When extending an existing pipe downstream, the new pipe is connected to the existing pipe, continuing downstream.
- When placing a section of pipe, verify that the elevation and alignment of the pipe conforms to the survey crew's stakeout.
- Confirm that corrugated metal pipe sections are joined with a coupler that is firmly bolted in place.
- For additional guidance on backfill, refer to "207 - Backfill", in this chapter.
- Require backfilling in a manner that will not displace joints.
- When used as siphons, corrugated metal pipe seams are soldered and couplings incorporate a rubber or other approved gasket material. Fill the siphon pipe with water and repair leaks before backfilling.
- Verify the required minimum cover before any loads are placed on the pipe.
- Ensure that pipes are protected from damage during construction operations.
- After the pipes have been installed and before the work is complete, verify that the pipes are clean and free of dirt and other debris. Verify that the pipe has not been deformed.

MEASUREMENT AND PAYMENT

Corrugated metal pipe and metal arch pipe are manufactured in standard lengths. The length of pipe measured for payment is the total length necessary to be placed before cutting (if necessary). If culvert end sections are incorporated into the work, structure excavation and backfill associated with the end sections are not paid, but included in the cost of the end section.

Refer to Subsection 604.04.01, "(Corrugated Metal Pipe and Metal Arch Pipe) (Method of Measurement) Measurement" and Subsection 604.05.01, "(Corrugated Metal Pipe and Metal Arch Pipe) (Basis of Payment) Payment", of the Standard Specifications and Chapter 14 of the *Documentation Manual* for additional measurement/payment guidelines and related instructions.

605 - PLASTIC PIPE

NOTE: "601 - Pipe Culverts: General"*, in this chapter, addresses pipe culverts as it applies to reinforced concrete pipe. The guidelines in this section clarify the installation of plastic pipe.*

Plastic pipe can have a solid wall or it can be perforated to allow water to enter or exit the pipe. The contract documents will specify the type of plastic pipe.

BEFORE CONSTRUCTION

Before work begins, the inspector will:

- Inspect the pipe for damage. Do not incorporate damaged plastic pipe into the work.
- Review manufacturer's recommendations on exposure of pipe to the elements.
- Monitor the Contractor's method of handling pipe to confirm that the pipe is not damaged.

Before structure excavation, the Contractor constructs embankments in accordance with the contract documents. Before the Contractor installs pipe, determine the acceptability of excavations and any required bedding.

DURING CONSTRUCTION

During plastic pipe installation, the inspector will:

- Verify that pipe of the specified size, type, and class is installed at the proper locations.
- Lay pipes from lower to higher elevations.
- When a section of pipe is placed, observe that the elevation and alignment of the pipe conforms to the survey crew's stakeout.
- For additional guidance, refer to "207 - Backfill", in this chapter.
- Require backfilling in a manner that will not displace plastic pipe or cause the pipe to float.
- Require minimum covers, as required by the manufacturer or as shown in the contract documents.
- Protect pipes from damage during construction operations.

After the pipes have been installed and before the work is complete, verify that the pipes are clean and free of dirt and other debris, and are not damaged.

MEASUREMENT AND PAYMENT

The length of pipe measured for payment is the total length necessary to be placed before cutting (if necessary). If plastic pipe end sections are incorporated into the work, structure excavation and backfill associated with the end sections are not paid, but included in the cost of the end section.

Refer to Subsection 605.04.01, "(Plastic Pipe) (Method of Measurement) Measurement" and Subsection 605.05.01, "(Plastic Pipe) (Basis of Payment) Payment", of the Standard Specifications and Chapter 14 of the *Documentation Manual* for additional measurement/payment guidelines and related instructions.

606 - STRUCTURAL PLATE CULVERTS

*NOTE: The guidelines in "*601 - Pipe Culverts: General*" and "*604 - Corrugated Metal Pipe and Metal Arch Pipe*", in this chapter, also apply to structural plate culverts.*

When the size and shape requirements of a culvert exceed the capabilities of corrugated metal pipe, structural plate culverts can be used. (See Figure 53.)

Figure 53: Structural plate culvert

Structural plate culverts are manufactured and transported to the job site where the components are assembled to construct the culvert. Structural plate culverts are fabricated based on the requirements of the contract documents.

The Contractor develops shop drawings based on the requirements of the contract documents. The Contractor submits the shop drawings to the Resident Engineer. The Resident Engineer submits the shop drawings to the Structures Division for review and approval. Based on the approved shop drawings, the structural plate culvert is manufactured. The manufacturer provides assembly instructions showing the position of each plate and assembly sequence. The inspector will review the contract documents relating to the structural plate culvert. Verify that anchorage assemblies are installed in accordance with the project plans and the manufacturer's recommendations.

BEFORE CONSTRUCTION

Refer to the corresponding section of "601 - Pipe Culverts: General" and "604 - Corrugated Metal Pipe and Metal Arch Pipe", in this chapter, for guidelines.

DURING CONSTRUCTION

Refer to the corresponding section of "601 - Pipe Culverts: General" and "604 - Corrugated Metal Pipe and Metal Arch Pipe", in this chapter, for guidelines.

MEASUREMENT AND PAYMENT

The length of structural plate culvert measured for payment is the average of the top and bottom centerline lengths.

Refer to Subsection 606.04.01, "(Structural Plate Culverts) (Method of Measurement) Measurement" and Subsection 606.05.01, "(Structural Plate Culverts) (Basis of Payment) Payment", of the Standard Specifications and Chapter 14 of the *Documentation Manual* for additional measurement/payment guidelines and related instructions.

607 - UNDERDRAINS

NOTE: "601 - Pipe Culverts: General"*, and other related sections in this chapter pertaining to the specific pipe material being used, also apply to underdrains.*

Underdrains are pipes that intercept underground flow and seepage to drain the roadway structural section. The most common use of underdrains is to intercept subsurface water moving toward the roadway. A system of interconnected underdrains can be used to remove the groundwater when drainage of a large area is necessary. Typically, a system of interconnected underdrains may include a drain backfill with a geotextile fabric to prevent sediment from entering the underdrains. Cleanouts are constructed at regular intervals and other locations, such as junctions. Cleanouts provide access to the underdrains for maintenance.

BEFORE CONSTRUCTION

Refer to the corresponding section of "601 - Pipe Culverts: General", in this chapter, for guidelines.

DURING CONSTRUCTION

Refer to the corresponding section of "601 - Pipe Culverts: General", in this chapter, for guidelines.

MEASUREMENT AND PAYMENT

Pipe connector pieces, such as bends, wyes and tees, are measured as pipe along centerlines and included in the quantity of underdrain pipe length.

Refer to Subsection 607.04.01, "(Underdrains) (Method of Measurement) Measurement" and Subsection 607.05.01, "(Underdrains) (Basis of Payment) Payment", of the Standard Specifications and Chapter 14 of the *Documentation Manual* for additional measurement/payment guidelines and related instructions.

608 - DOWNDRAINS

*NOTE: The guidelines in "*601 - Pipe Culverts: General*", in this chapter, also apply to downdrain pipes. Refer to the contract documents regarding the type of inlet and outlet structure for each downdrain.*

Downdrains are drainage systems that convey water down roadway slopes in a manner that prevents slope erosion. Downdrains are constructed to allow drainage from fill embankments, benches in cut sections, and other steep or long slopes. Downdrains are typically placed near bridges to remove runoff from the roadway before reaching the structure. A downdrain system consists of a catch basin (embankment protector), downdrain pipe and anchors, end section and riprap. Downdrain placement is important to ensure that drainage is collected and passed down the slope. Metal corrugated pipe and plastic pipe are the most commonly used downdrain pipes. Downdrain pipes are constructed so that the outlet end of the pipe extends to or beyond the toe of the slope to prevent erosion. Observe that anchorage assemblies are installed according to the project plans and the manufacturer's recommendations.

BEFORE CONSTRUCTION

Refer to the corresponding section of "601 - Pipe Culverts: General", in this chapter, for guidelines.

DURING CONSTRUCTION

Refer to the corresponding section of "601 - Pipe Culverts: General", in this chapter, for guidelines.

MEASUREMENT AND PAYMENT

The length of downdrain pipe measured for payment is the total length placed. Structure excavation, backfill, and riprap are not measured for payment in downdrain systems, but are included in the cost of other items. Pipe connector pieces are not directly paid for, but are included in the quantity of underdrain pipe length. Anchor assemblies are paid individually.

Refer to Subsection 608.04.01, "(Downdrains) (Method of Measurement) Measurement" and Subsection 608.05.01, "(Downdrains) (Basis of Payment) Payment", of the Standard Specifications and Chapter 14 of the *Documentation Manual* for additional measurement/payment guidelines and related instructions.

609 - INLETS AND MANHOLES

Catch basins, manholes and inlets are structures that connect to pipes and culverts. Section 609, "Inlets and Manholes", of the Standard Specifications, describes the requirements of materials and construction. Unless otherwise specified in the contract documents, catch basins, manholes and inlets may be precast or cast-in-place. The traffic control requirements of the contract influence the structure type selection, construction materials, and construction method. For example, if disruption of traffic must be kept to a minimum, pre-cast structures and quick-setting concrete could be used to reduce construction time and allow traffic to return to the roadway.

BEFORE CONSTRUCTION

Before work begins, manholes and inlets, the inspector will:

- Review the contract documents

- Verify existing drainage conditions
- Check that the structures are staked at the proper location and elevation.
- Verify submittal of the manufacturer's installation instructions.
- Review safety requirements for trenching operations and confined space entry. Do not enter manholes, inlets, vaults, trenches, or other confined spaces without taking the proper safety precautions.
- Conduct periodic field inspections at the precast yard to verify that structures are constructed as detailed in the project plans. Upon delivery of precast structures, verify receipt of proper material certifications. Check the type and dimensions of precast items for conformance. Where applicable, check the spacing of stair rungs for compliance. Pay particular attention to defects and damage that may have occurred during shipping.
- Where cast-in-place structures are used, check forms and reinforcing steel for proper condition and dimension.
- Verify the Contractor has provided all survey tie records, including permanent reference ties, to all covers to be adjusted and submits the documentation to the Resident Engineer before paving or making any adjustments.
- Clearly mark frames and matching lids as matched pairs to ensure that each lid is placed on its matching frame.

DURING CONSTRUCTION

During construction of catch basins, manholes and inlets, the inspector will:

- Verify receipt of proper certificates of compliance.
- Check pipe invert and flow-line elevations.
- Provide a smooth flow line between manholes and pipes. Check that a watertight union with pipes is achieved. Where precast sections are used, check that clean joints are constructed. Verify the proper use of concrete adjustment rings and mortar to make field adjustments.
- Check for proper dimension, formwork, concrete placement and curing.
- Check grates for acceptability with respect to type, dimension, orientation and galvanization. Grates and their matching frame must be delivered to the job site together. Grates must rest securely on their frames without rocking.
- Check that the type, label, dimension and utility company marking of manhole covers are in accordance with Subsection 609.03.01, "(Inlets and Manholes) (Construction) General", of the Standard Specifications. Where located within pavements, check the slope and elevation of covers.
- When adjusting existing covers:
  - Verify that adjustments are made by one of the methods described in Subsection 609.03.02, "(Inlets and Manholes) (Construction) Adjusting Manhole and Valve Covers", of the Standard Specifications.
  - Confirm that frames and lids are installed as matched pairs.
  - Verify that the material around the structure has been compacted prior to placing concrete for collars.
  - Replacement collars must be the same diameter as the original collar. If a smaller diameter collar is used, the structural section must be replaced. The patched roadway structural section must match the thickness of the adjacent section, prior to placement of the smaller diameter collar.

- For mortar or grout requirements, review the Qualified Products List (QPL) and Subsection 609.03.02, "(Inlets and Manholes) (Construction) Adjusting Manhole and Valve Covers", of the Standard Specifications. Verify that any needed mortar repairs and grouting around pipe and grade rings are properly performed.
- Verify concrete and reinforcement in the manhole collars comply with contract documents.
- Concrete patching material must be approved for use.
- Obtain local agency or utility company acceptance after covers are adjusted.

MEASUREMENT AND PAYMENT

Because third parties may reimburse the Department for the costs of manholes or manhole adjustments, enter the owner and agreement number in the Inspector Daily Report (IDR).

Refer to Subsection 609.04.01, "(Inlets and Manholes) (Method of Measurement) Measurement" and Subsection 609.05.01, "(Inlets and Manholes) (Basis of Payment) Payment", of the Standard Specifications and Chapter 18 of the *Documentation Manual* for additional measurement/payment guidelines and related instructions.

610 - RIPRAP

Erodible slopes within the right-of-way are typically treated with an erosion control measure. A common type of erosion control is riprap. (See Figure 54.)

Figure 54: Riprap

Riprap is the careful placement of relatively large stone on the erodible slope. Riprap is also used at culvert inlets and outlets to protect natural ground from erosion and as a means for dissipating energy from flowing water. Because conditions that require riprap are variable, different types or classes of riprap are required. The classes of riprap are described in Subsection 719.03.01, "(Riprap) (Physical Properties and Tests) Stone for Riprap", of the Standard Specifications. For additional erosion control protection, riprap may be grouted.

BEFORE CONSTRUCTION

Before construction begins, the inspector will:

- Review the contract documents with respect to the location, limits, and type of material required. Pay particular attention to the nominal size and material requirements of the stone, and placement depth.
- Review the requirements for riprap with respect to nominal size, shape, specific gravity, gradation, abrasion resistance. To reduce the likelihood of riprap stones moving under flowing water, specific gravity of the riprap is specified. The inspector will confirm the specific gravity of the riprap to be used by verifying that the source of the riprap has been approved. Visually observe the required material samples from the material source and job site in accordance with

Subsection 610.02.01, “(Riprap) (Materials) General”, of the Standard Specifications. Where the material is suspect, request lab results for verification or require the Contractor to provide the necessary equipment for gradation testing.

- Verify the acceptability of the slope after it is prepared, including the bedding for riprap if required. Check the excavation for the toe or cut-off wall, where required, to confirm that it conforms to the lines designated in the project plans.

DURING CONSTRUCTION

The stone for riprap is generally placed and spread using a combination of mechanical and hand methods. Before the riprap is placed, observe the placement of bedding material to confirm that the bedding is placed as stated in the contract documents. The Contractor shall place riprap so that it is tight, stable, and closely conforms to the details shown in the project plans. Verify the depth of the riprap. Regardless of the Contractor’s placement method, the final surface should be relatively smooth with interlocking faces of adjacent stones. Riprap is typically placed in a single layer by a means that does not cause segregation.

MEASUREMENT AND PAYMENT

Refer to Subsection 610.04.01, “(Riprap) (Method of Measurement) Measurement” and Subsection 610.05.01, “(Riprap) (Basis of Payment) Payment”, of the Standard Specifications and Chapters 13 and 14 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

611 - CONCRETE SLOPE PAVING

Concrete slope paving is used primarily for erosion control and is typically used on slopes around major structures. Concrete slope paving is typically a Class A or a Class AA Portland cement concrete with fiber reinforcement. Materials must meet the requirements outlined in Section 501, “Portland Cement Concrete” and Subsection 706.03.04, “(Aggregates for Portland Cement Products) (Physical Properties and Tests) Grout and Mortar Aggregate”, of the Standard Specifications. For further guidance on concrete inspection, refer to “501 - Portland Cement Concrete”, in this chapter.

BEFORE CONSTRUCTION

Before concrete slope paving begins, the inspector will:

- Review the contract documents. Pay particular attention to the location, limits, depth, and type of slope paving required.
- Review “501 - Portland Cement Concrete”, in this chapter.
- The Contractor shall have an approved mix design for concrete used in the slope paving. The concrete materials, including reinforcing fibers and color pigmentation, are described in the contract documents. Check the required materials for compliance, including required material certifications.
- Confirm that the area to receive slope paving is properly graded, compacted, and free of unsuitable materials. Check the toe or cut-off wall excavation for conformance to contract documents. (See Figure 55.)

Figure 55: Slope paving cut-off wall excavation

- Where unsuitable soil material is encountered, it may be necessary to replace the material. The grading of the slope may need to be adjusted in the field to match the ditch line or other boundaries. If the grade of the slope paving is adjusted in the field, the adjustment must be to flatten the grade, not to make the grade steeper.

DURING CONSTRUCTION

Review the contract documents to confirm that the Contractor mixes and places concrete as required. Where forms and reinforcement are required, check the conformance of forms and the placement of reinforcement. Verify that header boards are anchored. Monitor the depth of paving for compliance, and confirm that expansion joint materials, where required, are placed at the proper thickness and location.

Concrete consolidation is more effective with manual consolidation techniques, such as using a hand-tamping tool, rather than with mechanical internal vibrators, which may cause the wet concrete to flow out of the forms. Concrete slope paving is placed, starting at the bottom, moving up the slope. Verify compliance with requirements for slope paving during inclement weather, curing method and material, surface moisture, and curing period. The surface to receive concrete slope paving must be pre-wetted before placing concrete to reduce moisture loss in the concrete.

