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EVALUATION of 1988 CHIP SEAL TEST SECTIONS on US 50 BETWEEN FALLON and SILVER SPRINGS, NEVADA

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16. Abstract

Results of this study showed that pre-coated aggregates appeared to improve the overall rating when used with viscosity grade binders. The benefit obtained from pre-coating seemed to be dependent upon the binder quality. Given combinations of binders and aggregates, the overall rating appeared to be sensitive to changes in the quality of binder and aggregate. High float emulsions had slightly higher overall ratings than the LMCRS-2H.

The evaluation of laboratory Vialit tests resulted with these conclusions; Test results for samples prepared with emulsions were influenced by changes in aggregate source/gradation, binder quality, and aggregate quantity. Each combination of binder and aggregate required different quantities of materials to achieve an optimum percent material retained. The test was not sensitive to changes in the viscosity grade binders when samples were prepared at 300F. A comparison of the Vialit tests and field observations showed it appeared to identify the rate of set and potential construction problems when chip seals were constructed with emulsions. The standard Vialit test was not applicable for viscosity grade binders. The Vialit test could be adapted to simulated different binder temperatures at the time of aggregate application for chip seals constructed with viscosity grade binders.

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INTRODUCTION

Chip seals are commonly used as a maintenance tool. Extended pavement life can be gained by sealing minor cracks thereby reducing the infiltration of moisture and air. Other benefits obtained by using chip seals are improvements in surface texture, road noise, and demarkation of lanes. Raveling of moisture damaged or dry surfaces can also be helped with the use of a chip seal. However, as beneficial as chip seals can be, they are not without their problems.

Prior to the 1988 Nevada construction season, several reoccurring problems in chip seals had been noted. These problems included slow set rates of the binder, excessive aggregate whip-off when seal coats were initially opened to traffic, and failure to adequately adhere stones during the early years of the seal coats life. These problems prompted a condition survey of chip seals of various ages throughout Nevada by Lido Quilici of the Nevada Department of Transportation (NDOT), Jon Epps of the University of Nevada Reno and other NDOT personnel.(2) These condition surveys resulted in a decision to place various experimental chip seal test sections on US Route 50 between Fallon and Silver Springs, Nevada. Variables for the test sections were chosen based on NDOT personnel experiences, and successful experiences by the Texas Department of Transportation. The final selection variables included changes in aggregate gradations and source, types of emulsions and viscosity graded binder (modified and unmodified).

This report details construction, condition surveys immediately, one month and eight months after construction as well as laboratory testing conducted by the University of

Nevada, Reno.

BACKGROUND

Design Methods

Design methods for chip seals have been used since the 1930's. The original work and methodology was developed by Hansen (New Zealand).(1) This initial concept was based on the orientation of the aggregate after being subjected to traffic. Hansen suggested that aggregate tended to rotate under traffic so that the actual thickness of the chip layer, one stone deep, was the height of the least dimension of the aggregate. The concept of average least dimension (ALD) was developed based on this theory.

Hansen stated that when the particles were orientated in their densest configuration, lying on their flattest sides, they produce voids between the stones of 20 percent. The amount of binder to be used was then calculated as 70 percent of this 20 percent void. This 70 percent was based on "low" traffic volume; 60 percent was recommended for "high" traffic volume.

In the 1950's, McLeod reported Victoria, Australia's modification of Hansen's procedure. This included the use of a slotted plate for determining a Flakiness Index which was used for determining the ALD.(2) Suggestions for the selection of binders and aggregates were presented based on historical observations of performance versus traffic volumes and either aggregate type (e.g. limestone, quartz) and aggregate shape (e.g. crushed, rounded).

Mcleod also expanded Hansen's design to cover both graded aggregate and multiple layered chip. The design for the multiple layered chip seals was based on the concept of decreasing the maximum nominal stone size for each successive layer.(3)

Hveem, Lovering, and Sherman also developed a design procedure for California in the 1950's.(4) This method replaced the ALD with the effective maximum size of the aggregate. A series of nomographs were developed to aid in the selection of quantities of aggregate based on the effective maximum size and unit weight. Nomographs for selecting the optimum binder were based on the porosity of the aggregate and the existing pavement surface condition. Traffic considerations were only addressed when considering desirable aggregate properties for a specific traffic volume.

In the 1960's, the Texas Transportation Institute (TTI) developed another chip seal design method. This method calculates the quantity of aggregate needed based on the quantity of aggregate required to cover a known area (e.g. one square yard) with a layer one stone thick.(5) The quantity of binder is calculated as a function of the residual asphalt content on the binder, expected traffic volume, season of construction, and existing pavement condition.

Several variations of both Hansen's and Mcleod's design methods have been proposed. Marais suggested a single layer surface treatment design method based on the loose aggregate ALD percentage of voids.(6) Nomographs were developed that incorporated traffic conditions, embedment depth of aggregate, and aggregate properties such as degradation, wear, and strength.

Marek and Herrin, and Potter and Church proposed using a modification of the Marshall compaction method to determine the hardness of the existing pavement surface. This in turn was related to an estimation of final aggregate embedment.(7,8)

Semmelink proposed a design method that uses a modified tray test to determine the total voids in the chip seal, the hardness of the existing pavement (i.e. modified Marshall compaction method), and the effective layer thickness (ELT) in place of the ALD.(9) This design method is applicable for both single and double chip seals.

Other, less widely used, design methods and modifications are presented in the literature. Davidson proposed a design method based on long standing use of the same materials by the same contractor (South Africa).(10) Slurry seals have been used as "cape seals" in order to provide an interlocking layer for the chip seal in some locations.(11) Winnitoy incorporated values for the loose and compacted coverage of aggregate and the mean particle diameter into a combination of both Hansen's and Lovering's (et.al.) design procedures.

Test Methods for Design Procedures

Very few test methods provide results for input into the various design methods. These are:

1. Average Least Dimension (ALD).
2. Modified Tray Test Average Least Dimension (MALD).
3. Board Test.
4. Hardness of Existing Surface.

These tests are discussed below.

ALD: The most widely used test is for determining the ALD.(2,3,6,7,9,13) The ALD is the least height that the average stone in the chip seal can provide. First, the gradation for the chip seal aggregate is plotted. The sieve size that has approximately 50 percent height to width of stones is used to enter a nomograph to determine the ALD.

MALD: The modified tray test calculates the total voids in the chip seal (before binder).(9) This test uses a container that will hold a known volume of sand. The bottom of the empty container is then covered with the chip stone. An impervious flexible material is then placed over the chip stone, and the remaining volume is filled with sand. The voids in the chip stone are a function of the volume of sand minus the combined volume of the sand and chip stone.

Board Test: The board test provides a calculation of the quantity of aggregate necessary for the chip seal. This test simply involves spreading by hand a quantity of aggregate as dense as possible, one stone deep, over a given area. The weight of aggregate per square yard of surface area is then calculated.(5)

Hardness of Existing Surface: A 3/4 inch steel ball is placed between the pavement surface and a marshall hammer. Both the pavement temperature and the depth of penetration of the ball after 5 blows of the hammer are recorded.(9)

Materials

Binders: A wide range of binders have been used to construct chip seals: anionic, cationic, and high float emulsions, cutbacks, paving grade asphalt cements, epoxies, and latex or crumb rubber-modified binder systems. A detailed presentation of the physical and chemical properties of the anionic and cationic emulsions was developed by Holberg.(14) This report also presented guidelines for choosing an emulsion that is compatible with various classifications of aggregates.

Several people have preferred the use of high float emulsions over the anionic or cationic because of their non-newtonian nature.(15,16,17) Non-newtonian fluids are resistant to flow because of a rather complex dependency of shear stress on shear rate. Benefits attributed to these emulsions are the ability to be used with a graded aggregate, reluctance of material to flow into ruts, and an improved wetting of the aggregate surface due to the high percentage of light fractions.

Thermosetting epoxy resins have been used on a very limited basis for constructing chip seals on both portland cement concrete and asphalt concrete surfaces.(18) The limited test sections placed with these binders appeared successful.

Rubberized asphalt cements and latex modified emulsions have been used for several reasons.(19,20) These modified binders have been reported to seal cracks, inhibit reflective cracking, and aggregates tended to retain a more upright position (i.e. improving skid resistance). Construction comments noted that heavier rollers were needed (e.g. 18 ton followed by 3-12 tons) in order to embed the aggregate into the rubberized binder.(21)

Aggregates: Most sources agree that there are several desirable aggregate properties such as cleanliness, durability (i.e. Los Angeles Abrasion), an angular, cubical shape to aggregates (i.e. ALD), and resistance to polishing and crushing.(1 through 21)

Construction Practices

Construction practices vary a little but usually recommend that the distributor truck be followed immediately (within seconds) by the aggregate application.(22,23,24) One of three types of chip spreaders are typically used:

1. Self-propelled.
2. Wheel mounted (hooked onto the truck and pushed backwards).
3. Truck mounted or tailgate mounted.

Aggregates are usually rolled within ten minutes after application. Pneumatic rubber tired rollers are used for either older or uneven surfaces. Steel wheel tandem roller are occasionally used for smooth surfaces. It is not uncommon to see both types of equipment working in combination on the same job. Vibratory rollers are not recommended because of problems with crushing or dislodging the chips.(24)

Brooming can be started within one hour to 24 hours after the application of the aggregate depending on the binder system, atmospheric and other conditions.

RESEARCH PROGRAM

The purpose of this research program was to evaluate the performance of various binder-aggregate systems, field versus design quantities of binders and aggregates, and one-sized versus a graded aggregate. The goal was to develop a chip seal system that results in less vehicle damage, fewer motorist complaints, and good seal performance.

The scope of the research program included the following variables incorporated into 63 test sections placed on US 50 between Fallon and Carson City, Nevada during August and September, 1988:

1. Two emulsions (latex modified cationic rapid set (LMCRS-2H) and high float (HFE)).

2. Three paving grade binders (AR 2000, AC10 modified with an SBR, and a polymer-modified AR2000).

3. Two aggregate gradations (each gradation from a different source).

4. Light weight aggregate.

5. Pre-coated aggregate.

6. Various quantities of binders and aggregates.

Observations by the district engineer and other NDOT personnel, and University of Nevada, Reno (UNR) were recorded during construction of all test sections. A field condition survey was completed by the district engineer and UNR staff approximately one month after construction.

Concurrent laboratory testing at UNR was conducted with material obtained from both the binder suppliers and NDOT construction stock piles. The physical properties of the binders were obtained from NDOT Materials Laboratory testing construction records.

MATERIALS

Binders

Emulsions: The latex modified cationic and the high float emulsions were LMCRS-2H and HFE 100S, respectively. The LMCRS-2H was supplied by Reed and Graham of Sacramento, California. The HFE 100S was supplied by Elf Asphalt of Madras, Oregon. While large quantities of binders were not sampled during construction, all suppliers shipped duplicate batches of binders within one week of construction of the test sections. These duplicate materials were used for laboratory testing at UNR.

The physical properties of the LMCRS-2H and the HFE 100S emulsions used for the test sections are shown in Table 1.

Viscosity Grade: The physical properties of the AR2000, AC-10R, and the PM2000 are shown in Table 2.

The AR 2000 was supplied by Huntway refinery located in Benecia , California; the AC-10R by Conoco refinery located in Las Vegas, Nevada; and the PM 2000 by Asphalt Services, Inc. refinery located in Martinez, California. Suppliers shipped additional materials immediately after construction for laboratory testing at UNR.

Aggregates

Three sources of aggregates two in Nevada and one from Utah were used to construct the test sections. The first Nevada source (NV) produced a NDOT 1/2 inch specification chip stone of crushed river gravel and was obtained from Jack N. Telford, located in Fallon, Nevada. The second Nevada source (TX) produced a gradation conforming to the Texas Grade 4 and was obtained from Tibbals Construction Inc. located in Yerington, Nevada.(25) The differences in the gradations are shown in Table 3 and Figure 1. The Utah (UT) aggregate was light weight synthetic aggregate produced from expanded clay. This aggregate was obtained form the Utelite Corporation, located in Coalville, Utah. The gradation for the aggregate is also shown in Table 3 and is very close to the Texas Grade 4.

Stockpiles of pre-coated aggregate for both the NV and TX aggregate sources were created (NVP, TXP). Approximately three quarters of a percent of an AR 4000 asphalt cement was used to pre-coat both aggregates. Aggregates were stockpiled at least two to three weeks prior to use.

PROJECT DESCRIPTION

Test sections were placed in west central Nevada from August 31 through September 10, 1988 on US 50, crossing both Churchill and Lyon counties, between mileposts CH 10.85 and LY 33.94 (Figure 2). Average daily traffic for the length of this project is between 1290 and 1720 vehicles per day for two lanes (both directions).

The elevation is approximately 4,200 feet above sea level. Annual precipitation in this area is approximately 6.65 inches. Annual mean maximum and mean minimum temperatures are 67F and 36F, respectively. There are an average of 154 dry freeze/thaw cycles per year in this area of Nevada.

The weather during construction was predominately sunny and hot. However, towards the end of the construction , the maximum daily temperature dropped form the low 100's to high 70's.

The location of the test section is shown in Figure 3.

CONSTRUCTION

All sections were constructed in a consistent manner. Binder was applied with a distributor at spray rates ranging from 0.33 to 0.56 gallons/sq.yd. The aggregate was applied with an Etnyre chip spreader usually within 30 seconds after the binder. Rolling was completed with three staggered 8-10 ton 9-wheeled rollers with ten minutes of the construction of the emulsion sections. However, the NV and TX were either applied dry to the hot binders or were precoated when used with paving grade binders. The UTE was always applied dry to the hot binders and was pre-wet for emulsions.

The use of dry aggregate with the hot binders resulted in excessive dust (Figure 4). Adherence between the aggregate and the binder was prevented due to excessive dust drifting ahead of the chip spreader and coating the asphalt surface.

Viscosity binders were temperature critical as the temperature needed to be a minimum of 325F for proper application. Stringing occurred if the temperature of the binder was too high, greater than 200F, when the aggregate was applied. Also if the temperature was too low the binder did not adhere to the aggregate properly and adequate embedment depths were not obtained.

The most severe problems noted with the emulsion sections were aggregate pick up when pre-coated aggregate was used and damage to one section by too early brooming. Field comments during construction of all sections are presented in Table 4.

