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INVESTIGATION OF CORROSION OF MSE WALLS IN NEVADA

J. D. Thornley, R.V. Siddharthan, Ph.D., P.E., and Barbara Luke, Ph.D. P.E.

Nevada Department of Transportation has over 150 mechanically stabilized earth (MSE) retaining walls at 39 locations. Recently, high levels of corrosion were observed due to accidental discovery at two locations (I-515/Flamingo and I-515/Cheyenne intersections). The subsequent investigations of these walls produced direct measurements regarding the corrosion losses of the soil reinforcements and electrochemical properties of the MSE backfill. The I-515/Flamingo wall was replaced with a cast-in-place tie-back wall at great expense because of the significant metal loss due to corrosion. A UNR/UNLV research team that included Professors Raj V. Siddharthan and Barbara Luke undertook an investigation to evaluate the extent of the MSE wall corrosion in Nevada walls.

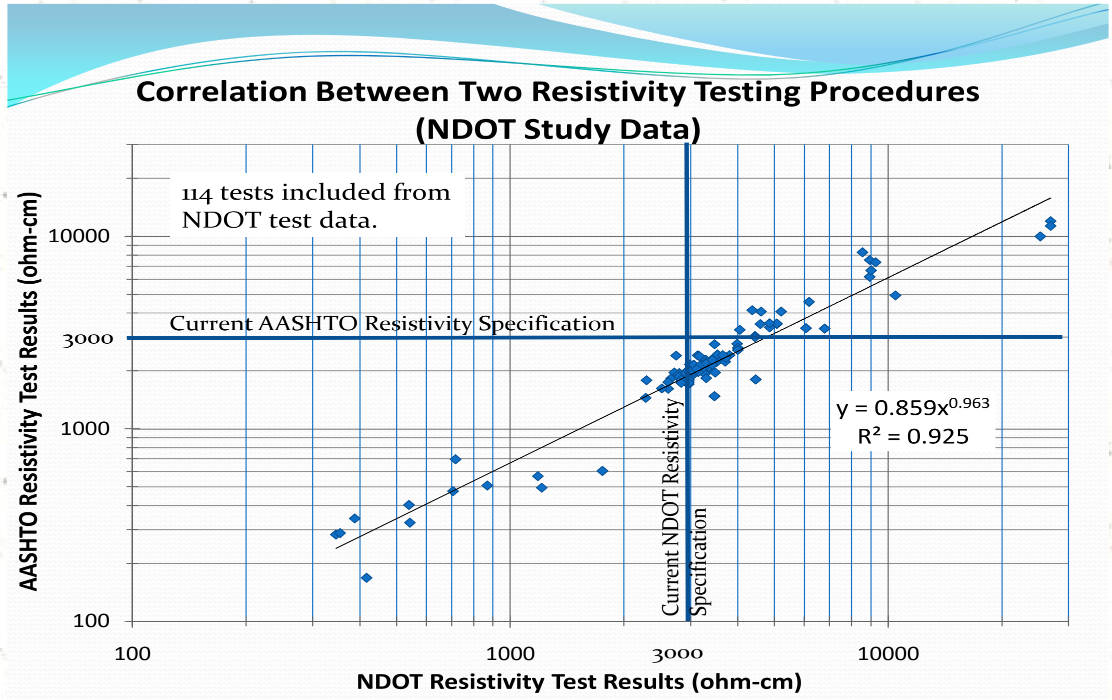

Fig. 1: Correlation Between AASHTO T-288 and NDOT T235B Test Methods for Resistivity Measurements

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It was shown that the original MSE backfill approval test results are significantly different from those measured in subsequent testing using in-situ backfill samples. A correlation (Fig. 1) has been developed between two distinctly different soil resistivity laboratory test methods, namely the Nevada T235B and AASHTO T-288 methods. The Nevada test method under-predicts the corrosive nature of backfill soils when compared to the AASHTO test method. Our MSE wall investigations show this under-prediction has proved detrimental to the service lives of MSE structures.