MEASUREMENT AND PAYMENT

Refer to Subsection 611.04.01, "(Concrete Slope Paving) (Method of Measurement) Measurement" and Subsection 611.05.01, "(Concrete Slope Paving) (Basis of Payment) Payment", of the Standard Specifications and Chapter 13 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

613 - CONCRETE CURBS, GUTTERS AND SIDEWALKS

Concrete curbs, gutters, and sidewalks are constructed on a solid foundation, typically base course material, which has been graded and compacted. Curb and gutter systems must be constructed so that water will not pond on the roadway or flow randomly over fill slopes. Materials must meet the requirements of Section 501, "Portland Cement Concrete", Section 502, "Concrete Structures" and Section 505, "Reinforcing Steel", of the Standard Specifications. Further guidance on concrete inspection is provided in "501 - Portland Cement Concrete", "502 - Concrete Structures" and "505 - Reinforcing Steel", in this chapter.

Curbs and gutters have two purposes: to direct drainage from the roadway, and to keep motorists on the roadway. A gutter guides water from rain and melted snow and ice into the storm drains, so that it does not accumulate on the surface. A curb channels the movement of traffic and redirects vehicles. Since curbs, gutters and sidewalks add to the cost of a road, they are generally limited to urban areas and are rarely built in rural areas except where certain drainage conditions warrant construction.

BEFORE CONSTRUCTION

If the Resident Engineer decides that curbs, gutters, or sidewalks are required, in addition to those shown in the project plans, the Resident Engineer should consult with the District Engineer and the Design Division. When adding curbs, gutters, or sidewalks, the Resident Engineer shall:

- Conform to the current policy of replacing existing facilities.
- Comply with requirements of the Americans with Disabilities Act (ADA).
- Comply with agreements.
- Ensure placement that provides proper drainage.
- Review right-of-way requirements.

Before curb, gutter, and/or sidewalk construction, the inspector will:

- Review the contract documents for details about the details concerning concrete curbs, gutters and sidewalks, and compare these details with conditions in the field.
- Discuss the construction operation with the Contractor. Determine whether the Contractor has considered the public's convenience. (The Contractor shall accommodate vehicle and pedestrian traffic in accordance with the contract documents). Advise the Contractor of any necessary modifications to the operation.
- Make a general check of the layout as staked, including the location of gutter depressions, curb ramps (wheelchair ramps), and driveways. Review the survey stakeout for accuracy.
- Mark and measure sections identified for removal before removal operations begin. Coordinate with the Contractor regarding removing sections to the nearest existing joint.
- Review the location and construction details of curb ramps that are designated in the project plans. Pay particular attention to the slope and surface finishing requirements of curb ramps. A textured surface finish or detectable warning devices are used, and field adjustments may be needed to meet slope requirements. Confirm that adjustments comply with ADA requirements.
- Review the locations of drainage structures to confirm that no new drainage structures are aligned with curb ramps.
- Verify that there is an approved concrete mix design for the curbs, gutters and sidewalks.
- Examine the base material to verify that:
  - The base has been constructed to the proper elevation and cross-section.
  - The foundation has been watered and compacted.
  - The appropriate density tests have been taken and meet the minimum density requirements.

- The base is wet immediately before placing concrete.

- Check that the Contractor has adequate materials on hand to cure and, as needed, protect the concrete during inclement weather.
- Verify that the Contractor has implemented appropriate measures for washing out concrete mixer trucks.
- Confirm that gutters will drain. When new curbs or gutters are to join existing facilities, confirm that the survey crew has checked the existing elevations against the planned grades.

DURING CONSTRUCTION

During curb, gutter, and/or sidewalk construction, the inspector will:

- Examine the forms to verify they:
  - Are placed to the lines and grades staked by the survey crew.
  - Are smooth on the side next to the concrete.
  - Have a true, smooth upper edge.
  - Are full depth.
  - Are rigid enough to withstand the pressure of fresh concrete without distortion. Replace forms that will not produce an end product within specified tolerances.
  - Are coated with form oil as specified.
- Confirm the Contractor adjusts the forms to remove any unsightly changes in vertical or horizontal alignment. Adjustment from staked grades is sometimes necessary near joints with existing curbs or sidewalks.
- Pay particular attention to how forms are set with respect to locations of drop inlets, curb ramps and driveways; make adjustments where needed.
- Finished appearance is important and is noticeable by the public. Do not directly use existing edges of pavement and sidewalks or existing pavement surfaces to establish a grade line for curbs.
- Where reinforcing steel is required, check spacing, clearance and supports for acceptability.
- Confirm that joints are scored as specified.
- If the contract documents require adhesive to bond the concrete to the pavement surface, verify that the Contractor cleans the pavement as specified and uses the required adhesive.
- Inspect the placement of weakened plane and expansion joints to confirm that they are constructed as specified.
- Observe concrete as it is placed. In the Inspector Daily Report (IDR), record the reasons for rejecting any concrete and the approximate amount rejected. Confirm that the Contractor does not allow concrete to segregate while being placed and consolidated in the forms. Stop the operation if the concrete requires patching with grout or mortar. Inform the Contractor to take corrective measures when concrete placement does not meet the requirements of the contract documents.
- When corrective measures are necessary, advise the Contractor and Resident Engineer, being specific as possible, and document the discussion in the IDR.

- Check that transverse expansion joints are located and constructed in in accordance with Subsection 613.03.04, “(Concrete Curbs, Gutters, and Sidewalks) (Construction) Curb and Gutter Joints” and Subsection 613.03.05, “(Concrete Curbs, Gutters, and Sidewalks) (Construction) Sidewalk Expansion Joints”, of the Standard Specifications. Joint types and locations should match those in adjacent concrete. Verify that edging is performed where required.
- Before the forms are removed, confirm that the Contractor uses the required trowel to finish the concrete surface as specified.
- Prohibit excessive finishing and addition of water. Confirm that the finishing is in accordance with the contract documents, and measure the finished product to verify it conforms to the required tolerances.
- Verify that concrete cures for the specified curing period. Verify an approved curing compound is applied to exposed concrete surfaces and that the rate and time of application is acceptable. Confirm that the Contractor complies with the provisions for concrete protection during cold weather.
- Do not begin form removal and backfill until the concrete is strong enough to prevent damage. Confirm that the edges are adequately shouldered. Watch for damage to the concrete during the backfill operation.
- Verify that the Contractor does not place concrete on frozen or ice-coated material and protects the concrete after placement according to Subsection 501.03.09, “(Portland Cement Concrete) (Construction) Weather Limitations”, of the Standard Specifications.

Construct curbs and gutters using either forms or equipment, such as a curb and gutter extrusion machine. The inspector will verify that the machine is configured to produce the required cross-section. Typically, the extrusion machine uses a guide wire to control the vertical and horizontal alignment. The survey crew should check the guide wires to verify the correct vertical and horizontal alignment before beginning the concrete placement.

Extrusion machines typically require clearance to operate the equipment. The amount of space depends on the type of equipment used by the Contractor. Discuss these details with the Contractor. Because the concrete is supported for a relatively short time, a low slump concrete is used to retain the desired shape. The extrusion machine should produce a consistent and uniform concrete surface with no major defects. Curing and protection requirements of the concrete remain the same as when forms are used. All exposed surfaces must be cured.

MEASUREMENT AND PAYMENT

Refer to Subsection 613.04.01, “(Concrete Curbs, Gutters, and Sidewalks) (Method of Measurement) Measurement” and Subsection 613.05.01, “(Concrete Curbs, Gutters, and Sidewalks) (Basis of Payment) Payment”, of the Standard Specifications and Chapter 15 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

614 - PAINTING

This section addresses the painting requirements for steel, timber, or concrete structures. Materials must meet the requirements of Section 714, “Paint”, of the Standard Specifications. Paint removal, disposal and painting requirements vary depending on the type of paint, as well as environmental and safety concerns. The Resident Engineer and crew should thoroughly review the contract documents for the work to be performed.

BEFORE CONSTRUCTION

Ensure the proper paints are approved prior to application. While certificates of compliance are most often required for paint, the Materials Sampling and Testing Checklist issued by the Materials Division provides direction for the specific project.

For structural steel members, an inspector from the Structures Division's Non-destructive Testing Section will monitor painting operations and at the fabrication facilities. Painting must be performed under clean, dry conditions. Confirm that the Contractor provides adequate protection from paint drift and overspray. The Contractor may need to tent the structure or portions of the structure or provide traffic detours to provide adequate protection. Moisture on the surface will be trapped by the paint and prevent bonding. Moisture or dust in the air will cause a speckled or blotchy appearance on the painted surface. Cold weather also inhibits bonding of the paint to the steel. Painting should not be conducted on surfaces that are below 32°F. Inspect the surface to be painted to verify it is prepared as described in Subsection 614.03.03, "(Painting) (Construction) Surface Preparation of Steel", of the Standard Specifications.

Paint systems must be applied in accordance with the paint manufacturer's recommendations utilizing proper mechanical mixers, thinners, pressures, paint guns, nozzles, and safety equipment. Review with the Contractor the procedure, system and safety clothing to be used. The Non-destructive Testing inspector discusses with the Contractor the surface preparation and paint application process to be used. Painting of structural steel requires that painters and sandblasters be qualified by experience and demonstrated abilities. The Resident Engineer may withdraw the qualification if the performance of the painter, sandblaster, or their equipment is in question.

When painting concrete, the concrete surface must be cured and dried for a minimum of 7 days before paint is applied. Concrete surfaces must be prepared for painting, including removal of curing compound, form release agents or other materials that may prevent the paint from bonding to the concrete. Painting operations must follow the manufacturer's recommendations.

DURING CONSTRUCTION

When the paint arrives at the job site, the inspector will verify that the paint formula and system is in accordance with the contract documents. If the Contractor desires to paint during inclement weather, the Resident Engineer should make certain that the Contractor provides suitable enclosures to protect the work. The Contractor receives no additional compensation for enclosures to protect the work. A clean surface is one of the most important aspects of a successful painting operation. Refer to the contract documents for painted surface requirements.

When paint removal is required, review the contract documents to determine submittal requirements. Typically, the Contractor shall submit a paint removal and disposal plan that incorporates environmental considerations. The Resident Engineer submits the plan to the Structures Division and the Environmental Division for review and approval.

The Structures Division's Nondestructive Testing Section inspector performs on-site painting inspection of steel girders. The inspector confirms that each coat of paint is of the proper thickness. To verify the proper thickness of paint on the surface, the inspector checks the dry film thickness of the paint using a gauge or meter. The inspector will choose checkpoints that are representative of the painted surface and document the locations of the paint thickness checks. The inspector will also frequently check difficult to reach areas for coverage.

MEASUREMENT AND PAYMENT

No method of measurement applies for this activity, and no direct payment is required for this activity. For more information, refer to Subsection 614.05.01, "(Painting) (Basis of Payment) Payment", of the Standard Specifications.

616 - FENCING

Fencing is installed to keep animals from entering protected areas. Fencing may be temporary or permanent, depending on the need. Different types of fencing designs exist to address specific conditions.

BEFORE CONSTRUCTION

Before the start of work, the inspector will review Section 616, "Fencing", of the Standard Specifications, and any project plans regarding fencing. After the survey crew stakes the fence, the inspector will review the stake-out and bring any concerns to the Resident Engineer.

Before the installation of the fencing, the inspector will:

- Confirm that all trees, brush, and other obstructions are removed to maintain a nearly smooth surface.
- Verify that any gates or openings are not moved, added or removed without first consulting the design project engineer and Resident Engineer.
- Determine whether it is necessary to construct fences to prevent livestock escaping from adjacent properties during reconstruction or installation of fencing.
- Compare the planned location with actual field conditions to ensure that fences, gates, openings, and other fencing items will serve as intended.
- Verify that fences do not obstruct flow in streams or drainage areas.
- For fences that may be constructed on top of retaining walls and wing walls, check the location of postholes and ensure accommodations are made for future post installation.

Upon delivery of the materials to the job site, ensure that chain link fences with a protective coating system have a certificate of compliance for the system. All other fencing materials must be field inspected. Submit field samples as required in Part 1 of the *Field Testing Guide*.

DURING CONSTRUCTION

During installation of the fencing, the inspector will:

- Ensure that the areas where fence will be placed have been graded and high points that may interfere with the placement of wire or mesh have been leveled. However, do not permit indiscriminate clearing where clearing and grubbing is restricted to the slope line.
- Observe the placement of fence posts. Also, measure the spacing of posts and measure the depth of holes to ensure placement to proper depths. Note such measurements in the Inspector Daily Report (IDR). Spacing should not exceed the spacing specified or shown in the project plans.
- Observe the placement of corner posts and posts to ensure they are placed at required locations and according to specified details. Also, ensure that the proper type and number of brace posts and diagonal wires are used. Ensure stress and end panels are constructed properly and at required spacing.
- Ensure that the fencing height is correct and the strands are properly spaced.
- Inspect the fastening of wire or fabric to ensure the use of specified materials and methods.
- Ensure that the fencing has additional strand or wire and/or rock deadman at all grade depressions when space between wire and ground exceeds 20 inches.

MEASUREMENT AND PAYMENT

Refer to Subsection 616.04.01, "(Fencing) (Method of Measurement) Measurement" and Subsection 616.05.01, "(Fencing) (Basis of Payment) Payment", of the Standard Specifications and Chapter 16 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

617 - CATTLE GUARDS

Cattle guards are typically installed on access roads and livestock fence line intersections. Their main function is to prevent livestock from passing along a road which penetrates the fencing. This work consists of furnishing and constructing cattle guards, which includes cattle guard grids, footings and cattle guard wings. The most commonly used cattle guards are steel cattle guards and precast cattle guards.

BEFORE CONSTRUCTION

Materials shall conform to the following:

- Section 501, “Portland Cement Concrete”, of the Standard Specifications
- Section 505, “Reinforcing Steel”, of the Standard Specifications
- Section 506, “Steel Structures”, of the Standard Specifications
- Section 614, “Painting”, of the Standard Specifications
- Section 714, “Paint”, of the Standard Specifications
- Subsection 718.03.04, “(Timber Material) (Physical Properties and Tests) Hardware”, of the Standard Specifications

Before installation of cattle guards, the inspector will:

- Review the contract documents in detail.
- Verify that the Contractor has submitted shop drawings of the cattle guard and drawings are approved.
- Check the type of cattle guard that is identified in the contract documents.
- Ensure concrete mix design is submitted and approved by the Resident Engineer.
- Check if there is any utility or drainage structure that crosses or goes along the proposed cattle guard location.
- After the survey crew stakes out the cattle guard, the inspector will review the stake-out and forward any concerns to the Resident Engineer.

Verify receipts of proper certificates of compliance. Steel shall be in accordance with Section 506, “Steel Structures”, of the Standard Specifications. If the Contractor is using a precast concrete, it shall be in accordance with section 503, “Prestressed Concrete and Precast Members”, of the Standard Specifications.

All materials will be examined and tested as necessary before fabrication.

DURING CONSTRUCTION

The inspector will verify that the excavation is at the grade and elevation shown in the project plans and as staked. The inspector will observe excavation operations closely so that any necessary alterations or changes can be made without delay. Structure excavation shall conform to Section 206, “Structure Excavation”, of the Standard Specifications. Over-excavation should be avoided if possible; but if it is necessary, it shall backfilled in accordance with Section 207, “Backfill”, of the Standard Specifications.

During installation of cattle guards, inspectors will:

- Observe safety procedures during excavation.
- Place footings or bottom of precast units to the elevation and location as shown in the project plans or as directed by the Resident Engineer.
- Place backfill uniformly on all sides of the structure. Unequal back filling may cause stress or displacement of the structure. The inspector will be aware of the maximum allowable placement depth of each layer of backfill and that the Contractor adheres to Section 207, "Backfill", of the Standard Specifications. Inspectors will closely monitor the compaction operations and coordinate with the testers. Sampling and testing requirements can be found in Part 2 of the *Field Testing Guide*.
- When the Contractor installs a cast in place cattleguard, verify that top of the steel grates are even with the finished road grade.
- When the Contractor is installing a precast cattleguard, verify that the top of each section is even with the finished road grade.
- Check for any drainage issues.
- Securely attach the end wings according to the details shown in the project plans.

MEASUREMENT AND PAYMENT

Refer to Subsection 617.04.01, "(Cattle Guards) (Method of Measurement) Measurement" and Subsection 617.05.01, "(Cattle Guards) (Basis of Payment) Payment", of the Standard Specifications and Chapter 19 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

618 - GUARDRAIL

Guardrail is installed to prevent errant vehicles from leaving the roadway and impacting fixed objects, steep side slopes and opposing traffic. Different types of guardrail designs exist to address specific conditions.