When aggregate pick up was a problem the rollers were "dusted" by driving them along side the highway; this reduced the tacky build-up on the wheels. Viscosity grade binder section were broomed within two hours of aggregate application. Field comments during construction of these sections are also presented in Table 4.

Sections damaged either during construction or by initial traffic were sanded the day of construction. The sections with the pre-coated aggregates were especially prone to traffic pick up during the pilot car operation prior to brooming. This was due to the excess aggregate sticking to the hot tires. Even though this was an irritant from the noise standpoint it did not cause damage or result in claims.

In order to improve performance those sections that did not have adequate embedment depth were either fog sealed or sand sealed approximately one week after construction. Control sections for evaluation purposes, were left in each section that was post treated. The post treatments of these sections are shown in Table 5.

Sections placed during the period of cool weather reported in the "Project Description" section (PM 2000 with TX aggregates) experienced extensive aggregate loss and needed to be re-chipped. It was felt at least a portion of the poor performance in these sections was related to a combination of low binder applications and cool weather and not necessarily a function of either the binder, aggregates or construction procedures. The impact of a lower temperature at time of application of the aggregate will be discussed in greater detail in the following "Laboratory Test Results" section.

POST CONSTRUCTION FIELD SURVEY-ONE MONTH

Approximately one month after construction of the test sections, the district engineer and UNR personnel conducted a field condition survey. The rating form used for this evaluation is shown in Figure 5. This form covers four major topics:

1. Overall condition of surface.
2. Aggregate retention both within- and between-wheel paths.
3. Flushing/Bleeding.
4. Aggregate embedment both within- and between-wheel paths.

The first three items are rated on a scale of 1 to 10 with 1 being poor and 10 being excellent. Aggregate embedment is expressed as an estimate of the percentage, 0 to 100 percent, of the height of the aggregate embedment in the binder.

Summary of Field Condition Survey

The results of field condition survey for each of the categories are presented in Figures 6 through 10. The outcome of these ratings are briefly discussed below. Because all sections received a rating of 10 for bleeding and flushing, a summary for bleeding and flushing was not included.

AR 2000: All sections that used this binder required 22lb./sq.yd. or less or pre-coated chips (both NV and TX); quantities of binder varied from 0.44 to 0.47 gal./sq.yd.

The overall rating for these sections ranged from 8 to 9. Aggregate retention was excellent both within and between the wheel paths. Aggregate embedment ranged from 40 to 70 percent within the wheel paths; it was 25 to 45 between wheel paths.

AC 10R: All sections that used this binder also required 22lb./sq.yd. or less of pre-coated chips (both NV and TX); quantities of binder varied from 0.40 to 0.48 gal./sq.yd.

The overall rating for these sections was approximately 8. Aggregate retention was excellent both within and between the wheel paths. Aggregate embedment ranged from 40 to 60 percent within wheel paths; it was 25 to 35 between wheel paths.

PM 2000-General: Thirty one sections were placed with this binder. Of these 31 sections, 17 were placed during a period of cool weather. The information for these sections is separated according to the typical construction weather and are labeled "Warm Weather" and "Cool Weather". Figures 6 through 10 the cool weather sections are emphasized by a heavy line around the applicable sections.

All three aggregates were used as well as both the pre-coated NV and TX. Binder quantities varied from 0.33 to 0.48 gal./sq.yd. It should be noted that the sections using the NV, NVP, and UT were placed during warm weather and sections using the TX and TXP were placed during cool weather. Because of this difference in construction weather, it would be inadvisable to make comparisons between the two groups of test sections.

PM 2000 - Warm Weather: The overall rating for sections ranged from 2 to 9. Sections with the pre-coated NV aggregate showed substantial improvement over the non-pre-coated sections.

Aggregate retention ranged from 8 to 10, and 6 to 10 for within and between the wheel paths, respectively. Again, the pre-coated sections were responsible for the higher ratings.

Aggregate embedment ranged from 40 to 65 percent within-wheel paths; it was 20 to 65 between wheel paths.

PM 2000 - Cool Weather: The overall rating for sections ranged from 3 to 9. Sections with the pre-coated TX aggregate showed substantial improvement over the non-precoated sections at the highest binder quantity.

Aggregate retention ranged from 7 to 10, and 5 to 10 for within and between the wheel paths, respectively. Again, the pre-coated sections with the highest binder quantity were responsible for the high ratings.

High Float Emulsions: All sections that used this binder also used a maximum of 22 lb./sq.yd. NV and TX aggregates; quantities of binder varied from 0.48 to 0.56 gal./sq.yd.

The overall rating for these sections ranged from 5 to 8. Aggregate retention was excellent within the wheel paths, and ranged from 8 to 10 between the wheel paths. Aggregate embedment ranged from 35 to 45 percent within-wheel paths; it was 15 to 25 between wheel paths.

The percent embedment for these sections were generally less than those for the paving grade binder sections.

LMCRS-2H: All three aggregates were used as well as both the pre-coated NV and TX. Binder quantities varied from 0.39 to 0.56 gal./sq.yd.

The overall rating for these sections ranged from 2 to 7. Some of the low ratings can be attributed to sections where construction problems were noted. Both the NV and NVP showed consistently higher ratings than the TX and TXP.

Aggregate retention was excellent within the wheel paths, and ranged from 5 to 10 between the wheel paths. Aggregate embedment ranged from 35 to 70 percent within-wheel paths; it was 15 to 50 between wheel paths.

POST CONSTRUCTION FIELD CONDITION SURVEY-EIGHT MONTHS

A field condition survey was conducted by the original survey team eight months after construction. Figures 11 through 15 present the results of this survey. Figure 16 shows the change in the condition of all sections between the one- and eight-month surveys.

LABORATORY TESTING

Laboratory testing for use with chip seal design methods consisted of:

1. Determining ALD
2. Board Test.

Based upon previous research performed by the University of Nevada, Reno, the Vialit test was also included in testing performed at UNR. This test is described in detail in the following sections.

Design Methods Testing

Two of the methods outlined in the "Background" section were used to calculate the optimum quantities of binders and aggregates. These two methods were:

1. McLeod's (as outlined in the Asphalt Institute Manual Series No. 13).
2. Texas Transportation Institute.(5)

The test results for the ALD and the board test are shown in Table 6. The results of the design methods using these test results are shown in Tables 7 and 8.

It can be seen that the TTI method suggested a lower quantity of both binder and aggregate than either the TAI method of the actual range of field quantities. The TAI design method provided quantities that were the closest to the ones used in the field sections, but well below those that appear to be optimum in the field.

Vialit Test

The Vialit test was used to determine the percent of aggregate retained after various times of sample curing. Use of this test method provided information on:

1. Appropriateness of aggregate design quantities,
2. Resistance of aggregate to an impact force over several time intervals, and
3. Rate of set of binders.

A preliminary draft of the standard vialit test method is described in Appendix A.

Equipment: This test uses a 0.62 cm. (0.25) in.) steel plate 17.5 by 17.5 cm (7 by 7 in.) square as a sample preparation medium. A 0.62 cm. (0.25in.) rim prevents binder run off. A force was imparted to an inverted chip seal sample by dropping a steel ball 5 cm (2 in.) in diameter from a height of 45 cm (18 in.). The apparatus for holding the inverted plate and guiding the ball is shown in Figure 17.

Sample Preparation-Emulsions: Both the plates and emulsions were preheated to 60C (140F). A quantity of binder equal to field application rates was applied to the steel plate. The plate was rotated until the binder was evenly distributed over the surface. Aggregates, again duplicating field test section quantities, were immediately applied to the plate. Rubber tired rolling was simulated with a weighted tire (396 to 440 kg (180 to 200 pounds)) and a tire pressure of 14.8 kg./sq.cm. (40 psi).

Three passes (one pass = forward and backward cycle) of the tire were required for one complete coverage of the plate. Two complete coverages were accomplished by starting with three passes, rotating sample 90 degrees, then applying a final three passes. When choke stone was used, it was applied after the first three passes.

Sample Preparation-Viscosity Grade Binders: Both plates and binders were pre-heated to 300F. Samples were then prepared as described for emulsions.

Procedure (Emulsions and Viscosity Grades): A total of 15 samples were prepared and three samples were tested at 10-minute, 30-minute, 2-hour, 5-hour and 24-hour intervals. A separate set of three samples was prepared for each time interval. All samples were stored at 25C (77F) (plus or minus 1.3C (5F)) and a relative humidity of less than 30 percent.

An initial weight of the sample and plate was obtained, then the specimen was inverted in the test apparatus for 10 seconds. A second weight was then taken. The percent of material retained on the sample plate was then calculated by:

$$\% \text{ retained} = 100 - \frac{(\text{Original wt.} - \text{wt. after invert})}{(\text{Original wt.})} \times 100$$

The plate was then immediately re-inverted in the apparatus and a steel ball was dropped in the center of the plate three times within a 10 second period. A final weight was then taken; percent retained after impact was calculated.

Use of Test Results: The data can be used to indicate the presence of excess aggregate and the rate of set of the binder by monitoring the increase in the material retained with time. The material lost during the initial invert testing at the 5- and 24-hour test times represents excess aggregates; plotting the percent material retained after impact versus time indicates the curing characteristics of the binder.(26)

Statistics for Test Method-Emulsions: Table 9 shows the standard deviations and range of percent material retained for the various test intervals.(26) At the earlier times less material was retained and the standard deviations are greater. This indicates that the ability of the binder to form an adhesive bond was more variable at the earlier times. As more material was retained, both before and after impact, the standard deviation decreases. This indicated that there was a progressively more consistent bond between the binder and aggregate as curing continued.

Statistics for Test Methods-Viscosity grades: An examination of test results indicate similar test variation at all test times. This variation is comparable to the 24 hour standard deviation for the emulsion samples.(26)

Test Results

Figure 18 shows the after impact Vialit test results for field test section variables that were evaluated in the laboratory. It can be seen that regardless of binder, almost all Vialit test results have greater than 90 percent material retained.

Limited comparisons of the laboratory results for the variables between the test sections are discussed in the following sections.

Emulsions: In general, the emulsions were more difficult to work with in the laboratory than the viscosity grade binders. This appeared to be due to their continued low viscosities within the first half hour after the samples were prepared.

Figure 19 shows there is no difference between either the LMCRS-2H and the HFE 100S when 22lb./sq.yd. of the TX aggregate is used.

Figure 20 shows that the percent material retained at the earlier test times is dependent upon the quantity of the HFE 100S. The percent of material retained is also dependent upon the type of aggregate; better results at 30 minutes are obtained with the TX aggregate then with the NV aggregate, regardless of binder quantity.

Figure 21 shows that better, more uniform, test results are obtained at the earlier times when a higher quantity of HFE 100S is used. The differences between the TX and the NV aggregate are substantial (30-minute test time) when the lower quantity of binder (0.45 gal./sq.yd.) binder is used.

Figure 22 indicates that samples prepared with the light weight aggregate and the HFE 100S were sensitive to changes in the amount of aggregate only at the 10 minute test time. More material was retained with the 16 lb./sq.yd. of aggregate than the 18 lb/sq.yd. at this test time.

Viscosity Grade Binders: Figures 23 through 27 show that virtually all test results, regardless of time, yielded better than 90 percent material retained. No improvement in test results was noticed between any of the test section variables.

Table 10 details the Vialit test results, laboratory comments, and field (during construction) comments for all test sections.

Emulsions

Table 11 summarizes construction problems noticed and lists ranges on Vialit test values at specific times. These times were chosen to correspond roughly with when the problems occurred during construction.

Both the initial invert and impact test results at 10 minutes are tabulated under the heading of "Pick up by rollers" (Table 11). The lack of differentiation between test results for the 30-minute initial invert suggests that this portion of the testing was not indicative of construction problems.

Two exceptions to the impact test results are noted in Table 11. The first involves the NVP aggregate which showed problems with pick up on the rollers while showing Vialit 10-minute impact test results of over 60 percent material retained. The second exception occurred for a sample prepared with the HFE 100S material retained at 30 minutes. Since the brooming was delayed for all emulsion sections, there is no way of ascertaining if this section would have been damaged by early brooming.

In summary, Vialit impact test results appear to depict construction problems. Vialit test results with less than 30 percent material retained at 10 minutes indicate potential problems with aggregate pick up. Less than 65 percent material retained at 30 minutes suggest that brooming should be delayed. No damage was reported for sections with more than approximately 65 percent material retained at 2 hours. These general limits are presented graphically in Figure 28.

Viscosity Grade Binders

It was not necessary to delay either the rolling or brooming of the majority of these sections. However, traffic pick-up of loose pre-coated aggregate was a problem. All Vialit test results at 24 hours showed results greater than 90 percent material retained. This is in agreement with the suggested guidelines in Figure 28.

Prediction of Chip Seal Performance

Field Condition Survey versus Vialit Test Results: Table 12 shows the within- and between-wheel paths aggregate retention, and the Vialit test results. While there are differences between the test sections, no good correlation appears to exist between any of the field condition survey parameters and the Vialit test results.

Poor correlation of the field evaluation and the Vialit test results are most likely due to one or more of the following:

1. Post treatment of section after construction.
2. Influence of existing pavement conditions on rate of set, and aggregate embedment depths.
3. Differences in laboratory test temperatures and actual construction temperatures.
4. Subjective nature of the overall condition rating.
5. Binders used in the lab were not samples of the field binders and may have had different properties.

Problems with Aggregate Retention Caused by Cool Weather Conditions: A variation of the Vialit test was used to see if cool pavement surface temperature problems with a viscosity grade asphalt could be identified with laboratory testing. Vialit sample preparation was modified as follows:

1. Two sets of Vialit plates and the viscosity grade asphalt cement (EVA PM 2000) were heated to 300°F.
2. Asphalt was applied to plates, covered, and one set of plates was then brought

to 140F; the other was cooled to potential pavement temperatures (hence binder temperatures) at the time of aggregate application.

3. Aggregates were then applied to the plates as previously described.

4. Testing was then performed as previously described.

Figure 29 shows the results of this modified testing. It can be seen that aggregates applied to the PM 2000 at a surface temperature of 140°F will loose progressively more aggregate as testing time increases.

There is a dramatic reduction of material retained at all test times for samples prepared with a surface temperature of 77°F. The material retained is substantially less at 24 hours for this surface temperature than for either of the other temperatures. While progressively more material is retained with time, the results indicate early loss of aggregate should be expected. This is confirmed by the necessity of having to re-chip these last test sections placed during the cool weather.