A statistical analysis of electrochemical test results from backfill samples obtained with pre- and post-construction of Nevada MSE walls were used to interpret the severity of wall corrosion. Figure 2 below shows the partial results obtained for all Nevada District 1 walls constructed from 1982 – 2008. The cut-off resistivity for approval of backfill for construction is 3000 ohm-cm, and the values below are considered unsuitable. The results shown in figure for District I indicate (1) as many as seven wall sites have average resistivity below the 3000 ohm-cm limit; and (2) the resistivity's at both I-515-Flamingo and I-515/Cheyenne sites are below the cut-off limit. Such plots along with other test data such as sulfates and chlorides contents were used to predict the aggressiveness of MSE backfills. The study resulted in the ranking of Nevada MSE walls relative to its estimated backfill aggressiveness. In addition, specific suggestions for future corrosion analysis and monitoring have also been made.

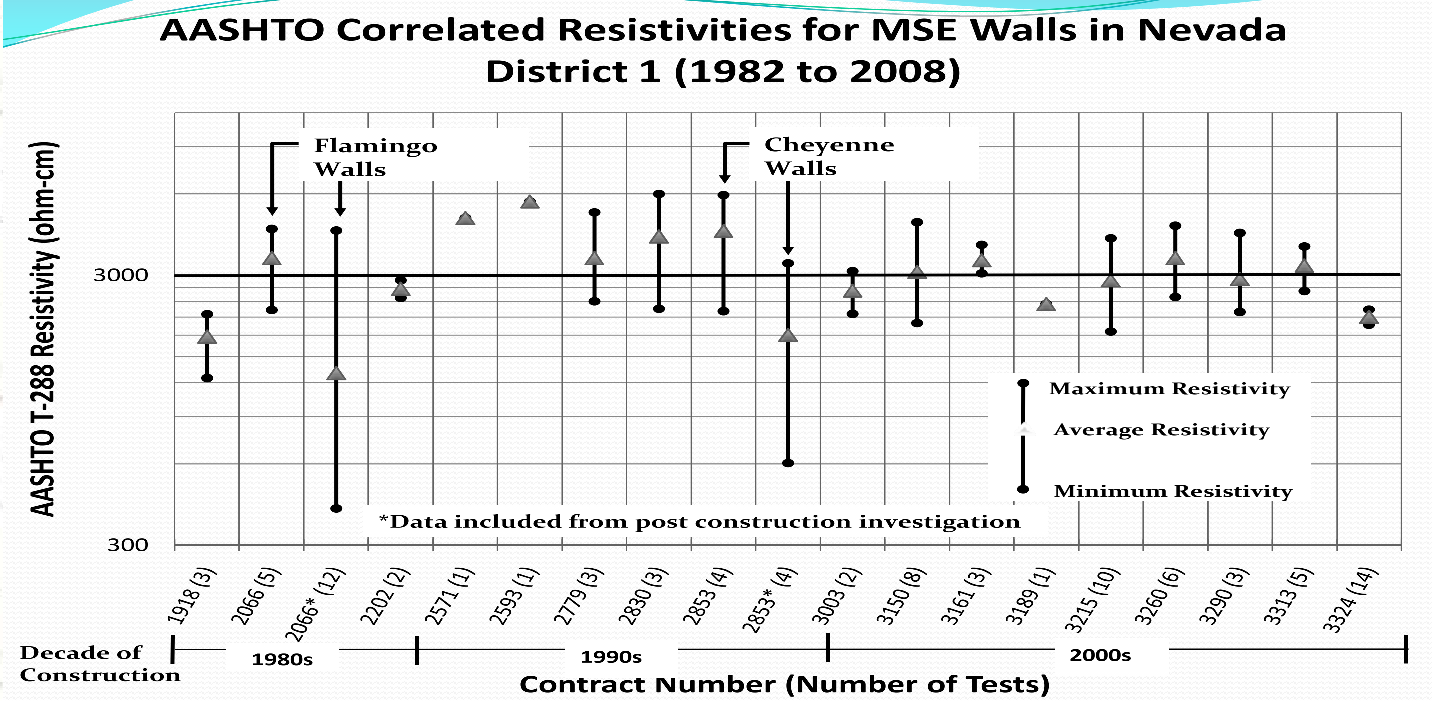


Fig. 2: Resistivity Measurements of MSE walls in Nevada District 1

The internal stability analyses (using AASHTO 2007 LRFD) of two remaining MSE walls at I-515/ Flamingo intersection were also performed using corrosion loss models developed from the statistical analysis of the direct measurements. The results of the analysis from these two intersections were subsequently extrapolated to other Nevada MSE walls.