BEFORE CONSTRUCTION

The Resident Engineer should refer to the current version of the *AASHTO Roadside Design Guide* when reviewing planned guardrail installations. Give attention to the stakeout and construction of required embankments for flared guardrail end sections. After the survey crew stakes the guardrail, the Resident Engineer should review the survey layout. The Resident Engineer should request a guardrail inventory from the Standards and Manual Supervisor in the Roadway Design Division's Specifications Section.

Before installation of guardrail, the inspector will:

- Review the contract documents.
- Check the type of guardrail system for conformance, including rail sections, hardware and posts.
- Verify survey stakeout.
- Check lateral offset, longitudinal length, termini location, post spacing, rail curvature, and parabolic flares.
- Confirm planned guardrail locations are consistent with current field conditions.

- Confirm that the embankments for flared guardrail end sections are staked.
- Guardrail identified for removal, removal and replacement, or remove and reset should be measured for payment before guardrail removal begins.
- Verify receipt of proper certificates of compliance.
- Check post layout for conflicts with utilities and drainage structures.

DURING CONSTRUCTION

During installation of guardrail, the inspector will:

- Unless designated otherwise, drive guardrail posts in place, or set them in dug holes. Check post spacing, elevation, depth, and alignment regularly. Where posts are driven, watch for irregular movement or heaving of the soil, possibly indicating an underground obstruction. Check driven posts for damage such as distortion or splintering.
- Where posts are set in pilot holes, watch for over drilling and require backfilling and compaction as needed to adjust depth and provide a firm foundation. After setting, place and compact backfill material in layers around posts. Compact backfill with an appropriate tool but do not displace the post from correct alignment. Check that all posts are set firm and plumb and that they are within tolerance of the required alignment and elevation.
- Where wood posts are cut in the field, verify that the exposed surface is treated as specified. Post lengths must be in accordance with the contract documents for the type and location of installation.
- If posts are installed in loose soil or within 2 feet of the top of a slope, use longer posts.
- Verify that connections to bridge railings, retaining walls, abutments, or other flat surfaces are in accordance with the contract documents.
- Check for correct construction of the embankment for flared guardrail end sections.
- Check that all fittings and metal plates are securely placed in the correct position. Check that rail sections are lapped so that the exposed ends will not face approaching traffic and are smooth and continuous.
- Check bolts for tightness and threaded rods for proper trimming. Make sure bolts are long enough and nuts are threaded completely onto the bolt. (One or two threads are insufficient.)
- Check for conformance in the rail height and rail face with respect to lateral offset and alignment and inform the Contractor of any necessary adjustment.
- Pay particular attention to the construction details for end treatments, median terminals and rail transitions, such as post type, post length, post spacing, number of rail sections, lapping direction, splices, method of connecting, fastener type and reflector tab location. Specialized hardware and designs are commonly used at these locations and require close inspection before acceptance. Refer to the manufacturer's installation instructions for specialized hardware.
- When the roadway remains open to traffic, the installation of rail sections immediately follows the installation of guardrail posts, unless other protection is provided for in the contract documents. At the end of the workday, check to confirm that the termini of exposed rail sections are treated with temporary end treatments such as a temporary impact attenuator.
- Install cable clips in the proper direction and tighten them to the required torque.
- Immediately before placing concrete, verify that holes for concrete anchors and footings are excavated to the dimensions shown in the project plans and on the manufacturer's drawings.

- Verify that anchor cables are tight enough to prevent any obvious slack in the cable once the footing concrete has cured for the required period.
- Check that plantmix bituminous dikes are positioned under the guardrail as shown in the project plans.
- Check that the construction of flares is in accordance with the project plans.
- Verify that installed guardrail is visually uniform, horizontally and vertically. Require the Contractor to adjust posts and rail if necessary.
- Verify each pay item for each guardrail installation.
- Keep accurate records and make sufficient measurements to support both partial and final payment.

At the completion of any project that installs or removes guardrail, the inspector will accurately complete the guardrail inventory sheet. Refer to the Traffic Safety Engineering Division's SharePoint site [https://nevadadot.sharepoint.com/sites/816] for a guardrail inventory sheet and a manual describing how to complete the inventory sheet. The completed guardrail inventory sheet is sent to the Standards and Manual Supervisor in the Roadway Design Division's Specifications Section. The guardrail inventory sheet is used to evaluate and address federal safety requirements.

MEASUREMENT AND PAYMENT

Refer to Subsection 618.04.01, "(Guardrail) (Method of Measurement) Measurement" and Subsection 618.05.01, "(Guardrail) (Basis of Payment) Payment", of the Standard Specifications and Chapter 17 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

619 - OBJECT MARKERS AND GUIDE POSTS

Object markers are used to mark obstructions within or adjacent to the roadbed, including paved shoulders. Guideposts are reflective devices installed in a series at the side of the roadway to indicate the roadway alignment.

BEFORE CONSTRUCTION

Before the installation of object markers and guide posts, the inspector will:

- Review the marker and delineator lists shown in the project plans, and inform the Contractor of any changes (preferably before material is ordered and mile posts are made).
- Provide the Contractor with a list of post mile values.
- Verify that guideposts and mileposts locations are properly marked and meet required spacing shown in Table 1 on Sheet R-9.1.1, "Guide Posts", of the Standard Plans.
- Examine markers and guideposts to ensure they meet specification.
- Verify receipt of proper certificates of compliance.

DURING CONSTRUCTION

During the installation of object markers and guide posts, the inspector will:

- Inspect the materials and method of installation according to Section 619, "Object Markers and Guide Posts", of the Standard Specifications.
- Verify that the Contractor's layout work conforms to the plans.
- Document and approve minor deviations from the plans.
- Obtain and submit field samples as required in Part 2 of the *Field Testing Guide*.
- Before the material is incorporated, inspect the material by matching the material against information in the certificate of compliance.
- Verify that the Contractor follows the method of placement specified in the contract documents. Verify height and spacing of posts from roadway are correct.
- Verify that the guidepost reflector conforms to the color of adjacent striped edge line.
- Verify that the orientation of the object marker plate is correct in relation to the side of the roadway it is on. When installed correctly, the pattern will be angled downward toward the traffic side of the panel.
- During the installations of reflector plates, check that the Contractor has used washers and installed nuts and rivets properly.
- After installation, check for any damage to the installed material; document any rejections.
- Perform a night inspection and document the reflectivity of the installed material. Notify the Contractor and the Resident Engineer immediately of any problems that need to be corrected.

MEASUREMENT AND PAYMENT

Refer to Subsection 619.04.01, "(Object Markers and Guide Posts) (Method of Measurement) Measurement" and Subsection 619.05.01, "(Object Markers and Guide Posts) (Basis of Payment) Payment", of the Standard Specifications and Chapter 20 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

621 - MONUMENTS

This work consists of perpetuating existing, or construction of new survey monuments. All materials shall conform to Section 501, "Portland Cement Concrete", and Subsection 713.03.01, "(Reinforcement) (Physical Properties and Tests) Bar Steel Reinforcement", of the Standard Specifications.

BEFORE CONSTRUCTION

Before work begins on monuments, the inspector will:

- Verify receipt of proper certificates of compliance.
- Identify and document all monuments to be perpetuated.
- Verify that the Contractor has submitted survey request for control staking and arrange for such necessary control staking.
- Verify that the monument work is done according to the requirements found in the Location Division's *Special Instructions for Location Consultants*.

DURING CONSTRUCTION

During work on monuments, the inspector will:

- Ensure that concrete construction is in accordance with Section 502, "Concrete Structures", of the Standard Specifications.
- Check all materials used to perpetuate or construct the monuments are in accordance with Subsection 621.02.01, "(Monuments) (Materials) General", of the Standard Specifications.
- Verify that all found stamped or tagged survey monuments and public land survey corners are listed on the plan and staked on the ground. Perpetuation of all the monuments is required if they will be destroyed by construction activities.
- Notify the resident Engineer of any other survey monuments found during construction that were not listed in the project plans, which may be disturbed by the construction activities. Perpetuating of those monuments may be required as directed by the Resident Engineer.
- Verify that monument details and dimensions are in accordance with the contract documents.

MEASUREMENT AND PAYMENT

Refer to Subsection 621.04.01, "(Monuments) (Method of Measurement) Measurement" and Subsection 621.05.01, "(Monuments) (Basis of Payment) Payment", of the Standard Specifications and Chapter 20 of the Documentation Manual for measurement/payment guidelines and related instructions.

623 - SIGNALS, LIGHTING AND INTELLIGENT TRAFFIC SYSTEMS

Traffic signals, street lighting, illuminated signs, and Intelligent Traffic Systems are all part of roadway electrical systems. Intelligent Traffic Systems (ITS) is a general term that includes items such as changeable message signs, communication systems, and traffic monitoring systems. Typically, electrical systems along local roadways, including traffic signals at highway ramp junctions, are maintained by the local agency and built to the local agency's specifications. Electrical systems along highways are constructed in accordance with the contract documents and maintained by the Department or the local agency. The technology and materials associated with electrical systems continually evolve. The evolution of the technology for these systems creates advances in equipment. Although equipment advances are common, the basic construction features typically remain the same.

Electrical systems are typically installed in urban areas, although lighting and ITS systems are also common in rural areas. The basic components of electrical systems consist of electrical service, controller, wiring, conduit, and signal/lighting/ITS components. The electrical service is the point at which an electrical utility company furnishes or provides electrical power to a user, typically with a meter to record electrical power usage. A controller is the equipment, similar to a computer, that controls and manages the components of the electrical system. Controllers are typically located in metal cabinets on the project, near the electrical system that they control. Wiring and conductors convey electrical power to the electrical components, including the electrical service. Conduits are plastic or metal pipes in which wiring is placed. Conduits allow for the installation or replacement of wiring underground without trenching after the initial installation. All electrical systems must meet certain standards and codes as detailed in the contract documents.

BEFORE CONSTRUCTION

The inspector's work on roadway electrical systems should begin before the Contractor arrives at the job site. The inspector needs to be familiar with the project; existing conditions should be thoroughly documented to help settle disputes during construction, quality of materials should be verified before use, and the construction schedule should be reviewed to confirm that it is appropriate for the work to be performed. Complete the following tasks before construction begins:

- Thoroughly review the contract documents to confirm compliance with regulations and codes and pay close attention to all project notes.
- If electrical systems that are not maintained by NDOT are constructed or modified, contact the local agency that performs the maintenance.
- Check the condition of any existing electrical equipment that is indicated in the project plans to remain in place, to be salvaged, or to be relocated; take photographs to document the condition of these items before the Contractor arrives at the job site.
- Confirm that electrical equipment and materials submittals have been provided by the Contractor, and approved by the Resident Engineer.
- The inspector will keep a copy of the Contractor's submittal to confirm that the proper products are used. As materials are delivered to the job site, verify that they match the description on the approved submittal. If the Contractor wants to substitute a specified product with a different product of equal quality and suitability that is not listed in the Qualified Product List, a request for substitution must be made in writing. The Resident Engineer approves or denies the substitute.
- If the contract documents call for any agency-furnished equipment such as traffic signal controllers and cabinets, confirm with the furnishing agency that these materials will be available when needed, that provisions have been made for testing if necessary, and that all parties have been properly contacted to control the pickup and delivery of these items.
- Review the Contractor's schedule of operations and confirm that arrangements are being made to maintain existing electrical systems, or that temporary electrical systems will be provided in accordance with the contract documents.
- Certain job-specific electrical equipment such as poles and controllers typically require substantial lead-time due to fabrication of specialized materials. Confirm with the Contractor that lead-time for the electrical equipment is accounted for in the schedule of operations; partial payment will not be given for these materials until they are delivered to the job site.
- Walk the project with the Contractor to determine the locations where cranes, pile-driving equipment, or other equipment may be needed, and advise the utility company representatives of overhead clearances necessary to accomplish the work. Also, if overhead wires for temporary lighting or signals will encroach on private property, refer the situation to the Right-of-Way Division.

Contact the project manager and district utility coordinator to discuss the status of electrical and utility agreements for the project. If an electrical or telephone service connection is needed, the district utility coordinator should submit an application to the utility company. Confirm that this is being provided early enough for the utility company to plan their work in an orderly manner.

DURING CONSTRUCTION

Before installing any underground equipment, the Contractor shall contact the appropriate underground utility locating service. The Resident Engineer should not allow the Contractor to perform any excavations until all underground utilities have been located.

Only journeyman electricians or electrical apprentices directly supervised by a journeyman electrician may perform electrical work or install electrical material. All work performed on traffic signals must be performed or be directly supervised by a journeyman electrician certified as International Municipal Signal Association (IMSA) Level II or higher.

The Contractor may need to provide a temporary system in order to maintain satisfactory operation during construction. Coordinate with the local agency for the operation of the signal system during construction. Any existing facilities damaged by the Contractor's operations must be promptly repaired or replaced in accordance with 107.16, "(Legal Relations and Responsibility to the Public) Contractor's Responsibility for the Work and Materials", of the Standard Specifications.

Throughout construction, it is important that the Contractor provide adequate warnings and safeguards in the form of signs, lights, and barricades. All temporary traffic control devices used must be in good condition and conform to the latest version of the *Manual on Uniform Traffic Control Devices* (MUTCD) and the Standard Plans. Any excavated foundation holes, where pedestrians may walk, must be covered with adequately braced plywood or an equivalent.

Underground work such as the installation of conduit and concrete foundations should be inspected while the work is being performed, since these items cannot be inspected once the work is complete. If any unexpected underground utilities are encountered while performing underground work, a representative of the utility owner should be contacted immediately.

All electrical equipment and installations must be properly grounded according to the bonding and grounding techniques explained in the contract documents. Electrical systems should be tested for system voltages, insulation resistance, ground continuity, and current before final inspection. If detector loops are being installed on the project, they should be tested before and after they are permanently secured in the pavement. The contract documents fully explain the testing techniques and acceptable tolerances. The tests should be performed by the Contractor, in the presence of the inspector, and documented. Any items that fail to test satisfactorily should be repaired or replaced.

Changes made during construction are recorded on the Inspector Daily Report (IDR) and on the As-Built Plans. Specific details of the changes made should be recorded. Significant changes require a contract modification.

CONDUIT

Conduit is an integral part of all electrical systems as it allows the installation of the wiring that powers the electrical equipment. The two different types of conduit used for underground installation on electrical systems include metallic (steel) conduit and non-metallic (plastic) conduit. An initial inspection of the conduit should be performed prior to conduit installation to confirm that the conduit is in good condition and that it is of the schedule and size specified in the contract documents. Non-metallic conduit used in electrical systems should be gray in color unless otherwise indicated in the contract documents. Conduit should also have the manufacturer's name, trade size, and schedule imprinted on the outside. Should the Contractor want to use a different conduit size and schedule not conforming to the contract documents, it must be approved by the Resident Engineer. Conduit should also be inspected for cracks, dents, excessive weathering, or signs of having been damaged. Any conduit in an unacceptable condition must be rejected.

For placing electrical conduit underground, the typical methods of installation are trenching and boring. The Contractor can typically choose which method of installation to use, provided it is in accordance with the contract documents. As conduit is being installed, the inspector will monitor the following:

- Verify that conduit is placed at the proper depth, and the trench is properly bedded, backfilled, and compacted in accordance with the contract documents. On new construction, all trenching for conduit located under paved surfaces should be placed prior to construction of the base course and pavement.
- For clarity, conduit runs as shown in the project plans, are schematic. Actual installation of the conduit should be as straight a line as possible between pull boxes or other terminations. Changes made to conduit routing during construction should be reflected on the As-Built Plans.
- When conduit is properly screwed together, all threads should be covered by the coupling, and the ends of the conduit should be butted tightly together. If threads are exposed, generally either the connection is not tight or the threads are crossed in the coupling.
- Rigid metallic conduit, when used underground, must be wrapped in accordance with contract documents to protect it from corrosion.

- When a conduit run containing signal cables is over 50 feet in length, all bends (sweeps) must be factory-coated PVC rigid metallic conduit. The friction created by the cable being pulled through a sweep on a long run, may "burn" through the side of a PVC sweep, creating a hole in the conduit.
- The total angle of bends (sweeps) used on a conduit run cannot exceed 360 degrees. For example, a conduit run with 90-degree sweeps can only have four sweeps.
- Field bends should be made only with approved tools, and conduit should never be bent to a radius smaller than the minimum bend radius specified by the conduit manufacturer.
- Conduits should be capped to prevent contamination such as dirt, debris, rodents, and water from entering them until the wiring is installed. After the wiring is installed, the ends of the conduit should be plugged with an approved duct seal to prevent contaminants from entering the conduit.
- Conduit used on a pole as a riser for power service must conform to contract documents and the power company's standards.
- Allow only the number and sizes of cables/conductors in a conduit that is shown in the project plans. The size of the conduit specified is based on the fill, or amount of space taken up by the wiring. The National Electrical Code (NEC) limits the number of conductors that may be installed in a single conduit. If approved, at the Contractor's expense, the Contractor may use a larger size conduit than specified in the project plans, provided the same size and type is used for the entire length of the conduit run.
- Verify that all conduit runs are complete and that all appurtenances such as pull boxes, poles, and controller boxes are connected by conduit runs. Conduits that terminate in pull boxes with multiple runs should be permanently labeled or otherwise identified to determine where they run.