CONCLUSIONS

The following general conclusions can be made from the field condition survey of these test sections (Figures 6 through 10):

1. Pre-coated aggregates appear to improve the overall rating when used with viscosity grade binders. The benefit obtained from pre-coating seems to be dependent upon the binder quantity.

2. For a given combination of binder and aggregate, the overall rating appears to be sensitive to changes in the quantity of binder and aggregate.

3. The high float emulsions had slightly higher overall ratings than the LMCRS-2H.

An evaluation of the laboratory Vialit test results indicated the following conclusions:

1. Test results for samples prepared with emulsions were influenced by changes in aggregate source/gradation, binder quantity, and aggregate quantity. Each combination of binder and aggregate required different quantities of materials to achieve an optimum percent material retained.
2. The Vialit test was not sensitive to changes in the viscosity grade binders when samples were prepared at 300F.

The following conclusions can be drawn from a comparison of the Vialit test results and field observations:

1. The Vialit test appears to be able to identify both the rate of set and potential construction problems when chip seals are constructed with emulsions.
2. The standard Vialit test is not applicable for viscosity grade binders.
3. The Vialit test can be adapted to simulated different binder temperatures at time of aggregate application for chip seals constructed with viscosity grade binders.

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Table 1 : Physical Properties of the LMCRS-2H and HFE 100S Used in Constructing the Nevada Test Sections

Binder Test	NV. Spec. CRS-2H	LMCRS-2H	HFE 100S
Furol Viscosity at 122F, sec.	75-400	132.8	92.7
Residue by Distillation (% by Wt.)	65+	69	68
Penetration of Residue, dmm	60-100	75	94
Charge	Positive	Positive	-----
Float Test, sec.	NA	NA	3943+

Note: Results provided by NDOT.

Table 2 : Physical Properties of Viscosity grade Binders

Test	NV Spec. AR 2000	AR 2000*	PM 2000	NV Spec. AC 10	AC-10R
ORIGINAL PROPERTIES					
Viscosity:					
140F, Poise	NA	378	1753	1600-2400	1315
275F, cSt	NA	157	486	150 min.	483
Penetration:					
77F, 5 Sec.	NA	78	50	70 min.	150
AFTER ROLLING THIN FILM OVEN TEST					
Viscosity:					
140F, Poise	1500-2500	1265	2801	4000 max.	6452
275F, cSt	200 min.	268	609	NA	996
Penetration:					
77F, 5 Sec.	40 min.	39	33	NA	71

* Subsequent tests showed original viscosity (140F) to be 595 poise and the after rolling thin film oven test viscosity (140F) to be 1998 poise.

Note: Results provided by NDOT.

Table 3. Physical Properties of Aggregate Used for the Nevada Test Sections

	NV	NV Specification	TX	TX Specification	Ute Lite
Bulk Specific Gravity	2.655	-----	2.552	-----	-----
Bulk Specific Gravity, SSD	2.655	-----	2.602	-----	-----
Absorbtion Capacity, %	1.6	-----	1.9	-----	-----
Gradation, Percent Pass.:					
5/8"	100	100	100	100	-----
1/2"	100	100	100	98-100	98
3/8"	65	50-80	73	65-85	79
#4	8	0-15	3	0-5	3
#8	1	0-5	2	-----	1
#10	---	-----	---	0-1	1
#16	1	-----	2	-----	1
#40	1	-----	2	-----	1
#50	1	-----	2	-----	1
#100	1	0-2	2	-----	1
#200	0	-----	1	-----	0Table

Note: Results supplied by UNR.

TABLE 4: COMMENTS DURING CONSTRUCTION OF LMCRS-2H SECTION (Construction Date 9-5-88, Section Numbers 1-22)

Asphalt/Emulsion Quan, Agg, Sample	Comments
LMCRS-2H	
0.39 NVP 22 (13)	looks good, slightly tacky on surface precoat during mid-morning, post treated with sand, clean roller wheels, changed roller to reduce pick up, high noise level for motorists
0.44 TX 22 (0)	aggregate application varied too much, not used
TXP 22 (14)	looks good, three pneumatic followed by one steel, further into section more problem with pick up on pneumatic rollers, asphalt close to balling
0.47 NV 16 (16)	looks good, post treated with sand, pick up on rollers
TX 22 (19)	sand seal, loosing stone one day after construction
TXP 22 (3)	balling occurred on tires, repaired later, sand, aggregate pick up, aggregate rolled over, tracking
0.48 UT 12 (15)	dusty material, steel roller crushed stone, aggregate application varied, tracking carried over from section 14, asphalt application rate varied - 0.35 for first 150 feet and 0.40 for next 150 feet, remainder of section done at higher rate, section average 0.483
0.50 NV 16 (12)	good section, pick up on rollers
NV 16 (17)	looks good, post treated with sand, some pick up on rollers, aggregate application varied from 19 pounds to 16 pounds

TABLE 4: COMMENTS DURING CONSTRUCTION OF LMCRS-2H SECTION (Construction Date 9-5-88, Section Numbers 1-22)

Asphalt/Emulsion Quan, Agg, Sample			Comments
LMCRS-2H			
0.50	NV 22	(18)	heavy sand, dusty material, some pick up and balling on rollers
	TX 22	(20)	looked good, some aggregate loss, no steel roller
0.51	TX 16	(2)	aggregate too light, post treated with sand
	TX 22	(8)	looks good
0.52	TX 22	(1)	aggregate application appeared thin, no noticeable aggregate loss, slight tracking
		(21)	looked good, some aggregate loss, no steel roller
0.54	TX 22	(22)D	post treated with sand, severe aggregate loss, moderate to severe dust
0.55	NV 22	(11)	excess aggregate, looked good going down, pick up on rollers, dusty material, post treated with sand
0.56	TX 16	(10)	good section, aggregate quantity changed from 16# to 22#
	TX 22	(9)	aggregate application delayed 8 minutes, wave in asphalt as aggregate hit the road in wheel path, emulsion drained into wheel path
0.57	TX 22	(7)	aggregate picked up on rollers, let emulsion set 5 - 8 minutes before applying aggregate, emulsion pooled in wheel paths

TABLE 4: COMMENTS DURING CONSTRUCTION OF HIGH FLOAT EMULSION 100S SECTION (Construction Date 9-6-88, Section Numbers 31-35)

Asphalt/Emulsion Quan, Agg, Sample			Comments
HIGH FLOAT EMULSION -			hold broom off emulsion for 2 - 3 hours, slower cure than LM CRS, not much better than LM CRS - not as much running
0.48	UL 16	(33)	good,
	NV 22	(34)	good,
	TX 22	(32)	good, post treated with sand, moderate aggregate loss,
0.52	TX 22	(31)	post treated with sand, broomed too early, moderate aggregate loss
0.56	NV 22	(35)	good,

TABLE 4: COMMENTS DURING CONSTRUCTION OF AR 2000 SECTION (Construction Date 9-6-88, Section Numbers 23, 24, 27 and 28)

Asphalt/Emulsion Quan,Agg,Sample	Comments
AR 2000	20-30 second to one minute delay to eliminate stringers, easy to spray and to work with
0.44 NVP 18 (24)	no comment
0.46 NVP 22 (23)	some pick up on tires
0.46 TXP 22 (28)	no comment
0.47 TXP 22 (27)	no comment

TABLE 4: COMMENTS DURING CONSTRCTION OF AC 10R SECTION (Construction Date 9-6-88, Section Numbers 25, 26, 29, and 30)

Asphalt/Emulsion Quan,Agg,Sample	Comments
AC 10R	paving grades ok to sweep after one hour, 20-30 second delay to one minute to eliminate stringers
0.40 TXP 22 (29)	looks good, post treated with sand
0.41 NVP 18 (26)	paving grades ok to sweep after one hour
0.44 NVP 22 (25)	asphalt stringy and forming web like globs,
TXP 22 (30)	looks good, post treated with sand

TABLE 4: COMMENTS DURING CONSTRUCTION OF PM 2000 SECTION (Construction Date 9-8-88, Section Numbers 36-43; Construction Date 9-9-88, Section Numbers 44-49)

Asphalt/Emulsion Quan,Agg,Sample	Comments
PM 2000	better at adhering aggregate in cracks
0.33 NVP 22 (42)	flush seal
0.34 NVP 16 (37)	post treated with sand, looks good, some aggregate loss
(43)	end of section had localized problem due to equipment
NVP 22 (36)	post treated with sand, some sticking to wheels if aggregate placed to soon, swept early, no sand
0.35 NV 16 (49)	sand seal, looks good, aggregate loss, chips too wet
0.37 UT 12 (45)	light aggregate application
0.38 NVP 16 (41)	no comment
0.40 UT 18 (44)	no comment
0.41 NV 22 (48)	looks good, aggregate loss
0.41 UT 12 (47)	good aggregate application, dirty pavement due to inadequate cleaning because of guard rail
0.43 NVP 22 (40)	flush seal, aggregate loss
0.44 UT 18 (46)	more aggregate than design, excess rock
0.48 NVP 16 (39)	looks good
NVP 22 (38)	some pick up on roller, some streaking

TABLE 4: COMMENTS DURING CONSTRUCTION OF PM 2000 SECTION (Construction Date 9-9-88, Section Numbers 50-52; Construction Date 9-12-88, Section Numbers 53-60; Construction Date 9-13-88, Section Numbers 61-68)

Asphalt/Emulsion Quan,Agg,Sample	Comments
PM 2000	better at adhering aggregate in cracks
0.34 TXP 16 (63)	sand seal, aggregate loss
0.35 TX 22 (64)	
TXP 16 (62)	sand seal, aggregate loss
TXP 16 (61)	sand seal, aggregate loss
0.37 TX 16 (66)	rechip, moderate aggregate loss
TXP 22 (57)	sand seal, moderate aggregate loss
(58)	sand seal, moderate aggregate loss
0.39 TXP 22 (53)	flush seal, aggregate loss
0.40 TXP 22 (59A)	no comment
(60)	rechip, fog seal, moderate aggregate loss
0.41 TX 16 (67)	moderate aggregate loss, fog seal
0.43 TXP 16 (54)	no comment
0.45 TXP 16 (56)	no comment
TXP 22 (55)	no comment
0.46 TXP 16 (52)	partial flush
TXP 22 (51)	flush seal, aggregate loss
0.47 TX 22 (65)	rechip, moderate aggregate loss
0.50 TX 22 (68)	moderate aggregate loss, fog seal

TABLE 4: COMMENTS DURING CONSTRUCTION OF PM 2000 SECTION (Construction Date 9-9-88, Section Numbers 50-52; Construction Date 9-12-88, Section Numbers 53-60; Construction Date 9-13-88, Section Numbers 61-68)

Asphalt/Emulsion Quan,Agg,Sample	Comments
PM 2000	better at adhering aggregate in cracks
0.53 TXP 22 (50)	originally 0.31 gal/sq yd with Texas aggregate, poor aggregate retention, section was broomed and sprayed with more asphalt, Texas precoat aggregate was used instead

TABLE 5: POST CONSTRUCTION TREATMENT OF LMCRS-2H SECTION

Asphalt/Emulsion Quan, Agg, Section	Date of Construction	Date of Treatment	Type of Treatment
LMCRS-2H			
0.39 NVP 22 (13)	9-5-88		None
0.44 TX 22 (0)	9-5-88		None
TXP 22 (14)	9-5-88		None
0.47 NV 16 (16)	9-5-88		None
TX 22 (19)	9-5-88		Flush Seal Sand Seal
TXP 22 (3)	9-5-88		None
0.48 UT 12 (15)	9-5-88		None
0.50 NV 16 (12)	9-5-88		None
NV 16 (17)	9-5-88		None
NV 22 (18)	9-5-88		None
0.50 TX 22 (20)	9-5-88	9-23-88	Sand Seal
0.51 TX 16 (2)	9-5-88		None
TX 22 (8)	9-5-88		None
0.52 TX 22 (1)	9-5-88		None
(21)	9-5-88	9-23-88	Sand Seal
0.54 TX 22 (22)D	9-5-88		Dry Chips
0.55 NV 22 (11)	9-5-88		None
0.56 TX 16 (10)	9-5-88		None
TX 22 (9)	9-5-88		None
0.57 TX 22 (7)	9-5-88		None

TABLE 5: POST CONSTRUCTION TREATMENT OF HIGH FLOAT EMULSION SECTION

Asphalt/Emulsion Quan,Agg,Section		Date of Construction	Date of Treatment	Type of Treatment
HIGH FLOAT EMULSION				
0.48	UL 16 (33)	9-6-88		None
	NV 22 (34)	9-6-88		None
	TX 22 (32)	9-6-88	9-23-88	Flush Seal
0.52	TX 22 (31)	9-6-88	9-23-88	Flush Seal
0.56	NV 22 (35)	9-6-88		None

TABLE 5: POST CONSTRUCTION TREATMENT OF AR 2000 SECTION

Asphalt/Emulsion F Quan,Agg,Section	Date of Construction	Date of Treatment	Type of Treatment
AR 2000			
0.44 NVP 18 (24)	9-6-88		None
0.46 NVP 22 (23)	9-6-88		None
TXP 22 (28)	9-6-88		None
0.47 TXP 22 (27)	9-6-88		Sand Seal

TABLE 5: POST CONSTRUCTION TREATMENT OF AC 10R SECTION

Asphalt/Emulsion Quan,Agg,Section	Date of Construction	Date of Treatment	Type of Treatment
AC 10R			
0.41 NVP 18 (26)	**9-6-88**		**None**
0.40 TXP 22 (29)	**9-6-88**		**None**
0.44 NVP 22 (25)	**9-6-88**		**None**
0.44 TXP 22 (30)	**9-6-88**		**None**

TABLE 5: POST CONSTRUCTION TREATMENT OF PM 2000 SECTION

Asphalt/Emulsion Quan,Agg,Section	Date of Construction	Date of Treatment	Type of Treatment
PM 2000			
0.33 NVP 22 (42)	9-8-88	9-23-88	Flush Seal
0.34 NVP 16 (37)	9-8-88	9-23-88	Sand Seal
(43)	9-8-88		None
NVP 22 (36)	9-8-88	9-23-88	Sand Seal
0.35 NV 16 (49)	9-9-88	9-23-88	Sand Seal
0.37 UT 12 (45)	9-9-88	9-23-88	Sand Seal
0.38 NVP 16 (41)	9-8-88	9-23-88	Flush Seal
0.40 UT 18 (44)	9-9-88	9-23-88	Sand Seal
0.41 NV 22 (48)	9-9-88	9-23-88	Sand Seal
UT 12 (47)	9-9-88	9-23-88	Flush Seal
0.43 NVP 22 (40)	9-8-88	9-23-88	Flush Seal
0.44 UT 18 (46)	9-9-88	9-23-88	Flush Seal
0.48 NVP 16 (39)	9-8-88		None
NVP 22 (38)	9-8-88		None