Precast U-girders Integrally Connected to a Cast-in-Place Substructure

Kevin Almer and David Sanders, Ph.D.

There are numerous advantages in using precast concrete for bridge components. In theory, the use of precast bridge components can significantly reduce the amount of construction time needed at a job site due to the fact the precast components are fabricated off-site, usually with better tolerances than their cast-in-place counterparts. Additionally, false work is virtually eliminated wherever the precast elements are used, thus saving construction time and effort at the job site and drastically reducing potentially dangerous situations to both construction workers and the general public. Since the highway infrastructure is rapidly aging, widening of older bridges and new bridge construction, often in highly congested areas, is becoming a necessity. Precast elements are a good solution to accelerate the construction process and reduce the inconvenience to motorists. The Nevada Department of Transportation has funded a research project at the University of Nevada to investigate how this technology can be integrated into the Nevada highway system. The purpose of this study is to investigate the longitudinal seismic behavior of the integral connection between precast concrete girders and cast-in-place concrete and develop design guidelines based on analytical and experimental testing for the Nevada Department of Transportation (NDOT).

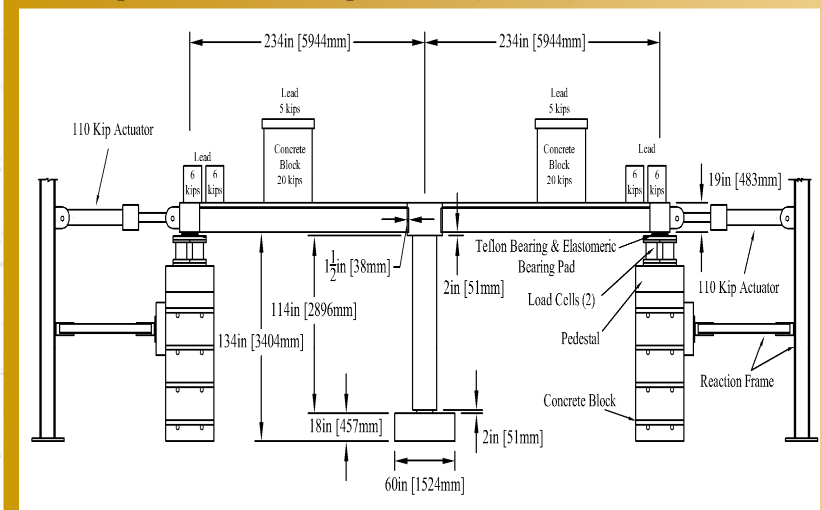


Figure 1: Experimental Test Configuration

A survey was conducted to determine what methods are being used by other states. Two primary options were identified. One option is to use post-tensioning and deck reinforcement for negative moment continuity and mild-reinforcement for positive moment continuity; the second option, utilized by the Washington State Department of Transportation, is to use only deck reinforcement for the negative moment region and unstressed prestress strands for the positive region. The drawback of using strands is its tendency to slip under cyclic loads, thus requiring some sort of mechanical connection. The post-tensioning detail is very advantageous because it allows the section to have a high negative moment capacity without having to increase reinforcement amounts in the deck. From this investigation, the most important parameter was the amount of post-tensioning used in the girders. Therefore, four precast U-girders were selected for experimental investigation using varying amounts of post-tensioning in the negative moment region of the girder connection and mild-reinforcement spliced through the bent-cap in the positive moment connection region.