For conduit that will be installed in or on a structure, the inspector will consider the following:

- Refer to the bridge plans for conduit installation details
- Verify that expansion fittings are provided when a conduit passes through an expansion joint on a structure

PULL BOXES

Pull boxes, vaults, or junction boxes are installed at conduit termination points, and facilitate wire pulling and splicing. The term vault is used for a large pull box and the term junction box is used for a pull box that is located in or on a structure. The size, type, and installation methods for pull boxes will be identified in the contract documents. Typically, pull boxes used on NDOT contracts are required to be traffic rated with metal lids. Initial inspections of the pull boxes should be performed prior to installation, and any pull boxes that are chipped, cracked, or have more than minor surface blemishes should be rejected. As pull boxes are being installed, the inspector will consider the following:

- Pull boxes should generally be placed at intervals as shown in the project plans. The Contractor may install additional pull boxes or junction boxes to facilitate operations however, it will be at the Contractor's expense
- Pull boxes are typically installed on a minimum of 6 inches of drain rock or as shown in the project plans. Additional drain rock may be required around and under the pull box to prevent the soil from eroding around the pull box
- The tops of pull boxes should be set flush with the final grade and slope; whether in pavement, sidewalks, landscaped areas, or in the roadway shoulder
- Verify that steel pull box lids are grounded
- On unpaved slopes, check that pull boxes are kept out of depressions so as not to collect water
- Pull boxes should not be placed in pedestrian ramps

- Pull boxes placed in structures must be constructed and placed in accordance with the contract documents. If the formed type of pull box is used, confirm that the Contractor places properly dimensioned wooden pull box templates at the correct locations and the conduit is stubbed into the pull box before concrete is placed for the structure
- Verify that pull boxes placed on or adjacent to a structure are placed away from where expansion joints will be located

Following construction, a final check of pull boxes should be performed to verify pull box lids are properly fastened, all metal pull box lids are properly grounded, and all lids are properly marked with embossed lettering identifying what the pull box is being used for.

WIRING

Wiring is used in electrical systems to convey electrical power to the system components. The wiring for electrical systems generally consists of conductors and cables. A conductor is a single wire, and a cable is a group of two or more insulated conductors wrapped in a common sheath. Wires are sized based on the standard American Wire Gauge (AWG) system which uses numbers to indicate the size of the wire; in general, the smaller the number, the larger the wire diameter. Since wiring is typically installed underground in conduit, it is important to perform a preliminary check of the wiring prior to installation to make sure the insulation is not damaged. Wiring with damaged insulation must be rejected. During installation of the wiring in conduit, the inspector will consider the following:

- The wiring being installed should match the size and type specified in the contract documents. The symbols for wire sizes, insulation types, and temperature and voltage ratings are imprinted on the insulation of single conductors or the non-metallic sheath of multi-conductor cables
- In general, wiring that is installed in conduit should be pulled through the conduit by hand. Pulling wire by mechanical means may damage the conductors, the insulation, or the conduit.
- All traffic signal conductors must be run continuously from terminal to terminal with no splices. (Terminals are the devices located on the poles and in the controller that are designed specifically for joining electrical circuits together)
- When a single conduit or pull box has multiple circuits passing through it, each circuit should be labeled. All traffic signal conductors and cables must be labeled and color coded in accordance with the contract documents. Labels should be banded to the conductors or cables with labels specifically designed for wiring
- When possible, high voltage wiring and low voltage wiring should be placed in separate conduit

As the Contractor installs the wiring, wire splices will sometimes be necessary. The contract documents give specific guidance on what types of wires can be spliced, appropriate splicing methods, and where splicing is allowed. As splicing requirements may be different for different types of wiring, it is important to thoroughly review the contract documents to understand these requirements. In general, splices are typically allowed only in pull boxes, junction boxes, or at the bases of lighting standards. Also, splicing is typically prohibited on certain types of wiring such as signal interconnect cable and detector loop cable.

SERVICE ENCLOSURES

Service enclosures are the cabinets that house the circuit breakers and electrical service equipment. There are two separate sections in a typical service enclosure, a line side and a load side. The line side is the section where the serving utility brings in the wires from the service point. The load side is the section that houses the circuit breakers and where the wires go out to power the electrical equipment.

Service enclosures are typically either pedestal mounted or surface mounted on a pole or cabinet. Pedestal mounted service enclosures are mounted on concrete pads, which can either be cast-in-place or precast. The cabinet is bolted into place on the pedestal and properly sealed to prevent seepage of water into the cabinet. If the service enclosure is mounted on a pole or cabinet, it should be securely fastened in accordance with the contract documents. Service enclosures should be placed in a location where utility access can be provided and oriented such that the meter can easily be read. The service address should be embossed onto a metal plate and permanently attached to the front of the enclosure.

Make sure the service cabinet is the type specified in the contract documents. The circuit breakers should have their ratings imprinted on them and a nameplate identifying what the circuit breaker controls. A nameplate should be placed adjacent to each circuit breaker. Confirm that these circuit breaker ratings match what is called out for in the contract documents. The cabinets should also be inspected for dents or chipped paint. Minor dings or paint chips can be field repaired, but cabinets with more than minor damage must be replaced.

Some service enclosures will also house transformers, which are devices that are used to boost or drop voltage. If a transformer will be installed in an enclosure, it will be called out for in the contract documents. Because transformers generate a certain amount of heat, the enclosure housing the transformer usually needs to be vented and may require a fan. Make sure the venting and screening is accounted for and in accordance with the contract documents. Also, check that the transformer is securely fastened and wired in accordance with the contract documents.

CONTROLLERS AND CONTROLLER CABINETS

Controllers are the equipment that control and manage the components of an electrical system and are typically located in metal cabinets on the project, near the electrical system that they control. Controllers are necessary at all traffic signals, and are needed to operate many ITS components such as changeable message signs, traffic monitoring stations, and closed-circuit television (CCTV) cameras. If a controller is necessary, the type of controller and cabinet to be installed will be called out for in the contract documents. The inspector will confirm that the controller and cabinet being installed are in good condition, are of the type that is specified, and include all equipment called out for in the contract documents.

The concrete base for the controller cabinet, conduits, and grounding systems is installed before the cabinet. The cabinets are supplied with a gasket that is placed between the clean concrete foundation and the cabinet. The cabinet must be bolted into place using the anchor bolts that are an integral part of the foundation, and properly sealed to prevent seepage of water into the cabinet. The door of the cabinet should be able to open fully without hitting any obstructions, and the cabinet should be oriented in the proper direction. Typically, the cabinet is oriented so that when a technician is working on the controller, the technician can see the system that it controls. Do not allow any electronic equipment, including the controller, to be placed inside the cabinet until the cabinet has been securely bolted into place on the foundation.

A wiring diagram should be provided with each cabinet. Confirm that the power input wiring, signal head (lights) output power wiring, detector wiring, and pedestrian push button wiring are connected to the labeled terminals in accordance with the wiring diagram furnished with the cabinet, and that all wiring is properly labeled in accordance with the contract documents. Any stranded conductors smaller than No. 14 should have crimp-on spade terminals installed on them to facilitate attaching them to the terminals. If any modifications are made to a signal system, the cabinet wiring diagram must be modified accordingly. Only certified IMSA Level II personnel should attempt to rewire any portion of the cabinet, or make modifications to any part of a signal system. Verify that the Contractor provides documents for all modifications and the reasons for the modifications.

When completed, the cabinet and wiring should be neatly organized. All the wiring should be neatly and firmly bundled together, either laced, bound, or tie-wrapped, and out of the way so that the wire bundles don't inadvertently come into contact with various components, such as the test switches mounted on the inside of the door. The wiring bundles should be arranged so that technicians cannot easily hook them or disturb them when opening the door.

POLES

Poles are used on electrical projects for traffic signals, lighting, overhead sign structures, and intelligent traffic systems. In general, all poles and anchor bolts should be inspected prior to installation to confirm that they are of the correct type and are in good condition. The type of pole to be installed at each location will be detailed in the project plans. Poles or pole arms with dents should be rejected, and any damaged galvanizing or paint should be properly repaired in accordance with contract documents.

Prior to installation, each pole location should be staked and the locations should be approved by the inspector. As signal pole locations often depend on pedestrian ramp and sidewalk placement, the locations of these items should be staked as well to facilitate pole location approval. Should any underground or overhead utilities prevent the placement of a pole at its specified location, the project coordinator should be contacted to provide an alternate location. When laying out pole locations for traffic signals, verify that no obstructions exist that will prevent vehicular or pedestrian traffic from seeing vehicular or pedestrian signal faces, or that will prevent pedestrians from accessing push buttons. Poles with push buttons must be located so that the button is ADA accessible and in accordance with the most recent editions of the MUTCD and the Standard Plans.

All poles must be mounted on properly prepared foundations with properly sized anchor bolts and be individually grounded in accordance with the contract documents. The finished pole foundations should not be placed in depressed areas and anchor bolts should be embedded to the proper depth. Poles should be mounted to the anchor bolts, plumbed, and the nuts should be properly tightened in accordance with the contract documents. When the project plans call for the installation of a lighting standard with a safety base, check that the safety base is properly installed by the Contractor. Specific safety base installation and torque requirements are explained in detail in the contract documents. Installing the safety base in accordance with torque requirements is critical for the safety base to perform as designed.

Concrete for pole foundations is typically placed without forms against the excavation. The resulting rough block of concrete is functionally satisfactory, however, confirm that the Contractor forms and finishes the exposed part of the footing and that all exposed forms are stripped after the concrete is at full strength. Verify that the foundation excavation is of the proper size and depth as detailed in the contract documents, and confirm that the specified concrete is used.

Mast arms on poles for traffic signals and lighting must be bolted to the flanges and installed in accordance with the contract documents. Traffic signal mast arms will require tenons, which are steel tubes to which the signal heads are attached. The Contractor may be required to field weld the tenons to the mast arms in order to properly align the signal heads with the travel lanes. All field welds shall be certified welds, performed in accordance with the contract documents. After welding, metal surfaces must be repainted or galvanized in accordance with the contract documents. Signal poles and mast arms are designed to withstand not only the dead loads that result from traffic signal heads and signs, but also from live loads caused by winds and truck gusting. The loads on the arms and poles must not exceed the loads for which they were designed. Do not allow any additional equipment or signs to be placed on the poles or mast arms, and do not allow the installation of a longer signal arm on an existing pole without approval from the Traffic Operations Division.

VEHICLE AND PEDESTRIAN SIGNAL HEADS

Vehicle and pedestrian signal heads are installed at traffic signals to control vehicle and pedestrian movements. Signal heads generally consist of indication lenses installed in a main housing; a back plate and visors are also usually required to be attached to the housing. All signal heads should conform to the contract documents and should be inspected for damage to the housings and lenses prior to and after construction. Minor paint scrapes or blemishes may be touched up in the field, but any housings or lenses with cracks must be rejected.

Signal heads are designated in the project plans under “pole schedule” by a standard code. For instance, a 1W3C head is a typical one-way, three-color head. Vehicle and pedestrian signal heads should be installed at the locations shown in the project plans and oriented towards the movement they are designed to control. Vehicle signal heads must be properly aligned with the travel lanes and leveled. The type of mounting for vehicle and pedestrian signal heads can also be found in the Signal Summary Sheet under “Pole Schedule”. There are three basic types of mounts: mast arm mounted heads, bracket or side mounted heads, and post-top mounted heads. Details of the various mounts can be found in the project plans. Make sure the Contractor places them in accordance with the project plans.

Signal heads are wired from the head to the terminal block on the pole with single conductors. All wiring should be performed neatly and labeled in accordance with the contract documents.

VEHICLE AND PEDESTRIAN DETECTION

The standard types of vehicle and pedestrian detection consists of loop detectors, video detection, preemption, and pedestrian push buttons. Vehicle and pedestrian detection is an area where evolving technology creates advances in equipment. Because of this, the contract documents for each project should be thoroughly reviewed to confirm that the detection equipment being provided is of the correct type, and is properly installed.

LOOP DETECTORS

Loop detectors are installed by saw-cutting slots into the pavement, wrapping a cable in the slots, and filling the slots with an approved loop sealant. The loop wires are run from the loop to the pull box, where they are spliced to a loop cable, and the loop cable runs from the loop wires to the controller cabinet. Typically, splicing of the loop cable is not allowed. Proper detector loop installation techniques and details are shown and explained in further detail in the contract documents. Proper installation and labeling of individual loop wires is essential, as improperly installed detector loops will cause ongoing problems with vehicle detection and can result in malfunctioning signal systems. Maintenance and replacement of improperly installed detector loops is time consuming and expensive.

When inspecting loop detector installations, check that the overall loop layout and proposed loop type match the plan details. Loops should not be placed across cracks or joints in the pavement and should be at least 2 feet from the lane lines. Generally, loops should be centered in the travel lane unless the project plans show otherwise. Placing loops across cracks can result in early loop failure, and placing them too close to a lane line may cause vehicles in the opposing lane to be detected. If no alternative location can be provided for loop wires and they must cross a joint or crack in the pavement, a flexible slip joint should be provided in accordance with the contract documents. If a manhole or water valve is located where a loop detector will to be installed, the loop detector must be modified; the Traffic Operations Division should be contacted for a design change.

Sawcuts should be inspected to verify that the cut is de-burred, cleaned out, and blown dry prior to installation of the loop wires. The Contractor performs testing on detector loops as required by the contract documents before and after they are permanently secured in the pavement. Test results should be documented by the inspector and submitted to the Resident Engineer.

The loop wires should have identification bands placed on them and be properly labeled in the pull box, and the loop cables should be properly labeled in the controller cabinet. If loops are installed for future use, the ends of the wires must be taped and waterproofed in the pull box, and the wires should be labeled.

VIDEO DETECTION

Video detection is a system that uses video cameras instead of loops for detecting vehicles. Cameras are typically mounted on poles or mast arms and pointed towards the approach that they will detect. The method used to mount the cameras should be in accordance with the contract documents, or the manufacturer's recommendations. The symbol shown in the project plans does not necessarily indicate the proper mounting location. There are many different types of video detection systems available, and the system used needs to be compatible with the controller.

Field wiring for the video cameras is relatively easy, consisting of a coaxial cable and power wiring run from the camera to the controller. Wiring should be done neatly and labeled properly. Wireless video detection systems are also available. If a wireless system will be used on the project, it will be specified in the contract documents.

PREEMPTION

Preemption is a type of vehicle detection that recognizes certain types of vehicles as they approach and assigns their movement priority at a traffic signal. Preemption is typically installed at traffic signals for emergency vehicles, but it can also be used for transit and for rail vehicles. Emergency vehicle and transit preemption equipment, if applicable, consists of detectors that are mounted on signal arms or luminaire arms and a phase selector that is mounted in the controller cabinet. The locations of the preemption detectors and mounting details will be shown in the project plans. Check that the proposed detector location is within the line of sight of an approaching vehicle from the direction that it controls. If the line of sight to the detector is impeded due to curvature of the roadway, landscaping, or any other fixed object, contact the Traffic Operations Division to provide an alternate location. Make sure the equipment is the type specified in the contract documents and is properly mounted. Special cable is typically used to connect the preemption detectors to the phase selectors in the cabinet, splicing of this cable between the detectors and phase selectors should not be allowed.

For railroad preemption, the railroad company provides the operator of the traffic signal system with a railroad preemption circuit that is connected to the controller. Wire will be run through conduit from the traffic signal controller to a pull box located at the railroad right-of-way that will be connected to the railroad's circuit. Railroad preemption at a traffic signal must be coordinated with the railroad and the coordination is typically handled through the Right-of-Way Division's Utilities Section. If railroad preemption is applicable for a project, the inspector needs to confirm that the conduits, pull boxes, and wiring are installed in accordance with the contract documents.

PEDESTRIAN PUSH BUTTONS

Pedestrian push buttons are used to detect pedestrians at traffic signals. A standard pedestrian push button assembly consists of a base, sign panel and push button. The push button assemblies will typically be mounted on a traffic signal pole or on a smaller pole called a pedestrian push button post. The mounting height, location, and accessibility of pedestrian pushbuttons must comply with the most recent editions of the Americans with Disabilities Act (ADA), the MUTCD, and the Standard Plans. If a proposed pedestrian push button location is not accessible, the Safety/Traffic Division should be contacted to provide an alternate location. The push buttons should be securely mounted to the pole at the correct height and in the correct quadrant, as shown in the project plans. Make sure the arrow on the sign panel points in the correct direction.