TABLE 5: POST CONSTRUCTION TREATMENT OF PM 2000 SECTION

Asphalt/Emulsion Quan,Agg,Section	Date of Construction	Date of Treatment	Type of Treatment
PM 2000			
0.34 TXP 16 (63)	9-13-88		Flush Seal
0.35 TX 22 (64)	9-13-88		Double Chip
TXP 16 (62)	9-13-88		Sand Seal
(61)	9-13-88		Sand Seal
0.37 TX 16 (66)	9-13-88	9-15-88	Double Chip
TXP 22 (57)	9-12-88	9-23-88	Sand Seal
(58)	9-12-88	9-15-88	Sand Seal
0.39 TXP 22 (53)	9-12-88	9-22-88	Flush Seal
0.40 TXP 22 (59)	9-12-88	9-15-88 9-15-88	Double Chip Flush Seal
(60)	9-12-88	9-15-88	Flush Seal
0.41 TX 16 (67)	9-13-88	9-23-88	Sand Seal
0.43 TXP 16 (54)	9-12-88		None
0.45 TXP 16 (56)	9-12-88		None
TXP 22 (55)	9-12-88		None
0.46 TXP 16 (52) TXP 22 (51)	9-9-88 9-9-88	9-22-88 9-22-88	Flush Seal Flush Seal
0.47 TX 22 (65)	9-13-88	9-15-88	Double Chip
0.50 TX 22 (68)	9-13-88	9-23-88 9-23-88	Flush Seal Sand Seal
0.53 TXP 22 (50)	9-9-88		Double Chip

Table 6: Results of Board Test

Aggregate	Unit Weight	Board Test (lb./sq.yd.)	ALD	
			Median Size	ALD, Inch
Texas		17	3/8"	0.318
Texas Precoat		19	3/8"	0.318
Nevada		15	1/4"	0.210
Nevada Precoat		16	1/4"	0.210
Utelite		10	3/8"	0.318

Table 7: Comparison of The Asphalt Institute, TTI, and Actual Field Quantities of Aggregate and Emulsions*

Aggregate	TTI		TAI		Range of Field	
	Agg.	Emulsion	Agg.	Emulsion	Agg.	Emulsion
Texas	19	0.216	20	0.384	16-22	0.45-0.55
Texas Pre-coat	17	0.214	20	0.384	16-22	0.45-0.55
Nevada	16	0.259	20	0.256	16-22	0.45-0.55
Nevada Pre-coat	15	0.204	20	0.256	16-22	0.45-0.55
Utelite	10	0.291	19	0.389	16	0.40

* Units: Aggregates - lb./sq.yd.
Emulsions - gal./sq.yd. at 140F application temperature

Table 8 : Comparison of The Asphalt Institute, TTI, and Actual Field Quantities of Aggregates and Viscosity grade Binders*

Aggregate	TTI		TAI		Range of Field	
	Agg.	Binder	Agg.	Binder	Agg.	Binder
Texas	19	0.164	20	0.292	16-22	0.35-0.55
Texas Pre-Coat	17	0.163	20	0.292	16-22	0.35-0.55
Nevada	16	0.197	20	0.195	16-22	0.35-0.55
Nevada Pre-Coat	15	0.155	20	0.195	16-22	0.35-0.55
Utelite	10	0.221	19	0.296	12-18	0.30-0.40

* Units: Aggregates - lb./sq.yd.
Binders - gal./sq.yd. at 300F application temperature

Table 9: Statistics for Vialit Test Results

Vialit Test Times	Initial Invert		Three Drops, Includ. Initial Invert	
	Std. Dev.	Range of Percent Material Retained	Std. Dev.	Range of Percent Material Retained
10 Minutes	9.8	44-98	11.5	7-64
30 Minutes	13.8	85-99	8.6	19-93
2 Hours	8.5	86-99	5.6	63-97
5 Hours	1.3	88-99	0.8	90-99
24 Hours	2.2	82-99	2.0	94-99

* Statistics for a set of three samples. These values represent 10 sets of 3 samples.

gal/sq.yd. = 4.53 l/sq.m.
lb/sq.yd. = 2.63 kg/sq.m.

TABLE 10: COMPARISON OF VIALIT TEST RESULTS AND BOTH LABORATORY AND FIELD COMMENTS

VIALIT (%)					COMMENTS	
10 Min	30 Min	2 Hour	5 Hour	24 Hour	Laboratory	Field
LMCRS-2H						
0.50 TX 22						
*31.2 + 5.4	98.7 56.5	99.9 96.2	98.7 95.9	99.3 97.0	moderate aggregate pick up, easier to work with than High Float Emulsion	(20)-looked good, some aggregate loss, no steel roller
0.51 TX 22						
31.2 5.4	98.7 56.5	99.9 96.2	98.7 95.9	99.3 97.0	moderate aggregate pick up, easier to work with than High Float Emulsion	(8)-looks good
0.55 NV 22						
97.5 23.2	79.1 22.8	97.8 93.0	97.6 89.8	98.2 95.6	moderate aggregate pick up, easier to work with than High Float Emulsion due to a thicker consistency	(11) - excess aggregate looks good going down, pick up on rollers, dusty material, post treated with sand

* First row of values from initial invert
\+ Second row of values from initial invert and impact

Table 11: Relationship Between Construction Problems and Vialit Test Results

Construction	Vialit Test Results
Excess Aggregate	5-, 24-Hours Initial Invert: Less than 97 % Material Retained
Pick Up on Rollers	10-Minute Initial Invert: Ranged from 97 to 19% Material Retained 10-Minute Impact*: Less than 30% Material Retained with One Exception
Damage of New Surface by Early Brooming	30-Minute Initial Invert: More than 85% Material Retained 30-Minute Impact*: Less than 65% Material Retained with One Exception

* Percent material retained includes material lost during initial invert.

TABLE 12: COMPARISON OF PERCENT AGGREGATE RETAINED ON PAVEMENT ONE MONTH AFTER CONSTRUCTION AND LABORATORY VIALIT TESTS

ASPHALT/EMULSION	PERCENT AGGREGATE RETENTION		VIALIT (%)				
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	10 Min	30 Min	2 Hour	5 Hour	24 Hour
LMCRS-2H							
0.50 TX 22 (20)	90.0	60.0	31.2 5.4	98.7 56.5	99.9 96.2	98.7 95.9	99.3 97.0
(20)S	90.0	60.0	31.2 5.4	98.7 56.5	99.9 96.2	98.7 95.9	99.3 97.0
0.51 TX 22 (8)	98.0	75.0	31.2 5.4	98.7 56.5	99.9 96.2	98.7 95.9	99.3 97.0
0.55 NV 22 (11)	100.0	98.0	97.5 23.2	79.1 22.8	98.7 93.0	97.6 89.8	98.2 95.6

* First row of values from initial invert
\+ Second row of values from initial invert and impact

TABLE 12: COMPARISON OF PERCENT AGGREGATE RETAINED ON PAVEMENT ONE MONTH AFTER CONSTRUCTION AND LABORATORY VIALIT TESTS

ASPHALT/EMULSION	PERCENT AGGREGATE RETENTION		VIALIT (%)				
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	10 Min	30 Min	2 Hour	5 Hour	24 Hour
HIGH FLOAT EMULSION 100S							
0.52 TX 22 (31)	100.0	95.0	19.9	84.8	99.5	99.4	99.7
			7.0	59.8	96.0	98.3	99.4
(31)F	100.0	98.0	19.9	84.8	99.5	99.4	99.7
			7.0	59.8	96.0	98.3	99.4

* First row of values from initial invert
\+ Second row of values from initial invert and impact

TABLE 12: COMPARISON OF PERCENT AGGREGATE RETAINED ON PAVEMENT ONE MONTH AFTER CONSTRUCTION AND LABORATORY VIALIT TESTS

ASPHALT/EMULSION	PERCENT AGGREGATE RETENTION		VIALIT (%)				
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	10 Min	30 Min	2 Hour	5 Hour	24 Hour
AR 2000							
0.46 NVP 22 (23)	100.0	98.0	*96.6	99.4	97.0	97.2	99.2
			+95.5	98.7	95.0	92.7	94.2
0.48 TXP 22 (27)	100.0	90.0	91.8	98.7	98.1	98.9	98.5
			87.0	97.0	95.4	96.7	96.9

* First row of values from initial invert
\+ Second row of values from initial invert and impact

TABLE 12: COMPARISON OF PERCENT AGGREGATE RETAINED ON PAVEMENT ONE MONTH AFTER CONSTRUCTION AND LABORATORY VIALIT TESTS

ASPHALT/EMULSION	PERCENT AGGREGATE RETENTION		VIALIT (%)				
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	10 Min	30 Min	2 Hour	5 Hour	24 Hour
AC 10R							
0.41 NVP 18 (26)	100.0	100.0	*93.5 +89.7	99.3 98.7	99.9 99.5	99.5 98.5	99.7 99.1
0.44 NVP 22 (25)	100.0	98.0	97.6 95.4	99.0 97.1	99.3 97.9	99.7 99.4	99.5 98.0
0.45 TXP 22 (30)	100.0	98.0	97.3 95.6	99.3 97.6	99.6 98.4	98.9 95.7	99.6 97.5

* First row of values from initial invert
\+ Second row of values from initial invert and impact

TABLE 12: COMPARISON OF PERCENT AGGREGATE RETAINED ON PAVEMENT ONE MONTH AFTER CONSTRUCTION AND LABORATORY VIALIT TESTS

ASPHALT/EMULSION	PERCENT AGGREGATE RETENTION		VIALIT (%)				
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	10 Min	30 Min	2 Hour	5 Hour	24 Hour
PM 2000 (Cold Sections)							
0.34 TXP 16 (63)	100.0	100.0	*99.2 +96.7	98.2 90.0	98.2 90.2	- -	99.2 77.4
0.35 TXP 16 (62)	100.0	100.0	99.2 96.7	98.2 90.0	98.2 90.2	- -	99.2 77.4
(61)	100.0	100.0	99.2 96.7	98.2 90.0	98.2 90.2	- -	99.2 77.4
0.45 TXP 22 (55)	100.0	98.0	98.6 97.0	99.7 99.3	99.0 96.9	99.9 98.4	99.7 98.9
0.48 TXP 22 (51)	100.0	90.0	95.3 93.9	98.8 98.2	99.3 97.6	99.4 94.7	100 98.1

* First row of values from initial invert
\+ Second row of values from initial invert and impact

TABLE 12: COMPARISON OF PERCENT AGGREGATE RETAINED ON PAVEMENT ONE MONTH AFTER CONSTRUCTION AND LABORATORY VIALIT TESTS

ASPHALT/EMULSION	PERCENT AGGREGATE RETENTION		VIALIT (%)				
Quan, Agg, Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	10 Min	30 Min	2 Hour	5 Hour	24 Hour
PM 2000							
0.41 NV 22 (48)	90.0	70.0	92.0 88.1	94.5 92.6	93.2 84.6	- -	94.6 88.5
(48)S	100.0	100.0	92.0 88.1	94.5 92.6	93.2 94.6	- -	94.6 88.5

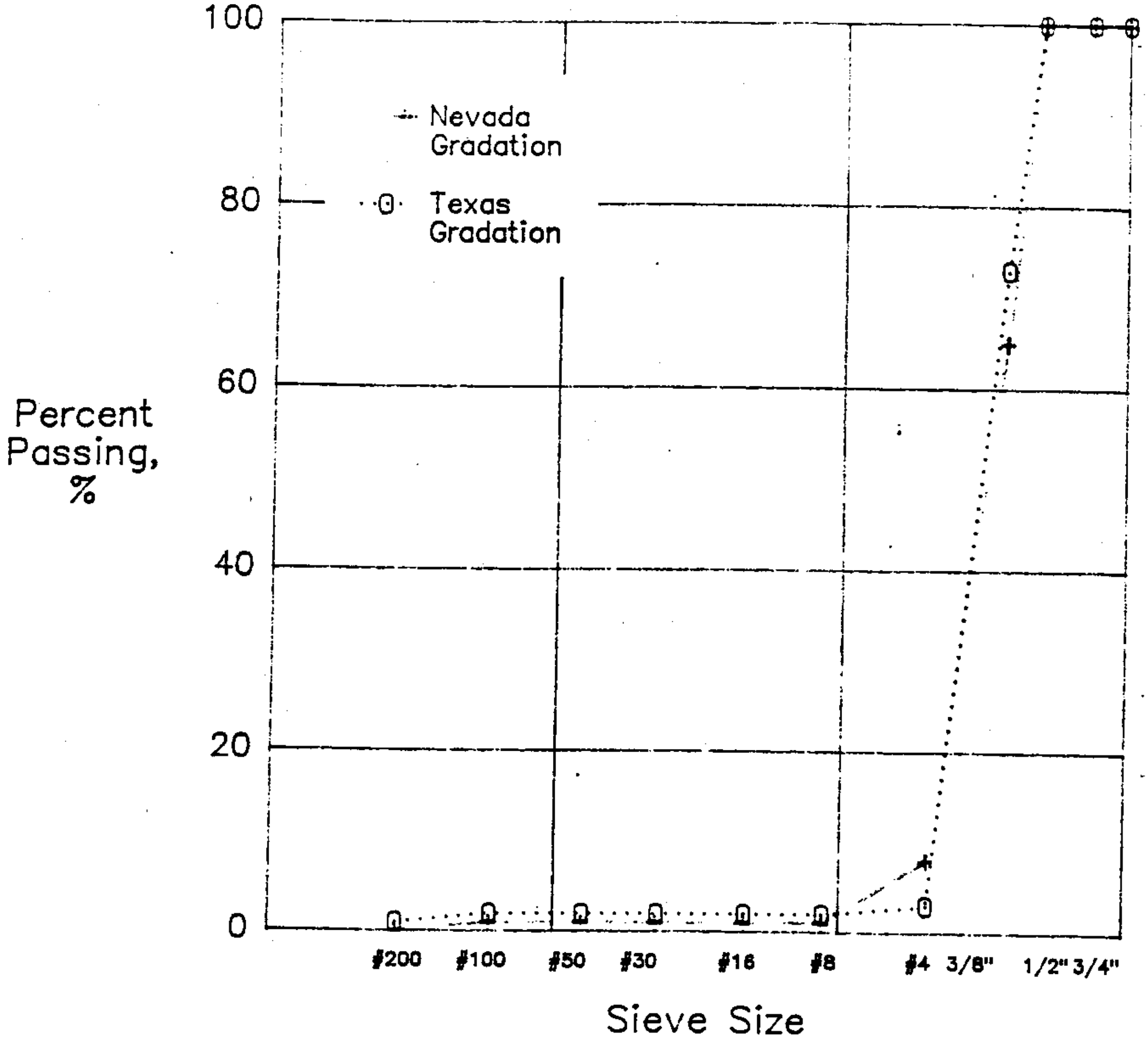


Figure 1 : Gradation of Aggregates Used for Construction of the Chip Seal Test Sections