The experimental program consists of testing four, 40% scale bridge specimens to investigate the ability of the integral connection to transfer seismic forces in the longitudinal direction between the substructure and superstructure. Figure 1 shows the test configuration adopted for this study. Notice that mass is added on both spans; this was necessary to achieve the correct scaled dead load and secondary moments in the region near the bent-cap. The first three specimens were designed with the inelastic behavior in the superstructure at the girder/bent-cap interface while allowing very limited inelastic behavior in the column. This is not what is done in design but it allowed a more detailed study of the joint region. The first three specimens investigated the level of post-tensioning: 1) Specimen 1, UGHP (U-shaped girder high post-tensioning) contained a post-tensioning level of 0.15 f'cAg; 2) Specimen 2, UGLP (U-shaped girder low post-tensioning), had a level of 0.11f'cAg; and 3) Specimen 3 had no post-tensioning. The fourth specimen, UGHPM (U-shaped girder high post-tensioning modified), had girder connection details identical to UGHP, but a reduced column size. This resulted in having all the inelastic behavior in the column while the superstructure remained elastic (similar to the tests at University of California San Diego) (1)). Essentially this test verified the connection details as it would be built in the field. Figures 2 and 3 show the specimen details. Figure 4 shows typical lateral load to horizontal displacement plots that come from the experiments.

Post-analysis analytical modeling was conducted to predict force-displacement response and compare against the experimental data. Computer models using SAP2000 were developed for each specimen using several techniques that consisted of inserting non-linear springs in potential plastic hinge locations that were defined based on moment-curvature cross-sectional analyses. These models were capable of capturing the behavior of the girder-to-bentcap connection. To understand the force transfer between the column and superstructure that occurs in the joint, 2-D and 3-D strut-and-tie models were developed based on experimental data gathered for each specimen. Extensions of these models to handle other loading cases such as when the girder centerlines are not collinear with the column centerline are proposed based on both research presented in this study and by others.

Based on both the experimental and analytical data presented in this study, design recommendations were proposed for integral connection design. Some of the primary conclusions are:

1. The girder-to-bentcap connection details used in this study, with or with-out post-tensioning, were adequate in providing full continuity to transfer seismic forces between the substructure and superstructure. The details included continuous mild-reinforcement in the deck, post-tensioning or lap-spliced mild-reinforcement

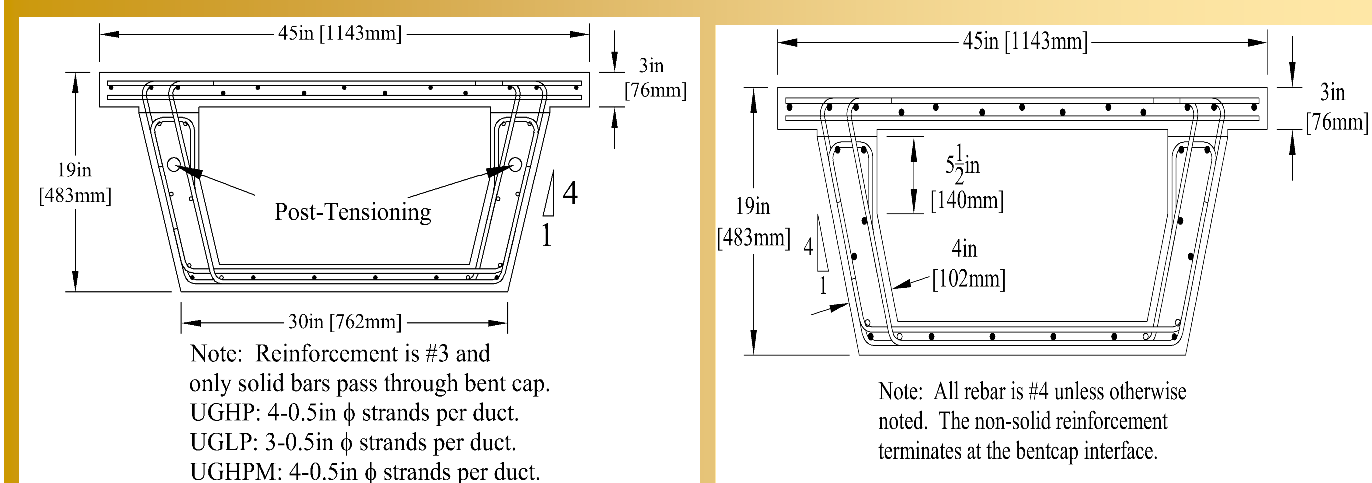


Figure 2: (a) Girder section UGHP, UGLP, UGHPM; (b) UGNP

2.Measured strains on joint reinforcement and measured average joint panel principle strains indicated a strong beneficial influence of post-tensioning on joint performance for each of the specimens.