LUMINAIRES

Luminaires are used on electrical projects for the lighting of roadways and overhead signs. Luminaires for overhead signs are mounted on the supporting framework in front of the sign, mounting details for these lights can be found in the project plans. Luminaires for roadway lighting can be mounted on a pole or on a structure. The contract documents will show mounting details and show the locations of all luminaires on the project. The inspector needs to check that all luminaires match the type and wattage identified in the approved equipment submittals and are properly mounted and oriented in the correct direction so that the light distribution lights the roadway as designed. For luminaires mounted on poles, the pole should be plumbed and the anchor bolts should be tightened before the tilt angle on the luminaire is set. Structure and wall mounted luminaires should be oriented and installed per the manufacturer's contract documents.

INTELLIGENT TRAFFIC SYSTEMS (ITS)

While many ITS components are commonly used electrical items, other ITS components may require highly specialized equipment. The contract documents should be thoroughly reviewed for all projects with ITS equipment to confirm that the equipment being installed meets the requirements of the project. There may also be test procedures and knowledge of operational parameters that require specialized expertise to be provided by the equipment suppliers, installers, or manufacturers. Any specialized tests and procedures should be observed and documented by the inspector.

UTILITY COORDINATION

Utility coordination will typically be required on electrical projects to obtain electrical and/or telephone service points. Prior to construction, contact the Safety/Traffic Division and district utility coordinator to discuss the status of electrical and utility agreements for the project. If an electrical or telephone service connection needs to be obtained, the district utility coordinator should submit an application to the utility company. Once the meter pedestal is installed and ready for inspection, the district utility coordinator should be notified to perform a final inspection. The district utility coordinator will work with the Resident Engineer and the utility company for the final meter installation and activation.

TESTING

Before completion and acceptance of electrical work, testing must be completed in accordance with the contract documents. All electrical systems should be tested for system voltages, insulation resistance, ground continuity, and current before final inspection. If detector loops are being installed on the project, they should be tested before and after they are permanently secured in the pavement. Testing techniques and acceptable tolerances are explained in detail in the contract documents. The tests should be performed by the Contractor, in the presence of the inspector, and documented by the inspector. Test results should be submitted to the Resident Engineer. Any items which fail to test satisfactorily should be repaired or replaced.

TRAFFIC SIGNAL TURN-ON

Prior to the turn on of a new traffic signal system, the following should be performed:

- Until signals are placed in operation, the signal heads shall be turned away from traffic and/or completely covered with an approved method
- Before a new traffic signal is opened to traffic, do a final check to verify that all traffic control devices are in place and working properly
- Check that the Contractor has properly installed all signing and striping items
- Give 2 weeks advance notice of the proposed turn-on of a signal system to the District traffic engineer, public information, local jurisdiction, local maintaining agency, local fire and police departments, and schools
- If timing information is required and not provided by the local agency, contact the Traffic Operations Division

MEASUREMENT AND PAYMENT

Refer to Subsection 623.04.01, "(Signals, Lighting, and Intelligent Traffic Systems) (Method of Measurement) Measurement" and Subsection 623.05.01, "(Signals, Lighting, and Intelligent Traffic Systems) (Basis of Payment) Payment", of the Standard Specifications and Chapter 8 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

624 - ACCOMMODATIONS FOR PUBLIC TRAFFIC

This section provides guidance on worker protection and the safe passage of public traffic through and around construction with as little inconvenience and delay as possible. Refer to the current version of the *Manual on Uniform Traffic Control Devices* (MUTCD) and the project plans for details on signs, lights and traffic control devices used on construction projects.

A traffic control plan addresses management of public traffic in and around a construction project. When the Department prepares the traffic control plan, the project coordinator, in consultation with the District, the Construction Division and the Traffic Operations Division, develops a plan to accommodate public traffic during construction. If the contract documents require the Contractor to prepare the traffic control plan, the Contractor, in consultation with the Resident Engineer, develops a plan to accommodate public traffic during construction, as required in Section 625, "Construction Signs", of the Standard Specifications. The purpose of the plan is to provide safe passage of traffic, and to create and maintain safe work areas. When the plan is prepared by the Department, it is based on a logical sequence of operations. When submitted by the Contractor, the plan is based on the Contractor's scheduled construction operations.

Traffic control plans have the following basic objectives:

- Protect the traveling public
- Protect construction workers

- Reduce traffic delays in work zones
- Channelize traffic
- Provide directional information to drivers
- Provide an acceptable level of service during construction operations
- Provide for pedestrian and bicycle traffic

For more information, refer to the *NDOT Work Zone Safety & Mobility Implementation Guide*.

Traffic control plans developed by the Contractor are reviewed and either accepted or rejected by the Resident Engineer. Typically, changes to traffic control plans are considered when field conditions are different from those contained in the plan, or the plan simply does not work when applied. The traffic control plan shall be appropriate for expected conditions during construction. If the traffic control plan is included in the contract documents, the traffic control may require modification to address the Contractor's proposed operations. The Resident Engineer documents the proposed traffic control changes and submits them to the District Engineer and the Traffic Operations Division for review and approval.

BEFORE CONSTRUCTION

Before work begins, the inspector will:

- Compare the traffic control plan to job site conditions. Note any unusual local traffic movements and the movements of emergency vehicles. Discuss the traffic control plan at the Pre-Construction Conference.
- Review Subsection 108.04, "(Prosecution and Progress) Limitations of Operations", of the Standard Specifications, for operations limitations as related to traffic control.
- Review proposed changes to traffic control plans with the Traffic Operations Division and the District traffic engineer.

DURING CONSTRUCTION

An inspector will monitor and document traffic control activities. The inspector will be certified by the American Traffic Safety Services Association (ATSSA) as a traffic control supervisor. The inspector will:

- Observe installation of specified signs and traffic control devices. Signs, barricades, drums, cones, and flagger paddles must meet specified retro-reflectivity requirements described in Section 625, "Construction Signs", of the Standard Specifications.
- To document the markings, devices and signs that exist during operations, maintain a detailed record of the placement and spacing of signs and other traffic control devices on the Inspector Daily report (IDR).
- On the back of each sign, print the assigned installation number, contract number, date of installation and inspector initials. Also enter this number in the IDR.
- Regularly drive through the job site and review the traffic control installed to confirm continued conformance with the traffic control plan. Monitor the effectiveness of the traffic control while driving through the job site. Discuss ideas for improving the traffic control with the Resident Engineer. Note deficiencies and immediately notify the Contractor to take corrective action.
- Regularly monitor the retro-reflectivity of signs, barricades, drums, cones and flagger paddles. The Contractor may be required to clean or replace devices with unacceptable retro-reflectivity.
- The Contractor's traffic control supervisor must submit the original and copies of completed NDOT Form 040-056B, (Work Zone Traffic Control Checklist)," as required by Subsection 624.03.06, "(Accommodations for Public Traffic)

(Construction) Traffic Control Supervisor", of the Standard Specifications. If documentation is not provided by the Contractor, the Resident Engineer may withhold payment to the Contractor for the traffic control supervisor bid item.

- Verify flaggers are at designated locations and that they meet the requirements of Subsection 624.03.03, "(Accommodations for Public Traffic) (Construction) Flaggers", of the Standard Specifications. Flaggers must have certifications in their possession.
- Record work hours for all flaggers on the job site using NDOT Form 040-036 (Uniform Traffic Control Officer and Flagging Hours) for proper payment.
- When unpredictable situations occur, a formally approved traffic control plan is not required, but written documentation is required to record actions taken and directions given.
- If the Contractor's operations interfere with or cause potential safety problems with vehicular or pedestrian traffic, notify the Contractor to correct the deficiency immediately. If the notification to the Contractor is verbal, document the notification in writing to the Contractor.
- Because the safety of the traveling public is of the utmost concern, NDOT Maintenance crews may need to correct traffic control deficiencies when the Contractor is physically unable or refuses to act. The Resident Engineer may terminate the Contractor's work operations if the Contractor fails to perform. Keep the Resident Engineer informed of traffic control deficiencies.

To reduce the impacts to existing traffic, the Department may require the Contractor to conduct construction activities when traffic volumes are low. These low volume periods typically occur at night. Although nighttime construction can reduce traffic impacts in the work zone, it can also create situations that require diligent attention to worker and motorist safety.

The Contractor's traffic control supervisor is responsible for initiating, installing, and maintaining all traffic control devices. A uniformed traffic control officer is required when a signalized intersection is interrupted for construction activities. Uniformed traffic control officers are city, county or state police officers.

The effectiveness of handling traffic through night construction depends on the contract documents and the details of the Contractor's operations. Consider the following during nighttime operations:

- Light the immediate work area and flagger stations with floodlights, taking care to not blind drivers.
- Require workers to wear bright colored clothing with reflective material that conforms to Subsection 108.05, "(Prosecution and Progress) Character of Workers; Methods and Equipment", of the Standard Specifications.
- Ensure that signs, barricades, and traffic control devices are clean and have proper retro-reflectivity.
- Confine the work area to the shortest practical distance.
- Verify the Contractor's operation plan provides sufficient room for construction vehicle access with the least impact to traffic.
- Either through illumination or suitable marking, all construction equipment shall be visible to traffic.

In the event of an accident within the work zone, the traffic control inspector will complete all documentation as required by the Resident Engineer.

Although a traffic control plan reflects the Contractor's operations and traffic conditions during construction, setting up the various elements of the plan at the appropriate time is also important. The traffic control measures must address current activities and conditions. For example, a flagger may or may not be present. If the flagger is not present, "Flagger Ahead" signs should not be visible to traffic. Traffic control measures create driver expectation of upcoming conditions. When traffic control measures do not accurately reflect upcoming conditions, drivers tend to disregard signage and other traffic control devices.

Timely information can significantly improve traffic behavior on a construction project. A motorist who is forewarned of construction conditions will be more tolerant of delay and inconvenience and probably will be more alert and responsive to construction zone traffic control. The Resident Engineer must verify that information on project road closures, new road openings, traffic rerouting and changes in traffic conditions is made available before such changes.

MEASUREMENT AND PAYMENT

Refer to Subsection 624.04.01, "(Accommodations for Public Traffic) (Method of Measurement) Measurement" and Subsection 624.05.01, "(Accommodations for Public Traffic) (Basis of Payment) Payment", of the Standard Specifications and Chapters 21 and 22 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

625 - CONSTRUCTION SIGNS

Construction signs are a part of accommodating public traffic through a construction project. The contract documents address requirements for construction signing, temporary traffic control devices, and traffic control plans. General guidance relating to construction signs is included in "624 - Accommodations for Public Traffic", in this chapter.

When the contract documents require the Contractor to develop a traffic control plan, the Resident Engineer reviews and either accepts or rejects the Contractor's traffic control plan. The Contractor shall submit a traffic control plan that complies with the contract documents at least 7 days before the Pre-Construction Conference.

Typically, changes to traffic control plans are considered when field conditions are different from those contained in the contract documents. The traffic control plan must be appropriate for conditions that will be encountered during construction.

BEFORE CONSTRUCTION

Refer to the corresponding section of "624 - Accommodations for Public Traffic", in this chapter for guidelines.

Ensure all traffic control devices placed on the job site meet the requirements of Section 625, "Construction Signs", of the Standard Specifications.

DURING CONSTRUCTION

Refer to the corresponding section of "624 - Accommodations for Public Traffic", in this chapter, for guidelines.

Ensure all traffic control devices are being maintained in a condition that meets the requirements of Section 625, "Construction Signs", of the Standard Specifications.

MEASUREMENT AND PAYMENT

Refer to Subsection 625.04.01, "(Construction Signs) (Method of Measurement) Measurement" and Subsection 625.05.01, "(Construction Signs) (Basis of Payment) Payment", of the Standard Specifications and Chapters 20 and 22 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

NOTE: Traffic control devices such as signs, barricades, cones, and drums are paid as rental items. As a traffic control device is installed, the sign installation is noted and it is measured for payment. The rental payment for each specific device is for the duration of the work. No additional compensation is paid if the same device is used at a different location.

627 - PERMANENT SIGNS

The placement and locations of permanent signs and sign foundations, both edge of roadway and over roadway, may require field adjustments due to existing conditions that prohibit placement or restrict view. Sign panels and foundations vary in size as well as the materials used to construct them. Refer to the contract documents for additional information.

BEFORE CONSTRUCTION

Before work begins, the inspector will:

- Ensure that the locations identified in the Contract Documents are achievable with the existing field conditions.
- Identify existing obstacles, structures, right-of-way and visibility issues that may require field adjustments for the sign location.
- Keep in mind the panel size, overall height and depth of footing required.
- Ensure that all survey is complete and accurately depicts location changes required by field conditions.
- Verify material certifications and required shop drawings have been provided prior to placement of sign panels and sign structure elements.

DURING CONSTRUCTION

During the placement of permanent signs, the inspector will:

- Ensure that compaction requirements are achieved when sign islands are required. Refer to the, Sheet T-34.1.6, “General Sign Islands”, of the Standard Plans, for the sign island details when a special detail in the contract documents is not provided. Inspect foundations prior to sign placement for correct location and orientation of sign base connecting elements. Ensure all posts are set plumb and to the correct height.
- Ensure that signs that provide directional information are covered until traffic is allowed to make the directional movement.
- Ensure that directional signs scheduled for removal should not be removed until the appropriate traffic control is in-place.
- Ensure that all permanent signs have been properly stamped or engraved, after being placed, in accordance with Section 627, “Permanent Signs” and Subsection 627.03.03, “(Permanent Signs) (Construction) Installation”, of the Standard Specifications.

MEASUREMENT AND PAYMENT

Refer to Subsection 627.04.01, “(Permanent Signs) (Method of Measurement) Measurement” and Subsection 627.05.01, “(Permanent Signs) (Basis of Payment) Payment”, of the Standard Specifications and Chapter 20 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

632 - PERMANENT PAINTED PAVEMENT MARKINGS

Pavement marking materials can be any of the following:

- Epoxy paint
- Waterborne paint
- Thermoplastic
- Polyurea paint

The location of the permanent painted pavement markings can be found in the project plans.

Materials shall conform with Section 729, “Traffic Paint” and Section 730, “Traffic Beads”, of the Standard Specifications.

NOTE: Employees working around thermoplastic material should wear suitable personal safety equipment, long-sleeved shirts, and eye protection. Thermoplastic material heated to excessive temperatures can flash and splatter when exposed to air. Review all applicable Safety Data Sheet (SDS) for safety requirements.

BEFORE CONSTRUCTION

Before work begins, the inspector will:

- Review striping and marking plans and details, and take note of any special requirements.
- Review existing field conditions. (The Resident Engineer will discuss any necessary changes with the District Traffic Engineer.)
- Discuss pavement marking materials and placement operations with the Contractor.
- Obtain material certificates of compliance before or when the materials are delivered to the job site. Examine the materials as they arrive. Look for clearly labeled containers. Verify the delivered materials are in accordance with Subsection 632.02.01, “(Permanent Painted Pavement Markings) (Materials) General”, of the Standard Specifications.
- Obtain required samples as specified in Part 2 of the *Field Testing Guide*.
- Inspect the Contractor’s equipment for compliance with Subsection 632.03.02, “(Permanent Painted Pavement Markings) (Construction) Striping Equipment”, of the Standard Specifications.
- Verify that the rate of application of the paint and glass beads will meet the requirements of the Subsection 632.03.04, “(Permanent Painted Pavement Markings) (Construction) Application”, of the Standard Specifications.
- Verify that the locations of pavement markings have been laid out as shown in the project plans.
- If installing pavement markings using stencils, verify that the Contractor’s stencils will produce pavement markings as per the dimensions shown in the project plans.

DURING CONSTRUCTION

During the application of the permanent painted pavement markings, the inspector will:

- Verify that the pavement markings are applied to the completed pavement surface within the time frame as outlined in the contract documents.
- The inspector will verify that the pavement markings meet the requirements as outlined in Section 632, "Permanent Painted Pavement Markings", of the Standard Specifications, and that the pavement markings are in the correct location as shown in the project plans.
- Verify that pavement marking material is placed within the temperature range as shown in the contract documents or as recommended the manufacturer.
- Before applying pavement marking material, check and document the pavement temperature, atmospheric temperature and expected weather conditions. Never apply materials when rain, fog or condensation could damage the freshly painted surface.
- Before applying pavement markings, check the condition of the pavement. The pavement must be dry and clean as specified.
- Check traffic stripes for the correct width, lengths of gaps and stripes, alignment and direction of application.
- Check that the applied paint material complies with thickness requirements. Check the paint thickness before application of glass beads and record it on NDOT Form 040-021 (Striping Paint Thickness Report).
- Check application rates for glass beads and paint. Inspect the stripes to verify that glass beads are spread uniformly and are properly embedded.
- Check thermoplastic markings for workmanship as the markings are applied. Do not permit bumps resulting from overlaps in extruded materials.
- Take samples, when necessary, in accordance with the sampling frequency as shown in Part 2 of the *Field Testing Guide*.
- After application, look for any damage to striping or marking. Document any deficiencies, and notify the Contractor and Resident Engineer to determine the appropriate required corrective action.
- Conduct and document an immediate night inspection to verify the retro-reflectivity of the installed material. Notify the Contractor and the Resident Engineer of any defective work.