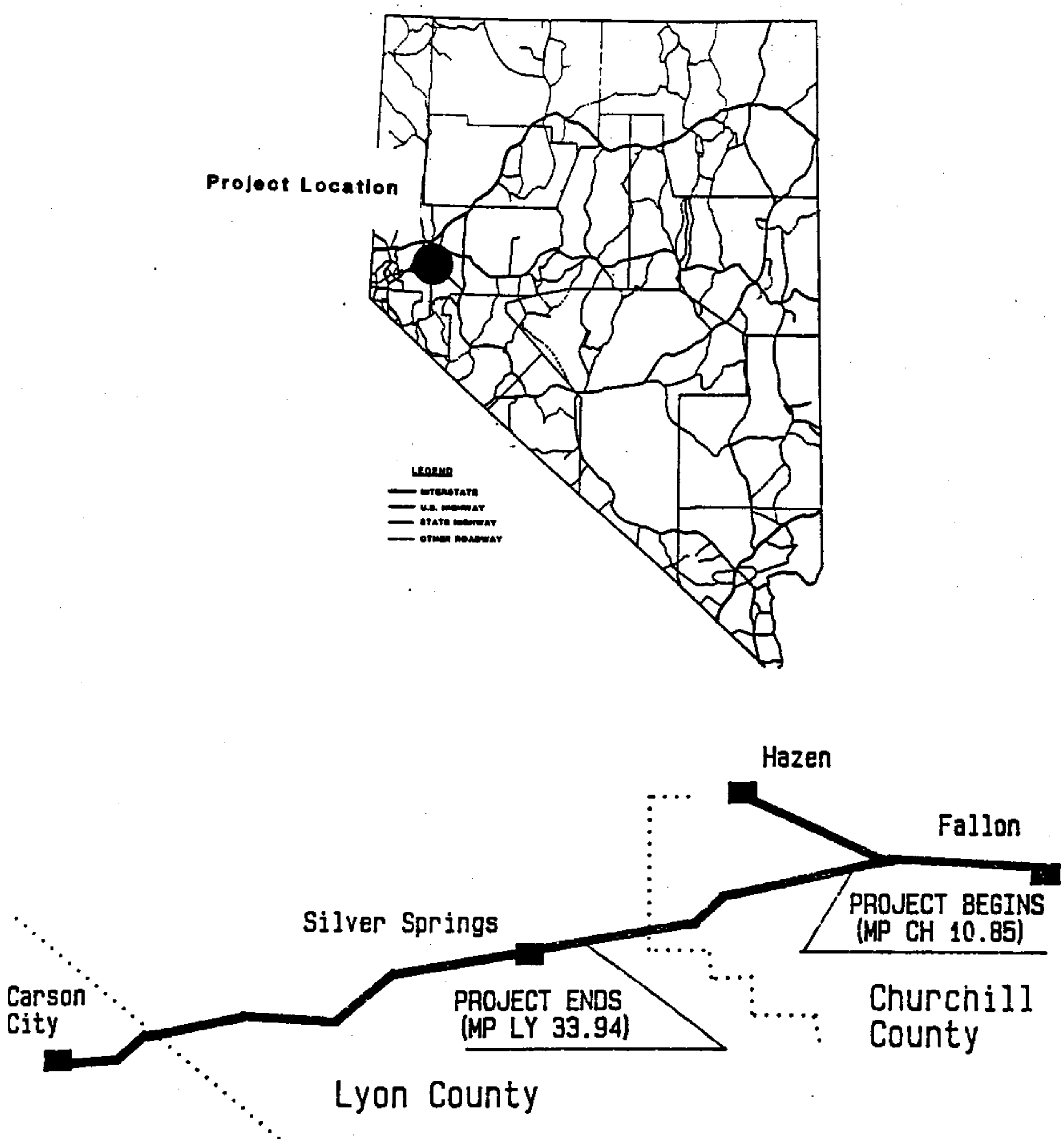


Figure 2 : Project Location

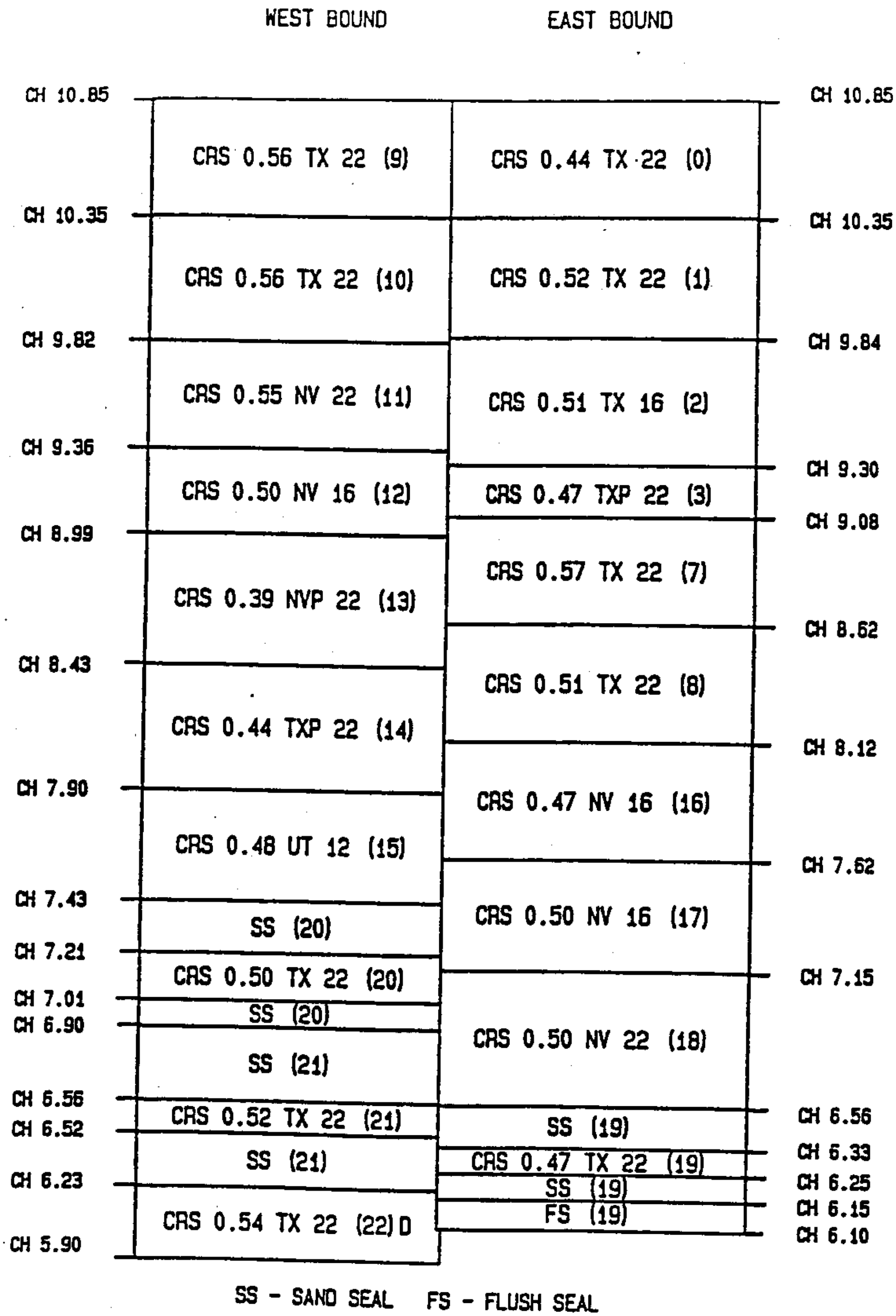
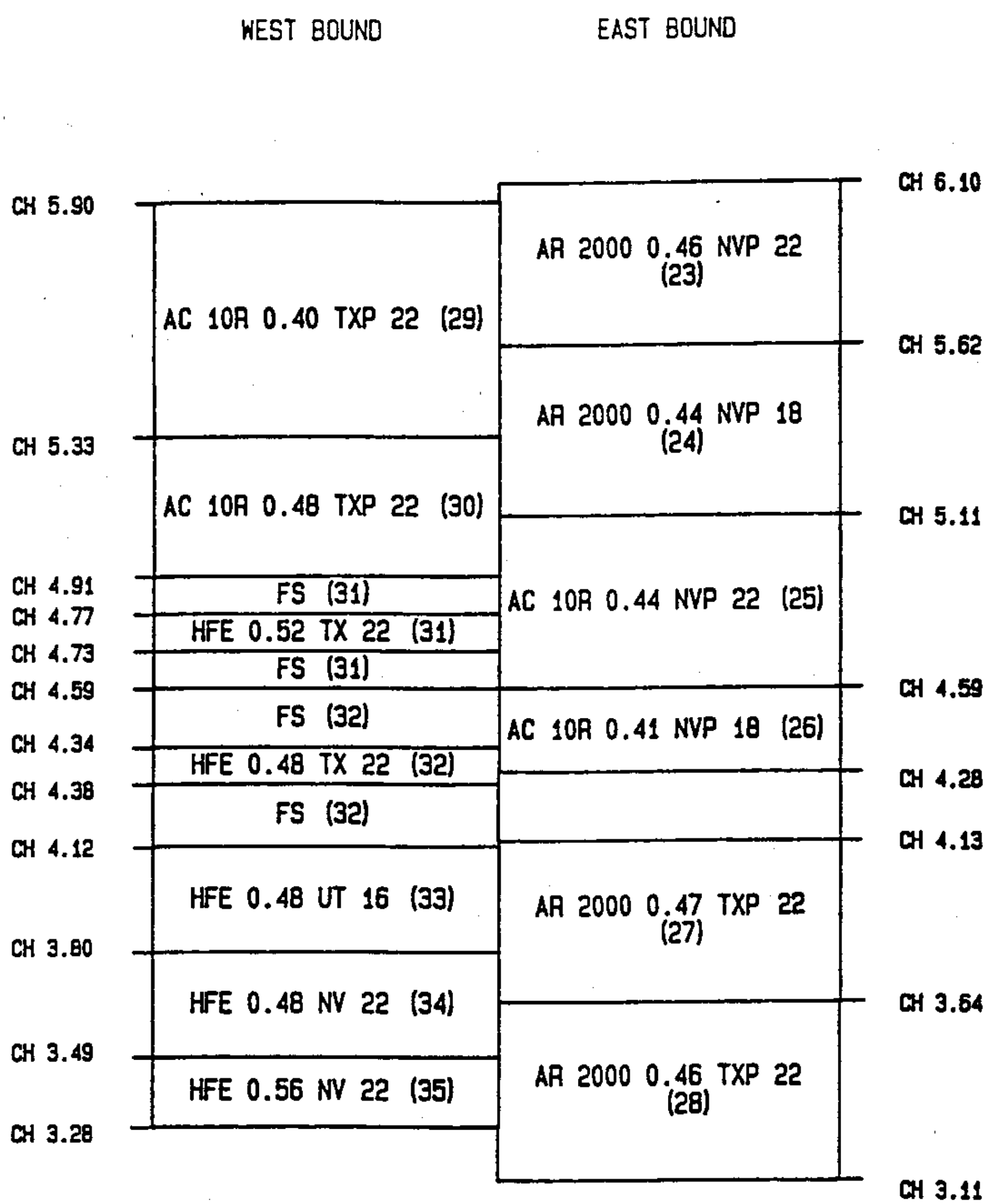
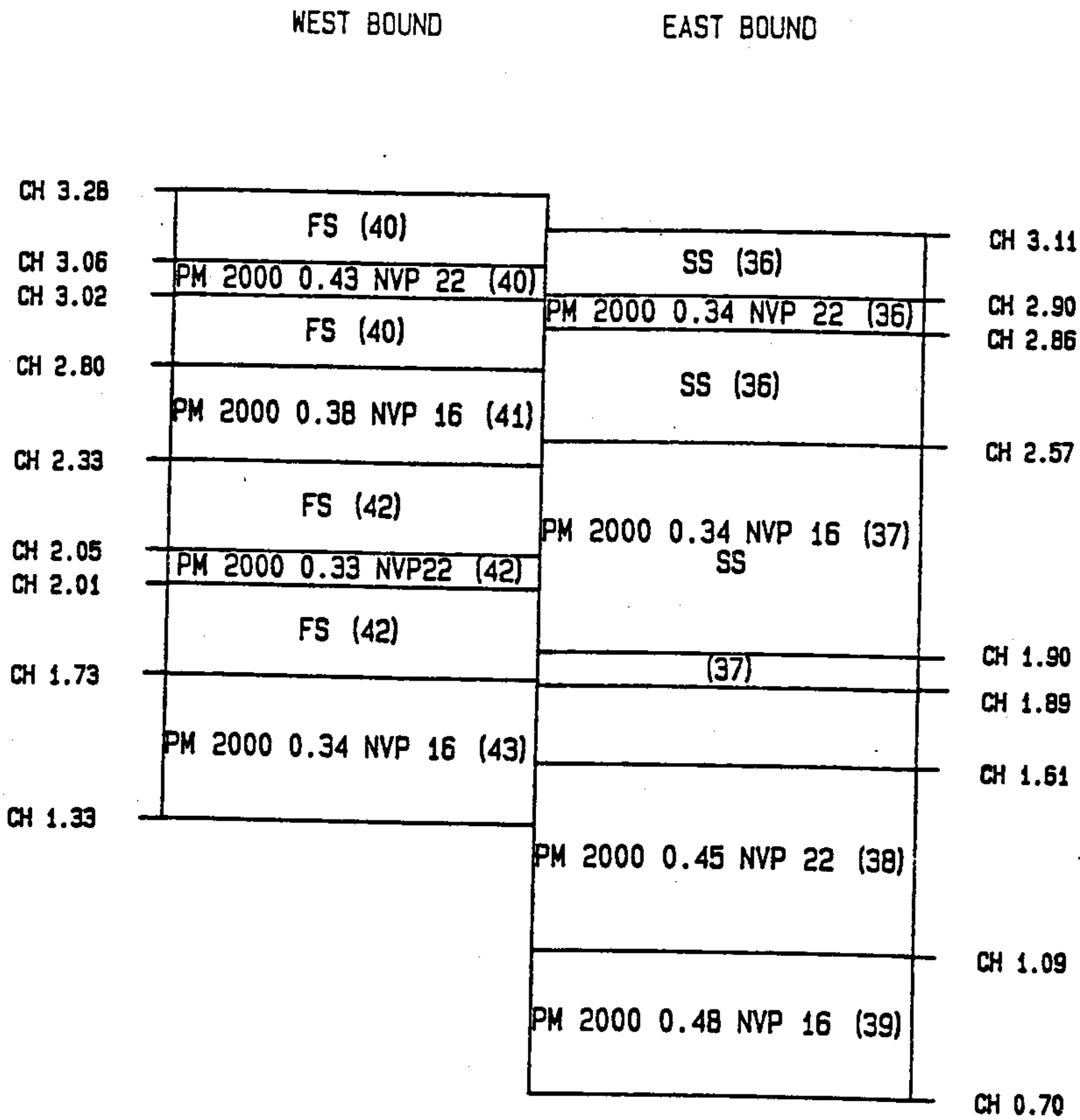