3.The lateral load capacity of each specimen was limited by a large, nearly horizontal crack that developed at the top of the joint, and as a result of load cycling, extended across the entire width of the joint. The size and location of the crack affected the force transfer within the joint resulting in premature failure in the girders. This crack had minimal influence for specimens UGHP, UGLP, and UGNP but had significant influence on specimen UGHPM by forcing the damage out of the column and into the superstructure. Current joint design models do not take this crack into account and are therefore unconservative.

(a) (b)

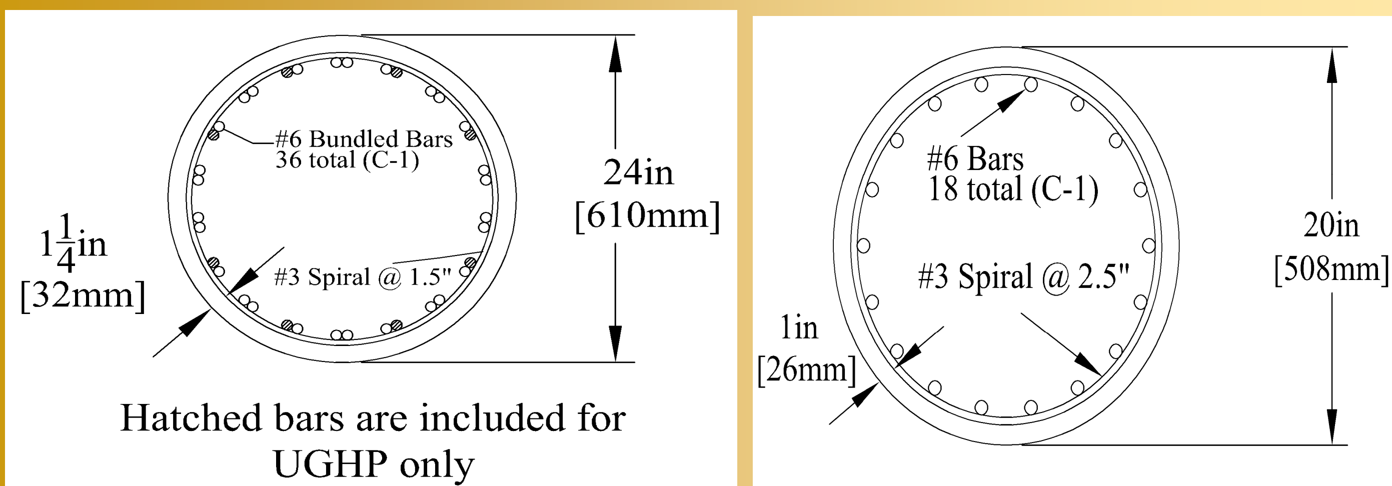
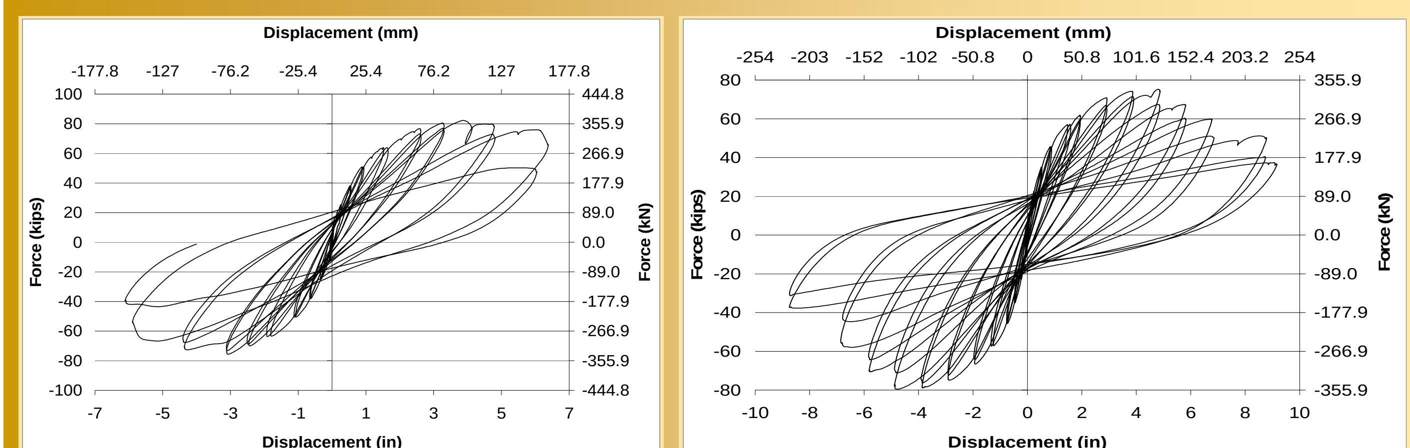