From 1 to 2 weeks after installation, monitor the Contractor checking the retro-reflectivity of the installed material with a reflectometer listed on the Qualified Product List. Checking the retro-reflectivity is required for final acceptance and is reported on NDOT Form 040-041 (Retroreflectivity Measurements). Notify the Contractor and the Resident Engineer if the retro-reflectivity fails to meet the requirements in Subsection 632.03.05, "(Permanent Painted Pavement Markings) (Construction) Final Acceptance", of the Standard Specifications.

MEASUREMENT AND PAYMENT

Refer to Subsection 632.04.01, "(Permanent Painted Pavement Markings) (Method of Measurement) Measurement" and Subsection 632.05.01, "(Permanent Painted Pavement Markings) (Basis of Payment) Payment", of the Standard Specifications and Chapter 19 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

633 - PAVEMENT MARKERS

Non-reflective pavement markers are made of a ceramic, plastic, polyester, acrylonitrile butadiene styrene (ABS) or material and coated to match the required color for the application they will be used for.

Reflective pavement markers are made of a methyl methacrylate or ABS plastic with a prismatic reflector embedded in one or either end, depending on the application. The color of the reflector and the marker shall be as designated in the project plans.

Raised pavement markers are usually adhered to the pavement surface using an adhesive recommended by the manufacturer of the pavement markers. The requirements for the adhesive can be found in Subsection 633.03.01, "(Pavement Markers) (Construction) Pavement Marker Installation", of the Standard Specifications.

Recessed pavement markers may be required in areas subjected to snow removal operations. These will require additional preparation as a slot, in which the pavement marker will be placed, needs to be installed. This slot is usually created using a specialized machine that grinds the pavement at the location of the marker to create the slot. The pavement marker is then glued to the bottom of the slot using an adhesive that is recommended by the pavement marker manufacturer.

BEFORE CONSTRUCTION

Before work begins, the inspector will:

- Review striping and marking plans and details, and take note of any special requirements.
- Review existing field conditions. The Resident Engineer will discuss any necessary changes with the District Traffic Engineer.
- Discuss pavement marker materials and placement operations with the Contractor.
- Obtain material certificates of compliance before or when the materials are delivered to the job site. Examine the materials as they arrive. Look for clearly labeled containers. Verify that the delivered materials are in accordance with Subsection 633.02.01, "(Pavement Markers) (Materials) Non-Reflective Pavement Markers" and/or Subsection 633.02.02, "(Pavement Markers) (Materials) Reflective Pavement Markers", of the Standard Specifications.
- Confirm that pavement markers and adhesive are on NDOT's approved Qualified Product List.
- Obtain required samples as specified in Part 2 of the *Field Testing Guide*.
- Verify that the locations of pavement markers have been laid out as shown in the project plans.

DURING CONSTRUCTION

during the installation of the pavement markers, the inspector will:

- Before placing pavement markers, confirm that new pavement has cured for the specified time.
- The inspector will verify that the pavement markers meet the requirements as outlined in Section 633, "Pavement Markers", of the Standard Specifications, and that the pavement markers are in the correct location as shown in the project plans.
- Before applying adhesives, check that the pavement or recessed surface is clean and dry.

- Determine that the patterns and types of pavement markers are placed correctly in accordance with the typical details in the project plans.
- After placement, determine that the pavement markers are not on longitudinal or transverse joints and that they are fully supported with adhesive.
- Also after placement, look for any missing or damaged pavement markers and document any deficiencies.
- Conduct and document an immediate night inspection to verify the retro-reflectivity of the installed markers. Notify the Contractor and the Resident Engineer of any defective work.

When installing temporary markers, the Contractor shall replace lost or damaged markers daily.

MEASUREMENT AND PAYMENT

Refer to Subsection 633.04.01, “(Pavement Markers) (Method of Measurement) Measurement” and Subsection 633.05.01, “(Pavement Markers) (Basis of Payment) Payment”, of the Standard Specifications and Chapter 19 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

634 - PAVEMENT MARKING FILM

Pavement marking film is designed to be inlaid into the fresh open-graded surface during final rolling of the mat. Coordination between the paving crew and the pavement marking crew is critical to proper installation of marking film. An additional roller may be necessary to properly install marking film. The location of the marking film can be found in the project plans.

BEFORE CONSTRUCTION

Before work begins, the inspector will:

- Review striping plans and details and take note of any special requirements.
- Review existing field conditions. The Resident Engineer should consult with the District Traffic Engineer if any changes to the contract documents are necessary.
- Discuss pavement marking materials and placement operations with the Contractor.
- Obtain material certificates of compliance before or when the materials are delivered to the job site. Examine the materials as they arrive. Look for clearly labeled containers. Verify that the delivered materials are in accordance with Section 732, “Pavement Marking Film”, of the Standard Specifications.
- Obtain required samples as specified in Part 2 of the *Field Testing Guide*.
- Verify that the locations of pavement markers have been laid out as shown in the project plans.
- If installing pavement markings using stencils, verify that the Contractor’s stencils will produce pavement markings as per the dimensions shown in the project plans.

DURING CONSTRUCTION

During the installation of the pavement marking film, the inspector will:

- The inspector will verify that the pavement marking film meets the requirements as outlined in Section 634, "Pavement Marking Film", of the Standard Specifications, and that the pavement marking film is in the correct location as shown in the project plans.
- Verify that the pavement marking film is installed before the surface temperature of the mat falls below 160°F.
- After placement, look for any missing or damaged pavement marking film and document any deficiencies.
- Conduct and document an immediate night inspection to verify the retro-reflectivity of the installed pavement marking film. Notify the Contractor and the Resident Engineer of any defective work.
- For final acceptance, the inspector will perform an adhesion test in accordance with Subsection 634.03.02, "(Pavement Marking Film) (Construction) Pavement Marking Tape", of the Standard Specifications. The test results are recorded on NDOT Form 040-047 (Pavement Marking Film Adhesion Test).

MEASUREMENT AND PAYMENT

Refer to Subsection 634.04.01, "(Pavement Marking Film) (Method of Measurement) Measurement" and Subsection 634.05.01, "(Pavement Marking Film) (Basis of Payment) Payment", of the Standard Specifications and Chapter 19 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

635 - TEMPORARY PAVEMENT STRIPING TAPE

The contract documents will describe the locations and type of temporary striping tape to be installed. Temporary striping tape must be completed before opening the roadway to traffic. The Contractor shall maintain and remove temporary striping tape as directed without additional compensation.

BEFORE CONSTRUCTION

Before work begins, the inspector will:

- Review striping plans and details and take note of any special requirements.
- Review existing field conditions. The Resident Engineer should consult with the District Traffic Engineer if any changes to the project plans may be necessary.
- Discuss pavement marking materials and placement operations with the Contractor.
- Obtain material certificates of compliance before or when the materials are delivered to the job site. Examine the materials as they arrive. Look for clearly labeled containers. Verify that the delivered materials are in accordance with Subsection 635.02.01, "(Temporary Pavement Striping Tape) (Materials) General", of the Standard Specifications.
- Verify that the locations of temporary pavement striping tape have been laid out as shown in the project plans.

DURING CONSTRUCTION

during the installation of the temporary pavement striping tape, the inspector will:

- Verify that the temporary pavement striping tape meets the requirements as outlined in Section 635, “Temporary Pavement Striping Tape”, of the Standard Specifications, and that the temporary pavement striping tape is in the correct location as shown in the project plans.
- Check the condition of the pavement prior to application of the temporary pavement striping tape. Ensure the pavement is dry and clean as specified.
- After placement, look for any missing or damaged temporary pavement striping tape and document any deficiencies.
- Conduct and document an immediate night inspection to verify the retro-reflectivity of the installed temporary pavement striping tape. Notify the Contractor and the Resident Engineer of any defective work.
- Verify that the Contractor maintains and removes all temporary pavement striping tape as directed by the Resident Engineer.

MEASUREMENT AND PAYMENT

Measurements are typically taken with a measuring wheel or a vehicle mounted electronic measuring device. Refer to Subsection 635.04.01, “(Temporary Pavement Striping Tape) (Method of Measurement) Measurement” and Subsection 635.05.01, “(Temporary Pavement Striping Tape) (Basis of Payment) Payment”, of the Standard Specifications and Chapter 19 of the *Documentation Manual* for additional measurement/payment guidelines and related instructions.

636 - TEMPORARY PAINTED PAVEMENT MARKING

On certain contracts, temporary traffic control plans will be provided by the Department and included in the project plans. Otherwise, the Contractor is responsible for providing traffic control plans for the contract, which includes detailing the layout of the temporary painted pavement markings.

Temporary striping must be completed before opening the roadway to traffic.

For temporary striping paint to adhere to the pavement surface the air temperatures must be at least 45°F and the surface temperature must be above 32°F. The Contractor shall maintain temporary pavement striping without additional compensation.

All materials shall conform with Section 729, “Traffic Paint” and Section 730, “Traffic Beads”, of the Standard Specifications.

BEFORE CONSTRUCTION

Before work begins, the inspector will:

- Review striping plans and details and take note of any special requirements.
- Review existing field conditions. The Resident Engineer consults with the District Traffic Engineer if any changes to the traffic control plans are necessary.
- Discuss pavement marking materials and placement operations with the Contractor.

- Verify that the locations of the temporary painted pavement markings have been laid out as shown in the project plans.
- If installing pavement markings using stencils, verify that the Contractor's stencils will produce pavement markings as per the dimensions shown in the project plans.

DURING CONSTRUCTION

During the application of temporary painted marking, the inspector will:

- Verify that the pavement markings are applied to the completed pavement surface within the time frame as outlined in Subsection 636.03.01, "(Temporary Painted Pavement Marking) (Construction) General", of the Standard Specifications.
- Verify that the temporary painted pavement marking meets the requirements as outlined in Section 636, "Temporary Painted Pavement Marking", of the Standard Specifications, and that the temporary painted pavement markings are in the correct location as shown in the project plans.
- Take samples, when necessary, in accordance with the sampling frequency as shown in Part 2 of the *Field Testing Guide*.
- After placement, look for any missing or damaged temporary painted pavement markings and document any deficiencies.
- Conduct and document an immediate night inspection to verify the retro-reflectivity of the installed temporary painted pavement markings. If any deficiencies are discovered, notify the Contractor and the Resident Engineer.
- Monitor the Contractor to verify that retroreflectivity readings have been obtained and meet the requirements of Subsection 636.03.01, "(Temporary Painted Pavement Marking) (Construction) General", of the Standard Specifications. Notify the Contractor and the Resident Engineer if the retro-reflectivity fails to meet specifications.

MEASUREMENT AND PAYMENT

Measurements are typically taken with a measuring wheel or a vehicle mounted electronic measuring device. Refer to Subsection 636.04.01, "(Temporary Painted Pavement Marking) (Method of Measurement) Measurement" and Subsection 636.05.01, "(Temporary Painted Pavement Marking) (Basis of Payment) Payment", of the Standard Specifications and Chapter 19 of the *Documentation Manual* for additional measurement/payment guidelines and related instructions.

637 - TEMPORARY POLLUTION CONTROL

Temporary pollution control consists of the construction, installation, maintenance and removal of temporary pollution and erosion control measures. This work prevents or minimizes air pollution, erosion, sedimentation and pollution of water and wetlands that can occur during a construction project.

During the design phase, a project is evaluated to determine estimated cost of the Temporary Pollution Control effort. Temporary pollution control will be included on all NDOT contracts. Location of project has a significant role in the level of effort required to achieve compliance. Projects within the Lake Tahoe basin require additional effort to meet the guidelines of the Tahoe Regional Planning Authority. Projects that are located in rural Nevada that do not have the potential to drain to a waters of the state will require a lower level of effort.

Regardless of permitting requirements the Contractor shall provide a Stormwater Pollution Prevention Plan (SWPPP). The SWPPP shall be updated and on site at all times.

In order to be in compliance, all disturbed areas must be stabilized. Stabilization effort may be rock mulch, hydro seeding, planting, decorative rock, or a combination of all. (Refer to the appropriate sections of the contract documents for this information.)

Temporary pollution control measures used to reduce water pollution and erosion are called Best Management Practices (BMPs). Temporary pollution control and erosion control work must conform to the requirements of the NDOT *Construction Site Best Management Practices Manual* and all permitting requirements. The Contractor and the Resident Engineer have the following responsibilities relating to temporary pollution control:

- Contractor responsibilities:
  - Contact the Nevada Department of Environmental Protection (NDEP) at least 7 days before the Pre-Construction Conference to obtain appropriate permits.
  - Prepare a Stormwater Pollution Prevention Plan (SWPPP) containing Best Management Practices that conform with the NDOT *Construction Site Best Management Practices Manual* before submitting the Notice of Intent (NOI) to NDEP.
  - File a NOI with NDEP at least 2 days before starting work.
  - Provide copies of the SWPPP and environmental permits to the Resident Engineer before beginning work.
  - Photograph areas that will be disturbed.
  - Designate an individual as the Water Pollution Control Manager (WPCM).
  - Update the SWPPP as needed and provide copies to the Resident Engineer.
- Inspector responsibilities:
  - Photograph areas that the Contractor will disturb.
  - Inspect BMP installations weekly and document on NDOT Form 018-001 NDOT (Construction Site Stormwater Inspection Form for NDOT Construction Crews). Inspections shall also be performed after a significant water event of 0.5 inches or more.
  - If deficiencies are noted, monitor the situation daily to confirm compliance within 7 days. If deficiencies are noted contact the designated WPCM immediately. Repair should begin within 24 hours and be completed within 7 days. The inspector will monitor the situation daily to confirm compliance.

The Best Management Practices in the NDOT *Construction Site Best Management Practices Manual* are minimum requirements that the Contractor implements on construction projects. As necessary, the Contractor may implement other best management practices in addition to the minimum required by the NDOT *Construction Site Best Management Practices Manual*.

The Contractor shall install and maintain erosion and sedimentation BMPs in accordance with the BMPs designated in the Contractor's SWPPP for the contract. Refer to the NDOT *Construction Site Best Management Practices Manual* for additional information.

BEFORE CONSTRUCTION

Before the Contractor begins temporary pollution control work, the inspector will:

- Review the Contractor's schedule to identify construction activities that require placement of temporary and permanent erosion control measures.

- Review the Contractor's approved SWPPP to identify the types and locations of the Best Management Practices (BMPs) that the Contractor proposes to use. Refer to the NDOT *Construction Site Best Management Practices Manual* for additional information.

DURING CONSTRUCTION

During temporary pollution control work, the inspector will:

- Observe installation of the Best Management Practices (BMPs) and verify that the installation conforms to the Contractor's approved SWPPP.
- Inspect the installed BMPs and verify that each is performing in the intended manner.
- Complete NDOT Form 018-001 NDOT (Construction Site Stormwater Inspection Form for NDOT Construction Crews). *This form must be completed weekly or after a significant moisture event.*
- Temporary erosion and sediment control features that have served their useful purpose must be removed by the Contractor, unless directed otherwise by the Resident Engineer.

When the Contractor is granted relief of maintenance, refer to the *NDOT Stormwater Guidance Manual for Construction Projects* for requirements for permit transfer or permit notice of termination requirements.

With projects that have a bid item for plant establishment, the Contractor is not relieved of maintaining the BMPs related to plant establishment until all plant establishment requirements are met.

MEASUREMENT AND PAYMENT

Refer to Subsection 637.04.01, "(Temporary Pollution Control) (Method of Measurement) Measurement" and Subsection 637.05.01, "(Temporary Pollution Control) (Basis of Payment) Payment", of the Standard Specifications and Chapter 24 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

640 - RETAINING WALLS

A retaining wall is a structure that holds back soil or rock. In roadway construction, retaining walls are used along cuts or fills where space is inadequate for construction of cut slopes or embankment slopes. Bridge abutments and foundation walls, which support earth fills, are also designed as retaining walls. Retaining walls are typically used for:

- New or widened roadways in developed areas.
- New or widened roadways in mountains or near steep slopes.
- Bridge abutments, wing walls, and bridge embankments.
- Slope stabilization.
- Protection against falling rock.
- Depressed roadway sections.