FIGURE 3: CHIP SEAL SECTIONS 0-3, 7-22 CONSTRUCTED 9-5-88



FS - FLUSH SEAL SS - SAND SEAL

FIGURE 3: CHIP SEAL SECTIONS 23-35 CONSTRUCTED 9-6-88



FS - FLUSH SEAL SS - SAND SEAL

FIGURE 3: CHIP SEAL SECTIONS 36-40 CONSTRUCTED 9-8-88

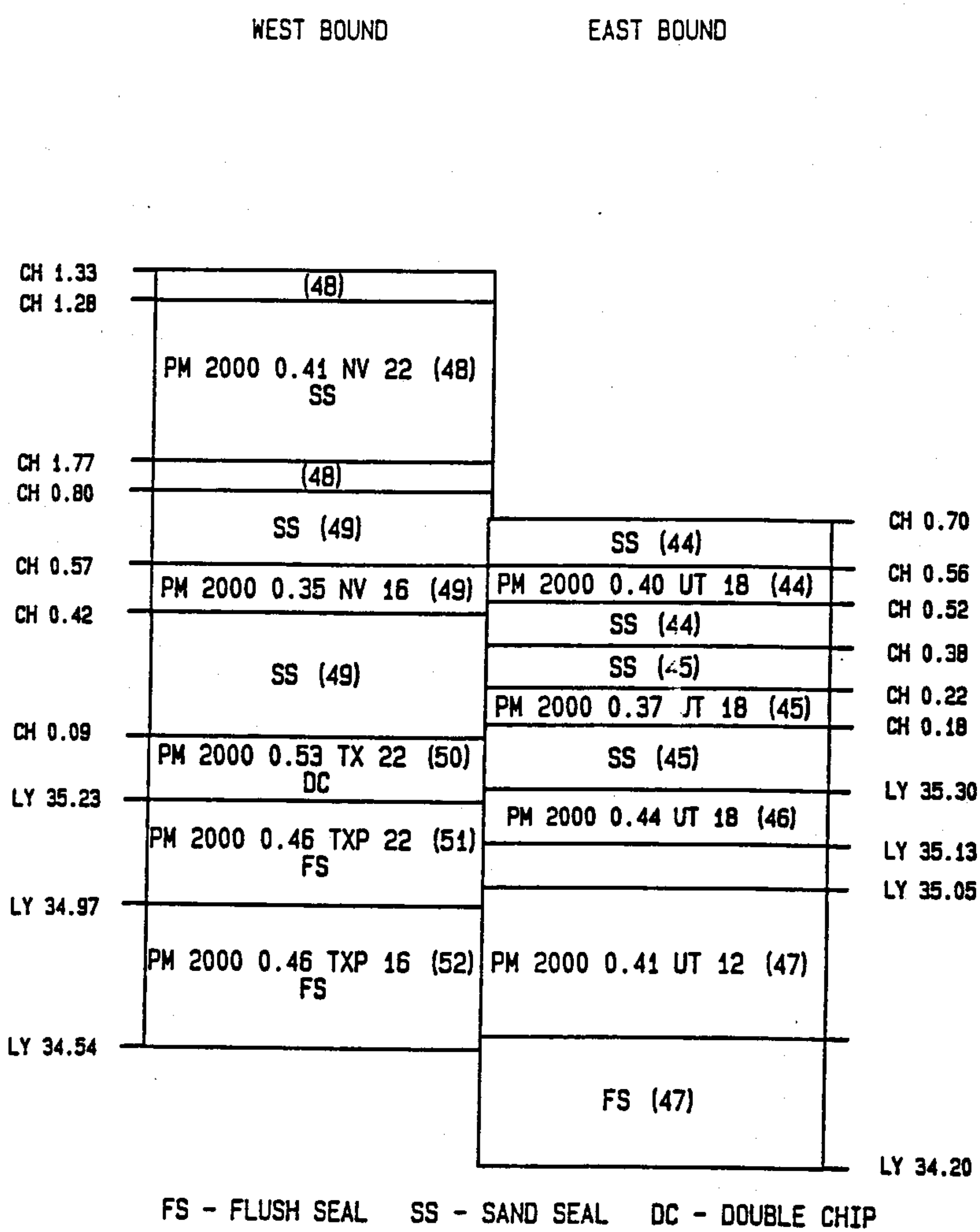
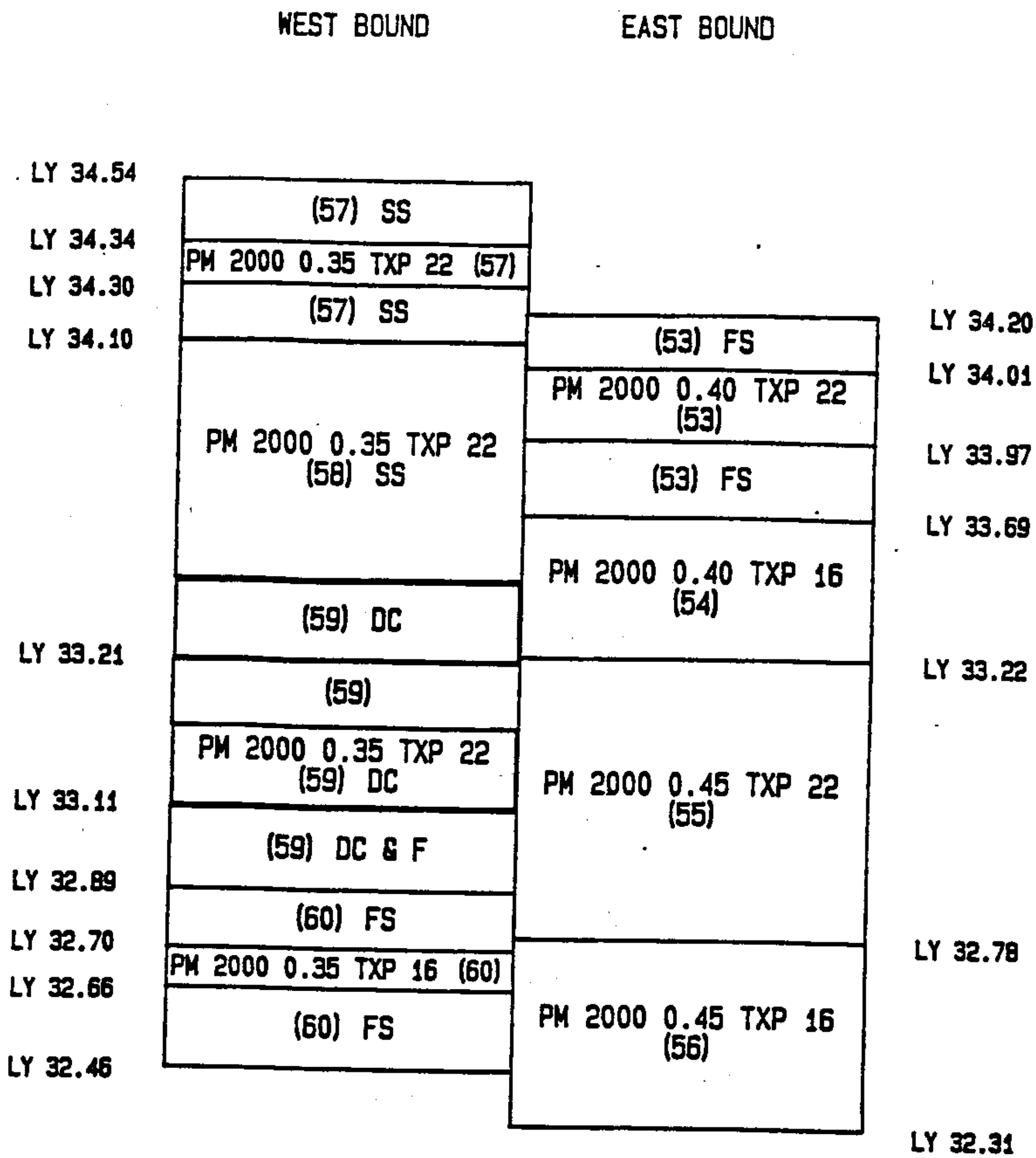