Figure 3: (a) Column section UGHP, UGLP, UGNP; (b) UGHPM

4. Strut-and-tie modeling indentified short-comings of current joint design guidelines. The experimentally developed 2-D strut-and-tie provide a rational means of determining both vertical and horizontal stirrup reinforcement necessary to avoid potential incomplete load paths.



(a) (b)

Figure 4: (a) UGHP Hystersis Curve (b) UGLP Hysteresis Curve

PRODUCT EVALUATION COMMITTEE (PEC) JUNE 2009 MEETING SUMMARY

Roma Clewell, NDOT Product Evaluation Coordinator

Vendor Presentations: Three (3) vendors made presentations to the Product Evaluation Committee (PEC) at the June 2009 meet-

McTech Group

Rick Jordan, McTech Group, presented information on UltraCure DOT Wet Curing Blankets. Wet Curing Blankets are used to hydrate concrete structures during the 14 day curing process. The light weight blankets can be applied using current NDOT practices. The blankets provide thorough hydration, less discoloration, and a more evenly cured slab. They can be pre-soaked or post-soaked and spread flatly across the concrete structure and will retain 100% relative humidity on the slab for approximately 7-14 days with minimal rehydration, depending on the type of blanket used and the curing period. By using UltraCure DOT Wet Curing Blankets, material, installation labor, rewetting time and costs are reduced.

Dow Corning Corporation and DM Figley Company

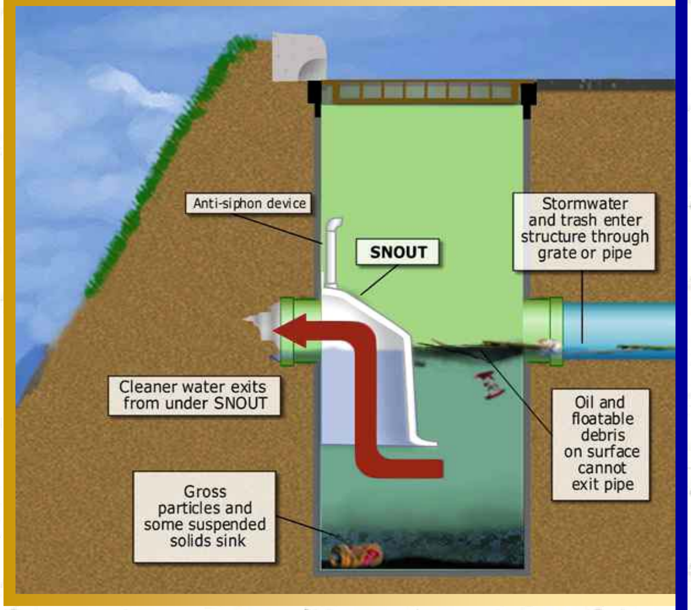
Jason Sika, Pavement Products Program Manager, Dow Corning Corporation, and Brian Des Rochers, DM Figley Company, shared information about Dow Corning's 888 Silicone Joint Sealant, 890-SL Self-Leveling Silicone Joint Sealant, and 902 RCS Silicone Sealant. Sealants are used to create adhesion and prevent small chunks of concrete from breaking away and becoming a safety hazard. Sealants are used in joints that call for a tough sealant that can withstand excessive horizontal and vertical movement (i.e. withstands extension of 100 percent and compression of 50 percent of original joint width), has good weatherability and work in a wide range of temperatures. They are easy to install with short downtime and long service life. Sealants have excellent recovery and can be used in transverse, longitudinal, centerline, and shoulder joints. Sealants are often used in remedial work, especially where other materials have failed because of excessive movement or poor weatherability.