Retaining walls prevent downslope movement or erosion and provide support for vertical or near-vertical grade changes. Retaining walls may be made of masonry block, stone, brick, concrete, steel or timber. This topic addresses masonry block retaining walls.

Because of their design, masonry block retaining walls are generally limited in height as they will not withstand a significant amount of lateral loading. Verify that the height of the wall does not exceed the height as detailed in the project plans.

Section 640, "Retaining Walls", of the Standard Specifications, contains the requirements for construction of masonry block retaining walls.

Materials for constructing masonry block retaining walls shall be in accordance with:

- Section 501, "Portland Cement Concrete", of the Standard Specifications.
- Section 505, "Reinforcing Steel", of the Standard Specifications.
- Section 701, "Portland Cement", of the Standard Specifications.
- Subsection 706.03.04, "(Aggregates for Portland Cement Products) (Physical Properties and Tests) Grout and Mortar Aggregate", of the Standard Specifications.
- Section 722, "Water", of the Standard Specifications.

BEFORE CONSTRUCTION

Before work begins, the inspector will:

- Review the contract documents.
- Verify that all materials delivered to the jobsite are in acceptable condition and are in accordance with the contract documents.
- Verify that the location and elevation of the retaining wall have been staked out according to the project plans.
- Verify that the Contractor has located all utilities within the work area.

DURING CONSTRUCTION

during construction of the retaining wall, the inspector will:

- Verify that the site is excavated to the proper elevation, all unsuitable material is removed and replaced with suitable or specified material, and the foundation soil is properly compacted.
- Verify that the footings have been constructed according to Section 502, "Concrete Structures", of the Standard Specifications.
- Monitor retaining wall construction to verify that it is in accordance with the contract documents.
- When drainage components are specified in the retaining wall, verify that the components are correctly located and constructed according to the contract documents.
- Verify reinforcing steel has been installed according to the contract documents.
- Confirm that sampling and testing requirements are met as specified in Part 2 of the *Field Testing Guide*.
- Make sure backfilling does not occur until the contract documents for concrete strength are met and the minimum number of days have passed.
- Monitor placement and compaction of backfill material until the top of the fill is reached. Verify the that the depth of each lift does not exceed requirements. (Refer to Section 207, "Backfill", of the Standard Specifications, for backfill requirements.)

- Verify that any traffic barriers, coping, or other appurtenances that may be attached to the wall are properly installed as shown in the project plans.

MEASUREMENT AND PAYMENT

Refer to Subsection 640.04.01, "(Retaining Walls) (Method of Measurement) Measurement" and Subsection 640.05.01, "(Retaining Walls) (Basis of Payment) Payment", of the Standard Specifications and Chapter 14 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

641 - VEHICULAR IMPACT ATTENUATORS

A vehicular impact attenuator is a device placed on the leading end of a barrier rail, guardrail, or other obstruction to reduce the damage that would otherwise be caused to the structure as a result of the impact from an errant motor vehicle. The impact attenuator can also help to reduce damage to motor vehicles and injury to motorists resulting from a collision as the impact attenuator is designed to reduce the speed of the vehicle gradually or possibly even redirect the vehicle after impact with the attenuator.

There are several different manufacturers and models of impact attenuator available for use. Unless otherwise specified, it is generally up to the Contractor to choose the manufacturer and model of impact attenuator they wish to install. Regardless of who selects or specifies the manufacturer and model of attenuator to be used, impact attenuators must be crash-tested and certified before they can be approved for use on NDOT contracts. Those models that have been tested and certified will be listed on the Qualified Products List (QPL).

BEFORE CONSTRUCTION

Before work begins, the inspector will:

- Review the contract documents and the QPL.
- Check the type of impact attenuator proposed and ensure that the manufacturer's shop drawings have been submitted and are approved.
- Obtain copies of the approved shop drawings for the exact model of impact attenuator as proposed and approved.
- Confirm that planned locations are consistent with current field conditions.
- Verify that the location and elevation of the impact attenuator has been staked out according to the project plans and/or shop drawings.
- Confirm concrete proposed for the foundation slabs will meet the required strength specified in Section 501, "Portland Cement Concrete" and Section 641, "Vehicular Impact Attenuators", of the Standard Specifications.
- Verify receipt of the proper certificates of compliance.

DURING CONSTRUCTION

during the construction of vehicular impact attenuators, the inspector will:

- Verify that the site is excavated to the proper elevation and is in the correct location, all unsuitable material is removed and replaced with suitable or specified material, and the foundation soil is properly compacted.
- Verify that reinforcing steel is installed into the foundation slab as detailed in the project plans and/or approved shop drawings and meets the requirements of Section 505, "Reinforcing Steel", of the Standard Specifications.

- Verify that the concrete foundation slabs have been constructed as detailed in the project plans and/or approved shop drawings and meets the requirements of Section 502, "Concrete Structures", of the Standard Specifications.
- Verify that all required anchor bolts are embedded into the concrete as it is being placed if specified in the approved shop drawings or plan details.
- Verify that the concrete for the foundation slab has been properly cured and meets the strength requirements of the contract documents or the manufacturer's recommendations before the impact attenuator is installed on the foundation slab.
- Verify that all bolts, nuts and miscellaneous hardware are installed and tightened according to the approved shop drawings and manufacturer's recommendations. If torque specifications are provided, ensure that bolts are tightened to the proper torque. If any hardware is missing or installed incorrectly, notify the Contractor and the Resident Engineer as soon as the error is discovered.
- Verify that the reflective panel on the nose of the attenuator is in the proper orientation. When installed correctly, the pattern will be angled downward toward the traffic side of the panel.
- Verify that backfilling of the foundation slab has been performed according to the contract documents and the compaction of the backfill meets requirements. Requirements for backfill can be found in Section 207, "Backfill", of the Standard Specifications. Sampling and testing requirements are in Part 2 of the *Field Testing Guide*.
- Verify that the slopes around the attenuator meet the requirements of the project plans and/or approved shop drawings, pay particular attention to the approach side of the attenuator.

MEASUREMENT AND PAYMENT

Refer to Subsection 641.04.01, "(Vehicular Impact Attenuators) (Method of Measurement) Measurement" and Subsection 641.05.01, "(Vehicular Impact Attenuators) (Basis of Payment) Payment", of the Standard Specifications and Chapter 19 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

642 - MECHANICALLY STABILIZED EARTH WALLS

A retaining wall is a structure that holds back soil or rock. In roadway construction, retaining walls are used along cuts or fills where space is inadequate for construction of cut slopes or embankment slopes. Retaining walls prevent downslope movement or erosion and provide support for vertical or near-vertical grade changes. Bridge abutments and foundation walls, which support earth fills, are also designed as retaining walls.

A common type of retaining wall is the Mechanically Stabilized Earth (MSE) wall. (See Figure 56.) MSE walls utilize metallic or polymer geogrid reinforcement that is embedded into the soil during backfilling of the MSE wall. The reinforcement comes in different forms, such as reinforcing strips or grid pattern reinforcement. The reinforcement is connected to precast MSE facing panels or modular blocks to create a reinforced soil mass. The backfill soil and reinforcement act together with the MSE panels to restrain the soil.

Figure 56: Typical MSE wall

MSE wall systems are available in a variety of patented configurations. MSE wall systems consist of leveling pads, or footings, precast facing panels, panel spacers, soil reinforcement, and connecting hardware. Because MSE wall systems are patented processes, the Contractor selects the MSE wall system based on the design constraints contained in the contract documents. MSE wall manufacturers that are approved for installation are listed on the Qualified Products List (QPL). Based on their choice of MSE wall manufacturer, the Contractor shall submit MSE wall shop drawings for review and approval.

MSE wall installation typically involves:

- Preparation of the base material. This includes excavating to the MSE wall foundation grade, removing and replacing any unsuitable soil, and compacting the foundation soil.
- Construction of a concrete leveling pad or footing for the MSE wall facing panels or modular blocks. Depending on the height of the retaining wall, a gravel pad may be substituted for a concrete leveling pad.
- Placement of the first row of MSE wall facing panels on the leveling pad or footing. The first tier of precast facing panels shall be braced in order to maintain alignment and stability.
- Placement and compaction of the MSE backfill, and embankment if specified in the project plans, up to the first layer of reinforcement.
- Placement of the second row of MSE wall facing panels.
- Layout and installation of the soil reinforcement.
- Placement and compaction of backfill over the soil reinforcement.
- Continued placement of wall panels, soil reinforcement and backfill to final wall height.
- Construction of traffic barriers, copings, or attachment of other appurtenances to the wall.

Materials for constructing MSE Walls shall conform to Section 501, “Portland Cement Concrete”, Section 505, “Reinforcing Steel”, Section 701, “Portland Cement” and Section 722, “Water”, of the Standard Specifications.

BEFORE CONSTRUCTION

Because the Contractor designs the MSE wall system based on the design constraints contained in the contract documents, the Contractor shall submit working (shop) drawings, calculations, and construction manuals to the Resident Engineer before construction can begin. The requirements for submittals from the Contractor are found in Subsection 642.01.04, “(Mechanically Stabilized Earth Walls) (Description) Submittals”, and Subsection 105.12, “(Control of Work) Inspection”, of the Standard Specifications. Upon receipt, the Resident Engineer will review the Contractor’s submittal for completeness and, if the submittal is sufficient, forward it to the Structures Division, which consults with the Materials Division for review and approval.

Before work begins, the inspector will:

- Review all contract documents.
- Confirm that the soil types and groundwater conditions encountered at the MSE wall locations match the conditions established in the geotechnical report for MSE wall design. If any differences are discovered, notify the Contractor and the Resident Engineer immediately.
- Review the Contractor's approved method of construction, working drawings, project plans and construction manuals related to the MSE wall.
- Verify that panels and soil reinforcement material delivered to the job site are in acceptable condition and stored appropriately.
- Verify that the location and elevation of the MSE walls have been staked out according to the project plans and/or shop drawings.
- Verify the Contractor has located all utilities within the work area.

A pre-activity meeting shall be held no more than 2 weeks in advance of the beginning of scheduled wall construction. Attendance will be mandatory for the Contractor's approved on-site supervisor, the MSE wall manufacturer's technical representative and Department representatives.

DURING CONSTRUCTION

The inspector will do the following during construction of the MSE wall:

- Verify that the site is excavated to the proper elevation, all unsuitable material is removed and replaced, and the foundation soil is properly compacted.
- Verify that the concrete leveling pads have been constructed in accordance with Section 502, "Concrete Structures", of the Standard Specifications.
- Monitor MSE wall construction to verify that it conforms to the Contractor's approved working drawings and contract documents.
- When drainage components are specified in the MSE Wall, verify that the structures are correctly located and constructed according to the contract documents.
- Verify that connectors are installed correctly and not in contact with non-galvanized reinforcing steel. Notify the Contractor and the Resident Engineer immediately of any differences.
- Monitor placement and compaction of backfill material and installation of soil reinforcement until the top of the fill is reached.
- Verify that compaction of the backfill is performed according to the requirements of Subsection 642.03.01, "(Mechanically Stabilized Earth Walls) (Construction) General", of the Standard Specifications.
- Confirm that sampling and testing have been performed in accordance with Part 2 of the *Field Testing Guide*.
- Verify that the traffic barrier, coping or other appurtenances that may be attached to the wall are properly installed in the project plans or working drawings.

Figure 57, Figure 58 and Figure 59 show elements of MSE wall installation, including placement of facing panels, stepped foundation excavation, soil reinforcement and temporary wall bracing.

Figure 57: MSE wall installation

Figure 58: Soil reinforcement connected to MSE wall facing panel

Figure 59: MSE wall facing panel

MEASUREMENT AND PAYMENT

Refer to Subsection 642.04.01, "(Mechanically Stabilized Earth Walls) (Method of Measurement) Measurement" and Subsection 642.05.01, "(Mechanically Stabilized Earth Walls) (Basis of Payment) Payment", of the Standard Specifications and Chapter 14 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

643 - GROUND ANCHORS

Ground anchors are steel tendons, such as bars or cables that are grouted in holes drilled into soil. The ground anchors transmit tensile loads into the ground, using the strength of the soil to restrain or anchor other structural elements (e.g., retaining walls).

Each ground anchor is installed into a pre-drilled hole and then grouted into place. Grouted ground anchors, also called tiebacks, are usually installed at a slight downward inclination. (See Figure 60.)

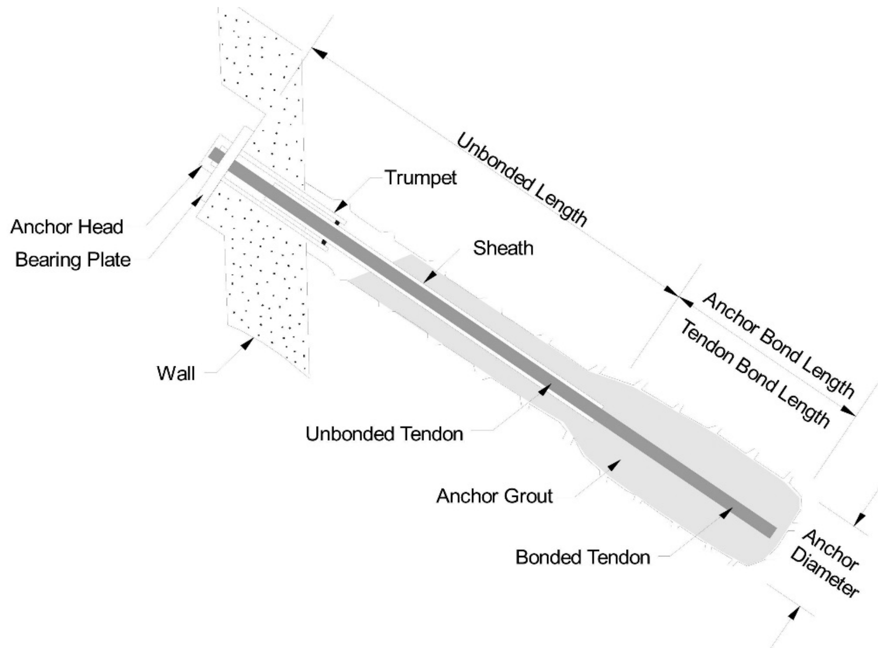

Figure 60: Ground anchor cross-sectional view

Many similarities exist with the installation of ground anchors and soil nails. One key difference is that ground anchors are post-tensioned after construction of the retaining wall. For post-tensioning and other detailed requirements, refer to Section 643, “Ground Anchors”, of the Standard Specifications.

Materials used for the construction of ground anchors shall be in accordance with Section 701, “Portland Cement”, Section 702, “Concrete Curing Materials and Admixtures”, and Section 722, “Water”, of the Standard Specifications.

BEFORE CONSTRUCTION

The Contractor performing the construction of the ground anchors must be qualified to perform ground anchor construction and shall provide its qualifications and submittals in accordance with Subsection 643.01.02, “(Ground Anchors) (Description) Qualifications” and 643.01.03, “(Ground Anchors) (Description) Submittals”. The Resident Engineer reviews the submittals for completeness and forwards it to the Materials Division for review and approval.

before work begins, the inspector will:

- Review the contract documents as they relate to ground anchor construction.
- Review the Contractor’s approved submittals.
- Verify the Contractor has located all utilities within the work area.
- Observe and document the pre-construction condition of the work area. (Photo images provide indisputable supporting documentation.)
- Verify that the locations and elevations of the ground anchors have been staked out according to the project plans and/or Contractor’s approved ground anchor details.

DURING CONSTRUCTION

During construction of the ground anchors, the inspector will:

- Check the layout of the ground anchors. Verify that adequate survey control is established.
- Verify that the construction is in accordance with the contract documents. Notify the Contractor and the Resident Engineer immediately of any defective work.
- Verify that the drilled holes for the ground anchors have been cleaned of all material resulting from the drilling operation or other material that would impair the strength of the anchors.
- Monitor the ground anchor for movement and the soil around the ground anchor for subsidence. Notify the Contractor and the Resident Engineer immediately of any movement or subsidence.
- Notify the Structures Division's Non-destructive Testing Section when performance tests are to be conducted on the ground anchors.
- Observe the performance of load testing, performance testing, proof testing and extended creep testing of the ground anchors in accordance with the applicable section of the Standard Specifications.
- Obtain the specified Contractor records that document the ground anchor construction and testing.

MEASUREMENT AND PAYMENT

Refer to Subsection 643.04.01, "(Ground Anchors) (Method of Measurement) Measurement" and Subsection 643.05.01, "(Ground Anchors) (Basis of Payment) Payment", of the Standard Specifications and Chapter 19 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

644 - SOIL NAIL RETAINING WALLS

Soil nailing is a technique for reinforcing soil slopes, excavations or retaining walls. Construction is accomplished by inserting relatively slender steel reinforcing bars into pre-drilled holes and then grouting them into place. In some cases, the soil nails are drilled and grouted simultaneously. Soil nails are usually installed at a slight downward inclination. (See Figure 61.) The soil is stabilized by installing threaded steel bars into the slope as construction proceeds from top down. Installing and grouting these bars creates a stable mass of soil.