FIGURE 3: CHIP SEAL SECTIONS 44-52 CONSTRUCTED 9-9-88



FS - FLUSH SEAL SS - SAND SEAL DC - DOUBLE CHIP

FIGURE 3: CHIP SEAL SECTIONS 53-57 CONSTRUCTED 9-12-88

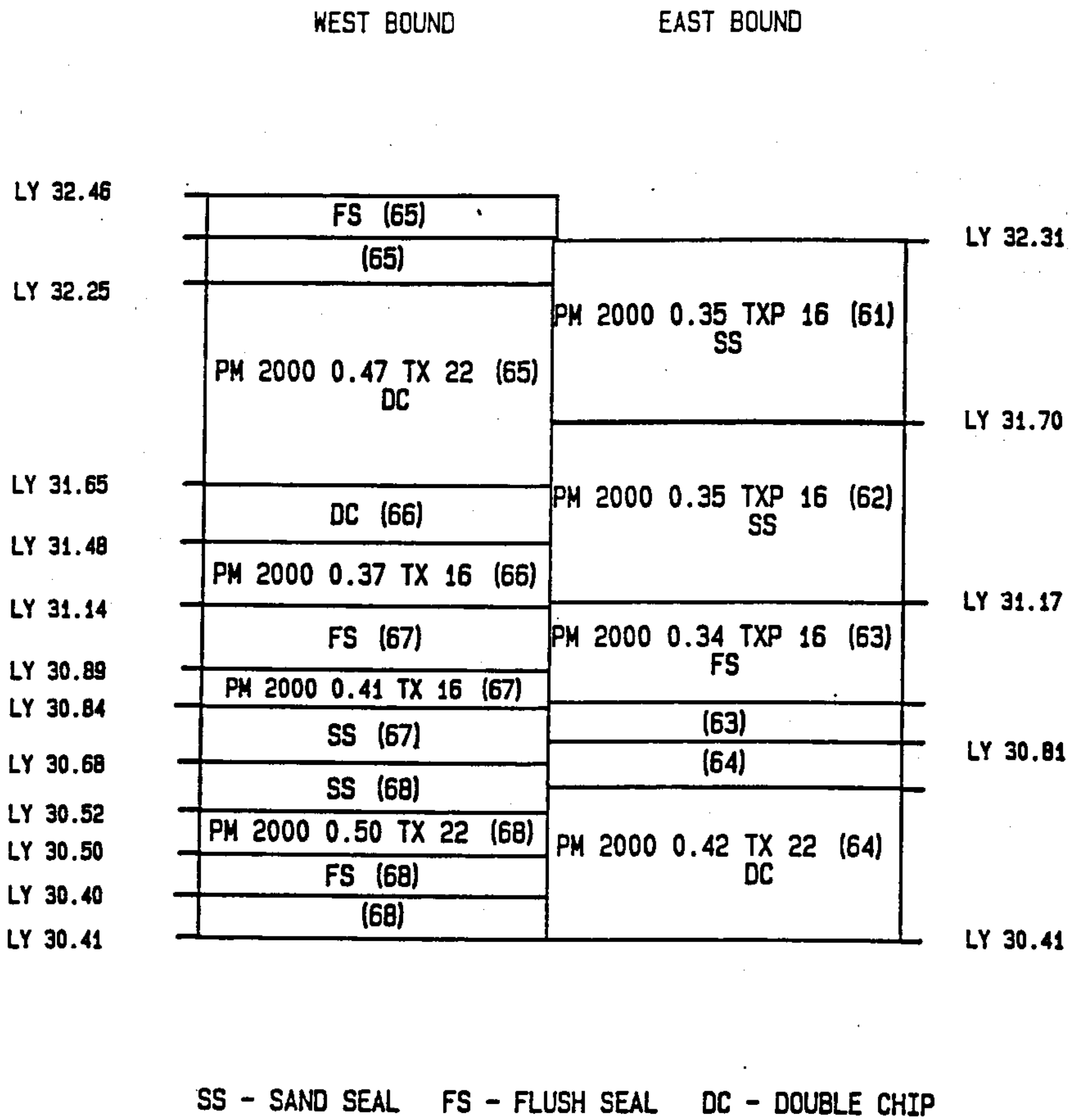


FIGURE 3: CHIP SEAL SECTIONS 61-68 CONSTRUCTED 9-13-88

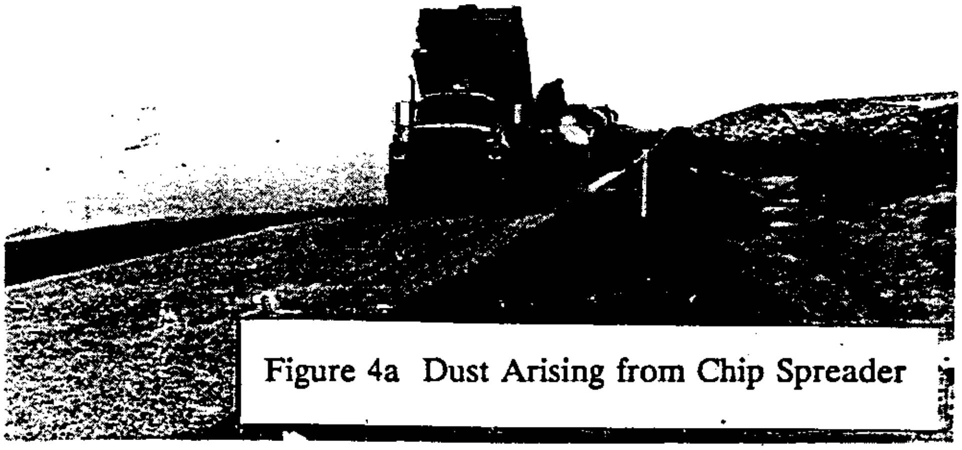


Figure 4a Dust Arising from Chip Spreader

Figure 4b Dust from Chip Spreader

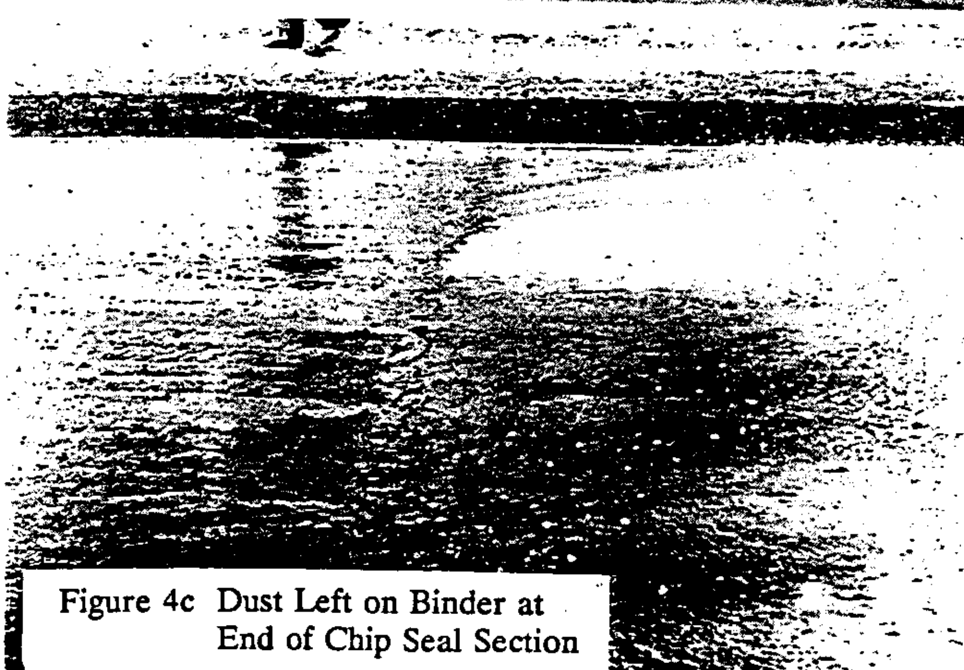


Figure 4c Dust Left on Binder at End of Chip Seal Section

Figure 4 Dust Problems

CHIP SEAL EVALUATION

LOCATION

State ______________ County ______________ Highway ______________

Mile Post or Station Limits: From ______________ To ______________

Section Identification Number ______________

CONDITION

	Poor		Fair		Good	
Overall Condition	0	2	4	6	8	10

AGGREGATE RETENTION

Percent Aggregate Loss

	100		50	25	15	10	5	2	0
Outer Wheel Path	0	2	4		6		8		10

Inner Wheel Path	0	2	4	6	8	10
Between Wheel Path	0	2	4	6	8	10
Centerline	0	2	4	6	8	10

BLEEDING

	Severe		Moderate		Slight	
Outer Wheel Path	0	2	4	6	8	10
Inner Wheel Path	0	2	4	6	8	10
Between Wheel Path	0	2	4	6	8	10
Centerline	0	2	4	6	8	10

AGGREGATE EMBEDMENT & SURFACE TEXTURE

	Embedment	Texture
Outer Wheel Path	______ %	______ cu. in./sq. in.
Inner Wheel Path	______ %	______ cu. in./sq. in.
Between Wheel Path	______ %	______ cu. in./sq. in.
Centerline	______ %	______ cu. in./sq. in.

OTHER INFORMATION

Skid Number SN_{40} ______

SN ______

SN ______

Comments ______________

Rater(s) ______________ Date ______________

Figure 5: Chip Seal Evaluation Form

		NV		NVP		TX		TXP		UT		
		16	22	16	22	16	22	16	22	12	16	18
LMCRS-2H	0.39				7							
	0.44								4			
	0.47	7					4		2			
	0.48									7		
	0.50	6, 7	5				4					
	0.51					2	5					
	0.52						2, 3					
	0.54						5					
	0.55		5									
	0.56					3	3					
	0.57						5					
HFE	0.48		7				5				7	
	0.52						8					
	0.56		8									
AR 2000	0.44			9								
	0.46				9				9			
	0.47								8			
AC 10R	0.40								8			
	0.41											
	0.44				8.5				8.5			
PM 2000	0.33				8							
	0.34			8, 5	7			5				
	0.35	2					8	4, 7		3		
	0.37					4			3, 3			
	0.38			8								
	0.39								5			
	0.40								3, 8			2
	0.41		5			3				3		
	0.43				8			5				
	0.44											4
	0.45							9	7			
	0.46							6				
	0.47						6					
	0.48			8	8							
	0.50						4					
	0.53								6			

Note: Box indicates sections constructed in cool weather

Figure 6: Summary of Overall Condition from Field Evaluation

		NV		NVP		TX		TXP		UT		
		16	22	16	22	16	22	16	22	12	16	18
LMCRS–2H	0.39				9							
	0.44								9			
	0.47	9					7		9			
	0.48									9		
	0.50	9, 9	9				6					
	0.51					6, 5	8					
	0.52						5, 6					
	0.54						8					
	0.55		9									
	0.56					7						
	0.57						7					
HFE	0.48		9				8				10	
	0.52						8					
	0.56											
AR 2000	0.44			9								
	0.46				9				10			
	0.47								9			
AC 10R	0.40								9			
	0.41											
	0.44				9				9			
PM 2000	0.33				9							
	0.34			9, 6	9			10				
	0.35	8					10	10, 10		6		
	0.37					10			7, 10			
	0.38			9								
	0.39								7			
	0.40								9, 9.5			6
	0.41		7			5				6		
	0.43				9			8				
	0.44											6
	0.45							10	9			
	0.46							9				
	0.47						9					
	0.48			9	9							
	0.50						6					
	0.53								8			

Note: Box indicates sections constructed in cool weather

Figure 7: Summary of Aggregate Retention Between Wheel Path from Field Evaluation

		NV		NVP		TX		TXP		UT		
		16	22	16	22	16	22	16	22	12	16	18
LMCRS-2H	0.39				10							
	0.44								10			
	0.47	10					9		10			
	0.48									10		
	0.50	10, 10	10				9					
	0.51					9	10					
	0.52						9, 9					
	0.54						10					
	0.55		10									
	0.56					9	10					
	0.57						9					
HFE	0.48		10				10				10	
	0.52						10					
	0.56		10									
AR 2000	0.44			10								
	0.46				10				10			
	0.47								10			
AC 10R	0.40								10			
	0.41											
	0.44				10				10			
PM 2000	0.33				10							
	0.34			10, 9	10			10				
	0.35	10					10	10, 10				
	0.37					10			9, 10	8		
	0.38			10								
	0.39								9			
	0.40								10, 10			10
	0.41		9			7				8		
	0.43				10			9				
	0.44											8
	0.45							10	10			
	0.46							10				
	0.47						10					
	0.48			10	10							
	0.50						9					
	0.53								10			

Note: Box indicates sections constructed in cool weather

Figure 8: Summary of Aggregate Retention in Wheel Path from Field Evaluation

		NV		NVP		TX		TXP		UT		
		16	22	16	22	16	22	16	22	12	16	18
LMCRS-2H	0.39				30							
	0.44								30			
	0.47	35					20		55			
	0.48									55		
	0.50	25, 50	25									
	0.51					15	20					
	0.52						15, 15					
	0.54						25					
	0.55		25									
	0.56					15	20					
	0.57						20					
HFE	0.48		15				20				25	
	0.52						25					
	0.56											
AR 2000	0.44			45								
	0.46				40				40			
	0.47								25			
AC 10R	0.40								25			
	0.41											
	0.44				25				20			
PM 2000	0.33				20							
	0.34			30, 20	30			25				
	0.35	20					25	20, 30		20		
	0.37					50			20, 40			
	0.38			25								
	0.39								20			
	0.40								25, 40			20
	0.41		25			20				25		
	0.43				25			20				
	0.44											15
	0.45							35	25			
	0.46							20				
	0.47						60					
	0.48			25	30							
	0.50						16.5					
	0.53								25			

Note: Box indicates sections constructed in cool weather

Figure 9: Summary of Percent Embedment Between Wheel Path from Field Evaluation

		NV		NVP		TX		TXP		UT		
		16	22	16	22	16	22	16	22	12	16	18
LMCRS–2H	0.39				60							
	0.44								45			
	0.47	65					40		55			
	0.48									70		
	0.50	40, 70	45, 35									
	0.51					25	35					
	0.52						30, 30					
	0.54						35					
	0.55		40									
	0.56					35	35					
	0.57						35					
HFE	0.48		35				35				40	
	0.52						40					
	0.56											
AR 2000	0.44			70								
	0.46				65				60			
	0.47								40			
AC 10R	0.40								45			
	0.41											
	0.44				50				40			
PM 2000	0.33				30							
	0.34			40, 30	40			35				
	0.35	20					50	30, 45		35		
	0.37					70			20, 40			
	0.38			35								
	0.39								25			
	0.40								55, 35			30
	0.41		40			25				30		
	0.43				45			35				
	0.44											25
	0.45							45	35			
	0.46							25				
	0.47						75					
	0.48			40	40							
	0.50						25					
	0.53								30			

Note: Box indicates sections constructed in cool weather

Figure 10: Summary of Percent Embedment in Wheel Path from Field Evaluation

		NV		NVP		TX		TXP		UT		
		16	22	16	22	16	22	16	22	12	16	18
LMCRS–2H	0.39				8							
	0.44								6			
	0.47	8.5					4		3.5			
	0.48									8		
	0.50	7.5, 8	7.5				2.5					
	0.51					3.5	4					
	0.52						2, 3					
	0.54						4					
	0.55		3.5									
	0.56					3	2					
	0.57						5					
HFE	0.48		8.5				5.5				7	
	0.52						6					
	0.56		8.5									
AR 2000	0.44			8								
	0.46				8.5				8			
	0.47								6.5			
AC 10R	0.40								8			
	0.41											
	0.44				9				7.5			
PM 2000	0.33				5.5							
	0.34			7, 7.5	4			3				
	0.35	2					8	8, 8		3.5		
	0.37					7			4			
	0.38			8.5								
	0.39								4.5			
	0.40								6, 8			1
	0.41		[illegible]			3				6.5		
	0.43				6							
	0.44											6
	0.45							7.5	6			
	0.46							8				
	0.47						2					
	0.48			8	8							
	0.50						3					
	0.53								8.5			

Note: Box indicates sections constructed in cool weather

Figure 11: Summary of Overall Condition Eight Months After Construction

		NV		NVP		TX		TXP		UT		
		16	22	16	22	16	22	16	22	12	16	18
LMCRS-2H	0.39				10							
	0.44								10			
	0.47	10					10		10			
	0.48									10		
	0.50	10	10				10					
	0.51					9	9					
	0.52						9, 10					
	0.54						10					
	0.55		10									
	0.56					10	9					
	0.57						10					
HFE	0.48		10				10				10	
	0.52						10					
	0.56		10									
AR 2000	0.44			10								
	0.46				10				10			
	0.47								10			
AC 10R	0.40								10			
	0.41											
	0.44				10				10			
PM 2000	0.33				10							
	0.34			10, 10	10			10				
	0.35	10					10	10, 10		10		
	0.37					10			10			
	0.38			10								
	0.39								10			
	0.40								10, 10			10
	0.41		10			10				10		
	0.43				10							
	0.44											10
	0.45							10	10			
	0.46							10				
	0.47						10					
	0.48			10	10							
	0.50						10					
	0.53								10			

Note: Box indicates sections constructed in cool weather

Figure 12: Summary of Aggregate Retention Between Wheel Paths Eight Months After Construction

		NV		NVP		TX		TXP		UT		
		16	22	16	22	16	22	16	22	12	16	18
LMCRS-2H	0.39				10							
	0.44								10			
	0.47	10					10		10			
	0.48									10		
	0.50	10	10				10					
	0.51					10	10					
	0.52						10, 10					
	0.54						10					
	0.55		10									
	0.56					10	10					
	0.57						10					
HFE	0.48		10				10				10	
	0.52						10					
	0.56		10									
AR 2000	0.44			10								
	0.46				10				10			
	0.47								10			
AC 10R	0.40								10			
	0.41											
	0.44				10				10			
PM 2000	0.33				10							
	0.34			10, 10	10			10				
	0.35	10					10	10, 10		10		
	0.37					10			10			
	0.38			10								
	0.39								10			
	0.40								10, 10			10
	0.41		10			10				10		
	0.43				10							
	0.44											10
	0.45							10	10			
	0.46							10				
	0.47						10					
	0.48			10	10							
	0.50						10					
	0.53								10			

Note: Box indicates sections constructed in cool weather

Figure 13: Summary of Aggregate Retention In Wheel Paths Eight Months After Construction