Advanced Drainage Systems Incorporated and Nyloplast

Mike Titchener, Southwest Area Manager of Nyloplast, and Christopher Karabinus, Sales Representative, Advanced Drainage Systems Incorporated, discussed Nyloplast's PVC Drainage Systems and Storm Water Treatment Products.

Nyloplast is a plastic drainage system, which provides better hydraulic performance, extended service life, and cost efficiencies in installation and maintenance costs.

Nyloplast also makes storm water treatment products such as inserts and inlet protection devices designed to improve water quality as part of the National Pollution Discharge Elimination System (NPDES) and EPA Phase II standards.



Field Review

The Product Evaluation Committee (PEC) approved a field review of East Jordan Iron Works Manhole Adjustment Risers. The manhole adjustment risers is a multi-purpose rubber composite adjustment riser capable of equalizing load distribution, dissipating vibrations, and preventing high stress concentration areas, all of which are detrimental to sewer infrastructures. Another advantage is purported to be cost effectiveness due to reduced water infiltration, prolonged structure life, reduced traffic vibration damage, and protection against load concentration stress. There is no need to tear out new paving, brick and mortar to grade, then re-patch the street. In addition, there are no traffic disruptions — when the street is paved the job is done and the EJIW riser is finished to grade. The system is also safe, has quick installation, precise and durable. Should our research determine the product is a valuable asset, NDOT may create a Qualified Products List (QPL) category for similar products.

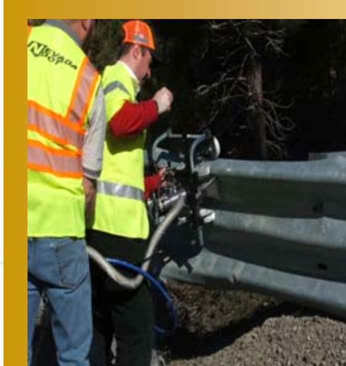
PRODUCT EVALUATION FIELD TEST

EZ Liner and Potters Industries Incorporated partnered to create the Ultra Guard Safety system. The system offers a unique, low cost delineation alternative to mounted reflectors.

Using EZ Liner's Ultra Guard Cart, an airless paint gun, and Potter Industries' Ultra Guard™ Bead system, a line of paint is striped toward the top of guard rails and barriers providing drivers a continuous retroreflective guide to changes in road direction, i.e. curves, work zones, etc. The intent is to provide drivers with more reaction time avoiding collisions due to increased preview time. Ultra Guard will delineate the roadway better and more effectively alert drivers to the change in road direction due to continuous delineation.

It is also purported that cost savings will be achieved because the marking life will last longer than the current mounted reflectors. Mounted reflectors pop off annually when hit by snow plows, but the retroreflective beaded line is protected from snow plow hits and may remain, conservatively, 3-5 years before re-striping the lines. Waterborne paint is used so the cost of the striping system is cheaper than the current system. The product requires very little equipment for the project. A small truck can be equipped with a large barrel to hold the paint and another barrel holding the beads. Paint-and-bead lines (adaptive hardware that cost approximately $500) are then attached to the EZ Liner's Ultra Guard Cart that cost approximately $6,000 and moved along the barrier on rollers while the pressurized paint and beads are applied.

Three field tests will be conducted one in each District. The first field test was placed in District II along the Mount Rose Highway on existing guardrail between milepost 15.3 and 15.4. Attached pictures show the installation of this project. Another test is scheduled this summer for Pequop Summit in District III on the median on the west side of I-80 at milepost 91.30 to 94.87. The retro reflective line will be placed on the constant slope concrete barrier rail. Finally, District I will also complete a demonstration of the project; the time and place have yet to be determined.



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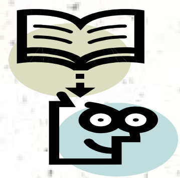

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The NDOT Research Division administers the Department's research, development and technology transfer program and serves as the "clearing-house" for product evaluations.

Research and Technology Review is published quarterly by the NDOT Research Division. Its purpose is to provide the latest information on the NDOT research activities including product information and other pertinent research topics.

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