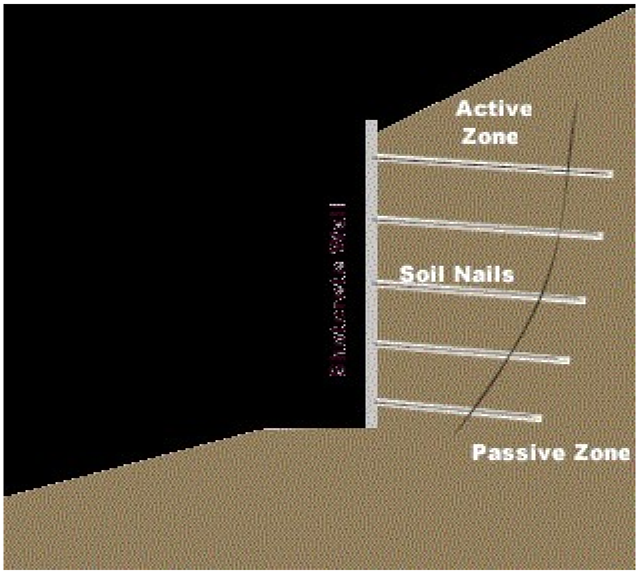

Figure 61: Cross-sectional view of a soil nail wall

Soil nail wall construction is sensitive to ground conditions, construction methods, equipment, and excavation sequencing. For soil nail walls to be economical, they shall be constructed in ground that can stand unsupported on a vertical or steeply cut slope of 3 to 6 feet for at least 1 to 2 days, and that can maintain an open drilled hole for at least several hours.

After soil nails are installed, the face of the slope is typically covered with shotcrete, which is reinforced using woven mesh. The following are common soil nail wall applications:

- Temporary and permanent walls for excavations
- Cut slope retention for roadway widening and depressed roadways
- Bridge abutments: Addition of traffic lanes by removing end slopes from in front of existing bridge abutments
- Slope stabilization
- Repair or reconstruction of existing structures

The following is a typical sequence for the construction of a soil nail wall:

1. Excavation of a vertical cut to the elevation of the soil nails.
2. Drill the hole for the nail.
3. Install and grout the soil nail.
4. Place drain strips and weep holes (if required), mesh reinforcing, the initial shotcrete layer, and install the bearing plates and nuts.
5. Repeat process to final grade.
6. Place the final facing (for permanent walls).

For detailed construction requirements for soil nail walls, refer to Section 644, “Soil Nail Retaining Walls”, of the Standard Specifications.

Materials used for the construction of soil nail retaining walls shall be in accordance with:

- Section 701, "Portland Cement", of the Standard Specifications.
- Section 702, "Concrete Curing Materials and Admixtures", of the Standard Specifications.
- Subsection 706.03.04, "(Aggregates for Portland Cement Products) (Physical Properties and Tests) Grout and Mortar Aggregate", of the Standard Specifications.
- Section 722, "Water", of the Standard Specifications.

BEFORE CONSTRUCTION

The Contractor performing the construction of the soil nail walls must be qualified to perform soil nail wall construction and shall provide its qualifications and submittals in accordance with Subsection 644.01.02, "(Soil Nail Retaining Walls) (Description) Qualifications", and 644.01.03, "(Soil Nail Retaining Walls) (Description) Submittals", of the Standard Specifications. The Resident Engineer reviews the submittals for completeness and forwards it to the Materials Division for review and approval.

Before work begins, the inspector will:

- Review the contract documents as they relate to soil nail wall construction.
- Review the Contractor's approved soil nail wall details and construction plan.
- Attend the mandatory pre-activity meeting.
- Verify that the Contractor has located all utilities within the work area.
- Observe and document the pre-construction condition of the work area. (Photo images provide indisputable supporting documentation.)
- Verify that the locations and elevations of the soil nails have been staked out according to the project plans and/or Contractor's approved soil nail details.
- Coordinate with the Structures Division's Non-destructive Testing Section for inspection of soil nail walls.

DURING CONSTRUCTION

During construction of soil nail retaining walls, the inspector will:

- Check the layout of the soil nails. Determine that adequate survey control is established.
- Before production soil nailing begins, complete a verification testing program. The verification program tests the installation methods and verifies that the soil performs as anticipated. Nails used in the verification testing are sacrificial and are not incorporated as production soil nails.
- Verify that the construction is in accordance with the contract documents and/or the Contractor's approved submittals. Notify the Contractor and the Resident Engineer immediately of any defective work.
- Verify that the drilled holes for the soil nails have been cleaned of all material resulting from the drilling operation or other material that would impair the strength of the soil nails.
- Monitor the soil nail for movement and the soil around the ground anchor for subsidence. Notify the Contractor and the Resident Engineer immediately of any movement or subsidence.
- Notify the Contractor and the Resident Engineer immediately if downward excavation uncovers unanticipated material.

- Notify the Structures Division's Non-destructive Testing Section when testing is to be conducted on the soil nails.
- Observe the performance of the required soil nail testing.
- Obtain the specified Contractor records that document the soil nail wall construction and testing.

MEASUREMENT AND PAYMENT

Refer to Subsection 644.04.01, "(Soil Nail Retaining Walls) (Method of Measurement) Measurement" and Subsection 644.05.01, "(Soil Nail Retaining Walls) (Basis of Payment) Payment", of the Standard Specifications and Chapters14 and 19 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

646 - DAMPPROOFING, WATERPROOFING, SEALING AND MEMBRANES

Waterproofing consists of sealing concrete surfaces to prevent the passage of water. Waterproofing materials include membranes with applications of waterproofing asphalt, and polymer concrete. For bridge decks, overlaying the deck with a thin layer of polymer concrete is the most common method of waterproofing a bridge deck. Polymer concrete is described in Section 496, "Polymer Concrete", of the Special Provisions. When membranes and asphalt are used to waterproof a bridge deck, a bituminous pavement is placed on the waterproof membrane. Waterproofing of other types of concrete surfaces, besides bridge decks, is accomplished with spray-on sealant chemicals.

Dampproofing consists of treating concrete surfaces to retard the passage or absorption of water or water vapor. Concrete surfaces, such as retaining walls, are dampproofed to protect the concrete from nuisance water that may discolor or otherwise detract from the appearance of the concrete. Typically, concrete is dampproofed by applying waterproofing asphalt.

Crack sealing consists of sealing random cracks in structures to prevent water penetration. Random cracks are sealed using chemical sealants. Concrete elements that may be sealed include bridge decks or other component parts of the bridge, such as footings, columns, or pier caps. The spray-on chemical silane is used to seal concrete cracks. Silane is typically used to seal concrete surfaces that are not bridge decks. For bridge decks, methacrylate is commonly used as the chemical sealant. While silane is sprayed onto the concrete, methacrylate, which is more viscous, is flooded onto the bridge deck. Guidance on using methacrylate is described in Section 496 Special Provisions. For the type of waterproofing, dampproofing, or crack sealing material to be used on the project, refer to Section 646, "Dampproofing, Waterproofing, Sealing, and Membranes", of the Standard Specifications.

Due to the specialized nature of this work, the Contractor shall have a skilled technical representative from the manufacturer on-site prior to and during placement to provide training and guidance on the equipment used, proper storage, handling, mixing and application procedures as well as the necessary safety requirements. The manufacturer's technical representative shall remain on-site until released by the Resident Engineer.

Materials used for dampproofing, waterproofing, sealing and membranes shall meet the requirements outlined in Section 646 of the Standard Specifications, and must be listed on the Qualified Products List (QPL).

SAFETY

Chemical sealants require special handling, storage and safety procedures. Because of the volatile nature of the chemicals used, strict adherence to handling and safety procedures is required to avoid violent chemical reactions. All personnel working, handling or transporting the materials, as well as inspectors and material testers, must review safety procedures for handling and applying the chemicals. They may be required to attend safety training before materials arrive at the job site. The inspector will carefully review and understand the Safety Data Sheets (SDS) that the Contractor shall provide.

BEFORE CONSTRUCTION

Before work begins, the inspector will:

- Review the contract documents, paying particular attention to the limits of treatment, type of treatment designated, required deck preparation, traffic control requirements, sampling and testing requirements, and the method and sequence of operation.
- Check the materials delivered to the site to verify they conform to the type designated for the contract. Obtain applicable certificates of compliance. Verify accordance with the contract documents.
- Review application requirements such as weather limitations, surface moisture, and surface and ambient temperatures. Pay particular attention to required drying periods of the sealant.
- Before application of the sealant, check that the age of the concrete is in accordance with the contract documents.

DURING CONSTRUCTION

During the application of waterproofing, dampproofing or sealing treatment, the inspector will:

- Verify that the manufacturer's technical representative is on-site.
- Confirm that the concrete surface has been prepared as required by Subsection 646.03.06, "(Dampproofing, Waterproofing, Sealing, and Membranes) (Construction) Grouting", of the Standard Specifications, and verify receipt of written approval of the surface preparation from the manufacturer's technical representative.
- Verify that the cleaning sequence, timing and methods meet contract documents and/or manufacturer's recommendations.
- Verify that the limits of cleaning for the bridge deck, approach slabs, height of curb above asphalt overlay, height of bridge rail above deck and sidewalks are in accordance with the project plans.
- When a primer is specified, observe the application and ensure that the limits and application rate comply with the manufacturer's recommendations.
- Verify that the dampproofing, waterproofing, crack sealant, surface sealant and/or liquid membrane are applied in accordance with the contract documents and/or manufacturer's recommendations.
- If sheet membrane is specified, verify that the membrane is placed at the appropriate time after the primer is applied. The Contractor shall place the membrane with an overlap at the seams so that a shingling effect is achieved that directs runoff toward curbs and drains. The placed membrane must not have wrinkles and air bubbles.
- Notify the Contractor and the Resident Engineer immediately of any defective work.

MEASUREMENT AND PAYMENT

Refer to Subsection 646.04.01, "(Dampproofing, Waterproofing, Sealing, and Membranes) (Method of Measurement) Measurement" and Subsection 646.05.01, "(Dampproofing, Waterproofing, Sealing, and Membranes) (Basis of Payment) Payment", of the Standard Specifications and Chapter 19 of the *Documentation Manual* for measurement/payment guidelines and related instructions.

660 - PNEUMATICALLY PLACED CONCRETE MORTAR

Pneumatically placed concrete is mortar or concrete that is applied under pressure through a hose. Pneumatically placed concrete mortar is also called shotcrete. Shotcrete is pneumatically projected at high velocity onto a surface. Placement and compaction occurs at the same time due to the force with which it is projected from the nozzle. Shotcrete can be applied or impacted onto a variety of types or shapes of surfaces, including vertical or overhead areas.

Shotcrete is used for lining ditches and channels, slope paving, temporary wall facings, and other similar features. When used as a ditch lining or slope paving, shotcrete stops soil from eroding. As a temporary wall facing, shotcrete also restrains the soil during the process of constructing retaining walls that require soil to be excavated from the top to the bottom.

When shotcrete is used as a temporary wall facing, it is generally used in conjunction with ground anchors or soil nails, providing a system that stabilizes a slope prior to constructing a permanent retaining wall. For details relating to ground anchors and soil nails, refer to "643 - Ground Anchors" and "644 - Soil Nail Retaining Walls", in this chapter. The sequence of construction operations when using shotcrete as a temporary wall facing begins at the top of the slope being excavated and proceeds downward. For example, if a slope will be excavated in thirds, the top third is excavated first. If specified, ground anchors or soil nails are installed next, and then shotcrete is applied to the wall face. The process repeats as the excavation progresses downward to the middle third, then to the bottom third. After the bottom third is completed, construction of the permanent retaining wall facing begins. The dimensions of the excavation are detailed in the contract documents.

Shotcrete used with ground anchors and soil nail walls has specific requirements relating to Contractor qualifications and material submittals and must be constructed in conformance with the approved submittals. For other applications in which shotcrete has no structural function, refer to the contract documents for further guidance.

Materials used for pneumatically placed concrete mortar shall be in accordance with Section 701, "Portland Cement", Section 702, "Concrete Curing Materials and Admixtures" and Section 722, "Water", of the Standard Specifications.

BEFORE CONSTRUCTION

The Contractor performing the construction of the soil nail walls must be qualified to perform soil nail wall construction and shall provide its qualifications and submittals in accordance with Subsection 644.01.02, "(Soil Nail Retaining Walls) (Description) Qualifications", and 644.01.03, "(Soil Nail Retaining Walls) (Description) Submittals", of the Standard Specifications. The Resident Engineer reviews the submittals for completeness and forwards it to the Materials Division for review and approval.

The Contractor shall be qualified to perform placement of the shotcrete and shall provide its qualifications and submittals in accordance with Subsection 660.01.02, "(Pneumatically Placed Concrete Mortar) (Description) Qualifications", and Subsection 660.01.03, "(Pneumatically Placed Concrete Mortar) (Description) Submittals", of the Standard Specifications. The Resident Engineer reviews the submittals for completeness and forwards it to the Materials Division for review and approval.

Before work begins, the inspector will:

- Review the contract documents as they relate to temporary wall construction.
- Review the Contractor's approved methods of shotcrete placement.
- Attend the mandatory pre-activity meeting.
- Obtain a copy of the approved shotcrete mix design.

- Verify the qualifications of the persons applying the shotcrete.
- If used in conjunction with ground anchors and/or soil nails, verify that ground anchors and/or soil nails have been successfully proof tested.
- Verify that the pre-construction test panels have been constructed, tested and accepted before beginning the shotcrete operation.

DURING CONSTRUCTION

Before the shotcrete operation begins, inspect the excavation face, observing that the face is free of loose debris. The face of the excavation shall be free of irregularities that could cause quantity overruns. Monitor placement of drainage elements, such as geocomposite drainage strips. Geocomposite drainage strips shall be connected to weep holes (drainage holes that allow water to escape from behind the wall) and then secured to prevent movement during shotcrete placement. Confirm that weep holes are located above the finish grade, thereby providing unobstructed drainage. Shotcrete wall facings are reinforced with welded wire fabric or mesh, or reinforcing steel. Before shotcrete placement, inspect reinforcement in accordance with the contract documents.

During excavation for the retaining wall or slope, the Contractor shall produce a face that is relatively smooth and free of loose debris, mud or other foreign matter that prevents or reduces concrete bond. The face of the excavation should be free of irregularities that could cause areas of excessive thickness. After the surface is prepared and prior to the application of the shotcrete material, drainage elements, such as geocomposite drainage strips must be installed as shown in the project plans or working drawings and will usually be connected to weep holes. Weep holes will be located above the finish grade, thereby providing unobstructed drainage. Shotcrete wall facings are reinforced with welded wire fabric or mesh, or reinforcing steel. The weep holes, geocomposite strips, and shotcrete reinforcement must be secured to prevent movement during shotcrete placement. The finished surface should be as applied by the shotcrete gun or rough screeded to remove any high points. Curing will not be required for the shotcrete surface.

The Contractor shall obtain core samples of the placed shotcrete, and the inspector will observe the coring, collect the Contractor's samples and transmit them to the Materials Division for compressive strength testing. Requirements for sampling and testing are outlined in Section 660, "Pneumatically Placed Concrete Mortar", of the Standard Specifications, and Part 2 of the *Field Testing Guide*.

during construction of pneumatically placed concrete mortar surfaces, the inspector will:

- Verify that the construction is in accordance with the contract documents.
- If ground water is encountered during construction, verify that the water flow is diverted and any standing water is removed.
- Shotcrete placement shall be suspended during inclement weather, such as rain and wind, unless the Contractor provides approved protection methods.
- If the shotcrete is being applied as part of ground anchor and/or soil nail construction, confirm that the Contractor installs the bearing plate and nut to each nail head before the initial set of the shotcrete.
- Verify that the proper controls are in place to monitor the thickness of the applied shotcrete. Incorrect shotcrete thickness can negatively affect permanent retaining wall construction.
- Verify that any anchors for cast-in-place (CIP) forms for the finished wall face are installed and tested as required in the contract documents and/or working drawings.
- Verify that the Contractor has obtained the required core samples as required by Subsection 660.03.01, "(Pneumatically Placed Concrete Mortar) (Construction) General", of the Standard Specifications.

- Verify that the core holes are filled after completion of sampling.

MEASUREMENT AND PAYMENT

Refer to Subsection 660.04.01, "(Pneumatically Placed Concrete Mortar) (Method of Measurement) Measurement" and Subsection 660.05.01, "(Pneumatically Placed Concrete Mortar) (Basis of Payment) Payment", of the Standard Specifications and Chapter 19 of the *Documentation Manual* for measurement/payment guidelines and related instructions.