		NV		NVP		TX		TXP		UT		
		16	22	16	22	16	22	16	22	12	16	18
LMCRS—2H	0.39				50							
	0.44								30			
	0.47	45					30		20			
	0.48									50		
	0.50	40	40				20					
	0.51					25	25					
	0.52						20, 20					
	0.54						30					
	0.55		25									
	0.56					25	30					
	0.57						40					
HFE	0.48		35				30				35	
	0.52						30					
	0.56		30									
AR 2000	0.44			45								
	0.46				50				60			
	0.47								50			
AC 10R	0.40								40			
	0.41											
	0.44				50				35			
PM 2000	0.33				20							
	0.34			30, 30	20			35				
	0.35	70					50	35, 35		40		
	0.37					75			15			
	0.38			35								
	0.39								25			
	0.40								40, 40			40
	0.41		20			40				30		
	0.43				30							
	0.44											20
	0.45							30	30			
	0.46							30				
	0.47						40					
	0.48			50	30							
	0.50						30					
	0.53								30			

Note: Box indicates sections constructed in cool weather

Figure 14: Summary of Aggregate Embedment Between Wheel Paths Eight Months After Construction

		NV		NVP		TX		TXP		UT		
		16	22	6	22	16	22	16	22	12	16	18
LMCRS—2H	0.39				65							
	0.44								50			
	0.47	65					45		40			
	0.48									70		
	0.50	70	55				30					
	0.51					40	40					
	0.52						30, 30					
	0.54						50					
	0.55		45									
	0.56					35	50					
	0.57						60					
HFE	0.48		45				40				50	
	0.52						6					
	0.56		50									
AR 2000	0.44			65								
	0.46				70				70			
	0.47								60			
AC 10R	0.40								40			
	0.41											
	0.44				50				35			
PM 2000	0.33				30							
	0.34			45, 35	30			40				
	0.35	10					60	45, 45		40		
	0.37					75			30			
	0.38			40								
	0.39								30			
	0.40								60, 60			40
	0.41		35			50				40		
	0.43				40							
	0.44											35
	0.45							45	40			
	0.46							40				
	0.47						40					
	0.48			40	40							
	0.50						40					
	0.53								30			

Note: Box indicates sections constructed in cool weather

Figure 15: Summary of Aggregate Embedment in Wheel Paths Eight Months After Construction

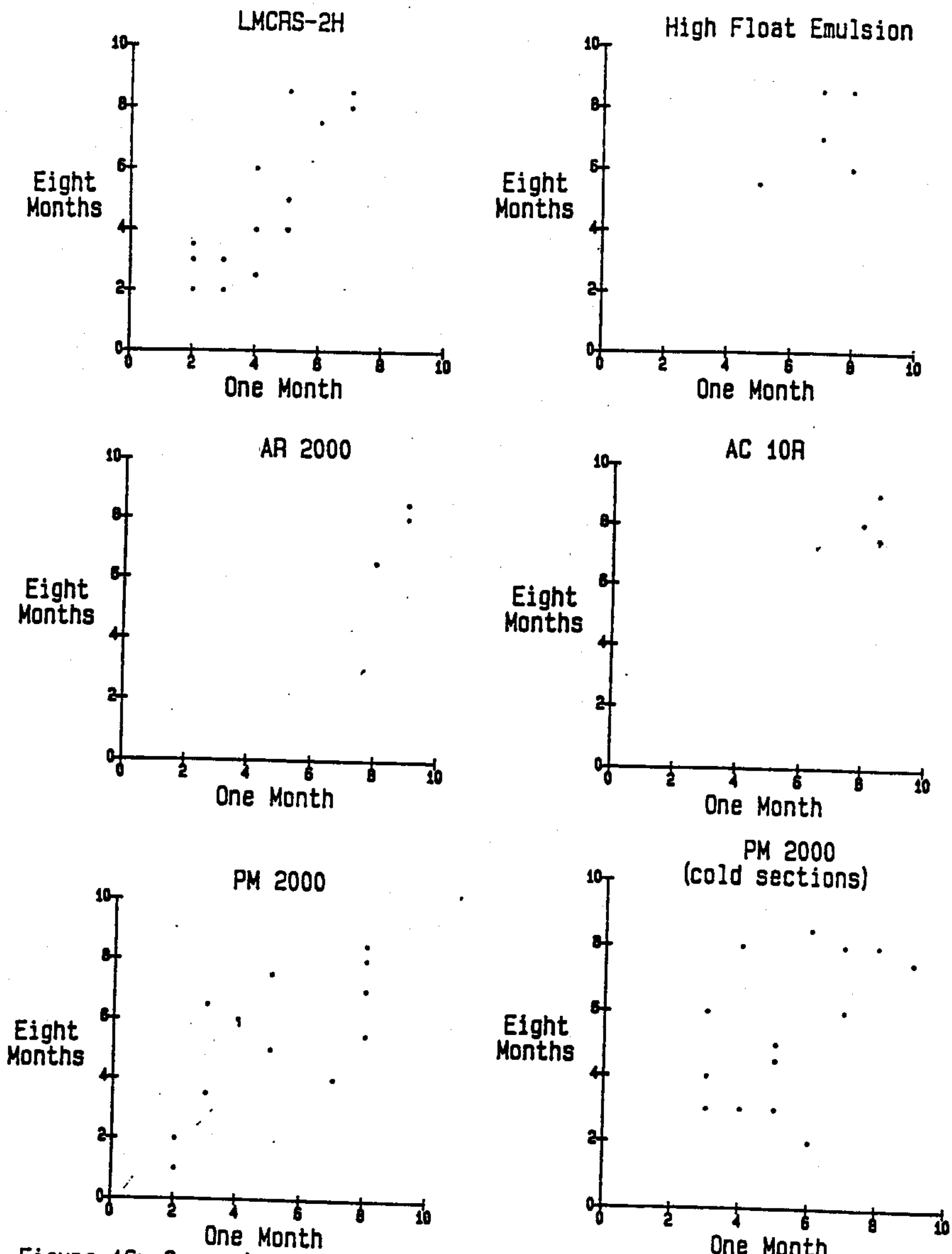


Figure 16: Comparison of overall condition one month after construction to overall condition eight months after construction

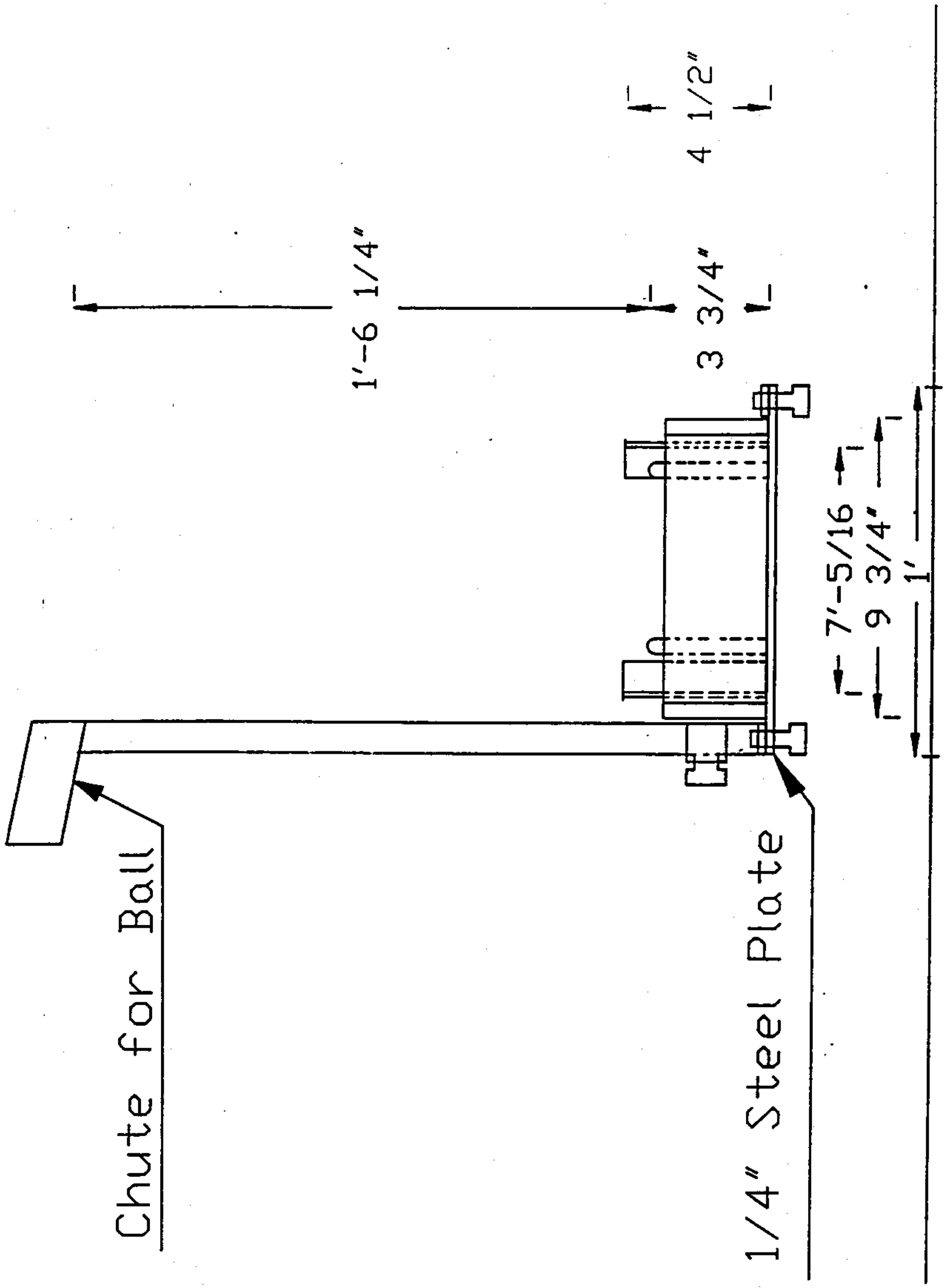


Figure 17: Vialit Test Apparatus

		NV		NVP		TX		TXP		UT		
		16	22	16	22	16	22	16	22	12	16	18
LMCRS-2H	0.39											
	0.44											
	0.47											
	0.48											
	0.50						97					
	0.51											
	0.52											
	0.54											
	0.55											
	0.56	98	96									
	0.57											
HFE	0.48											
	0.52											
	0.56											
AR 2000	0.44											
	0.46				94							
	0.47								97			
AC 10R	0.40											
	0.41											
	0.44				98				98			
PM 2000	0.33											
	0.34											
	0.35							97				
	0.37											
	0.38											
	0.39											
	0.40	89	89		85							
	0.41											
	0.43											
	0.44											
	0.45			97	96				96			
	0.46											
	0.47											
	0.48								98			
	0.50											
	0.53											

Note: Box indicates sections constructed in cool weather

Figure 18: Summary of Aggregate Retention from Vialit Test After Impact

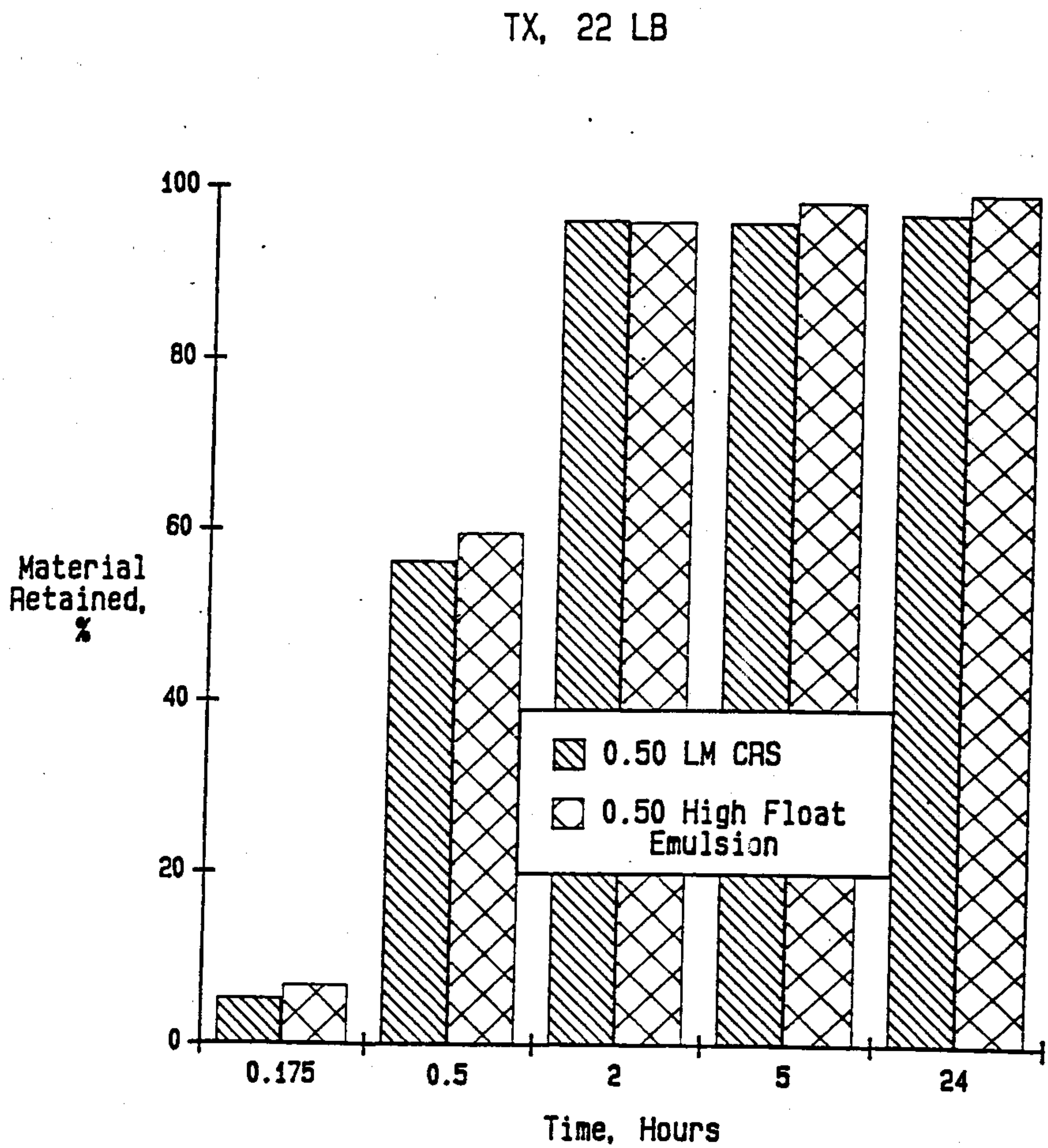


Figure 19: Comparison of 0.50 LM CRS and 0.50 High Float Emulsion with TX, 22 LB Aggregate

HIGH FLOAT EMULSION

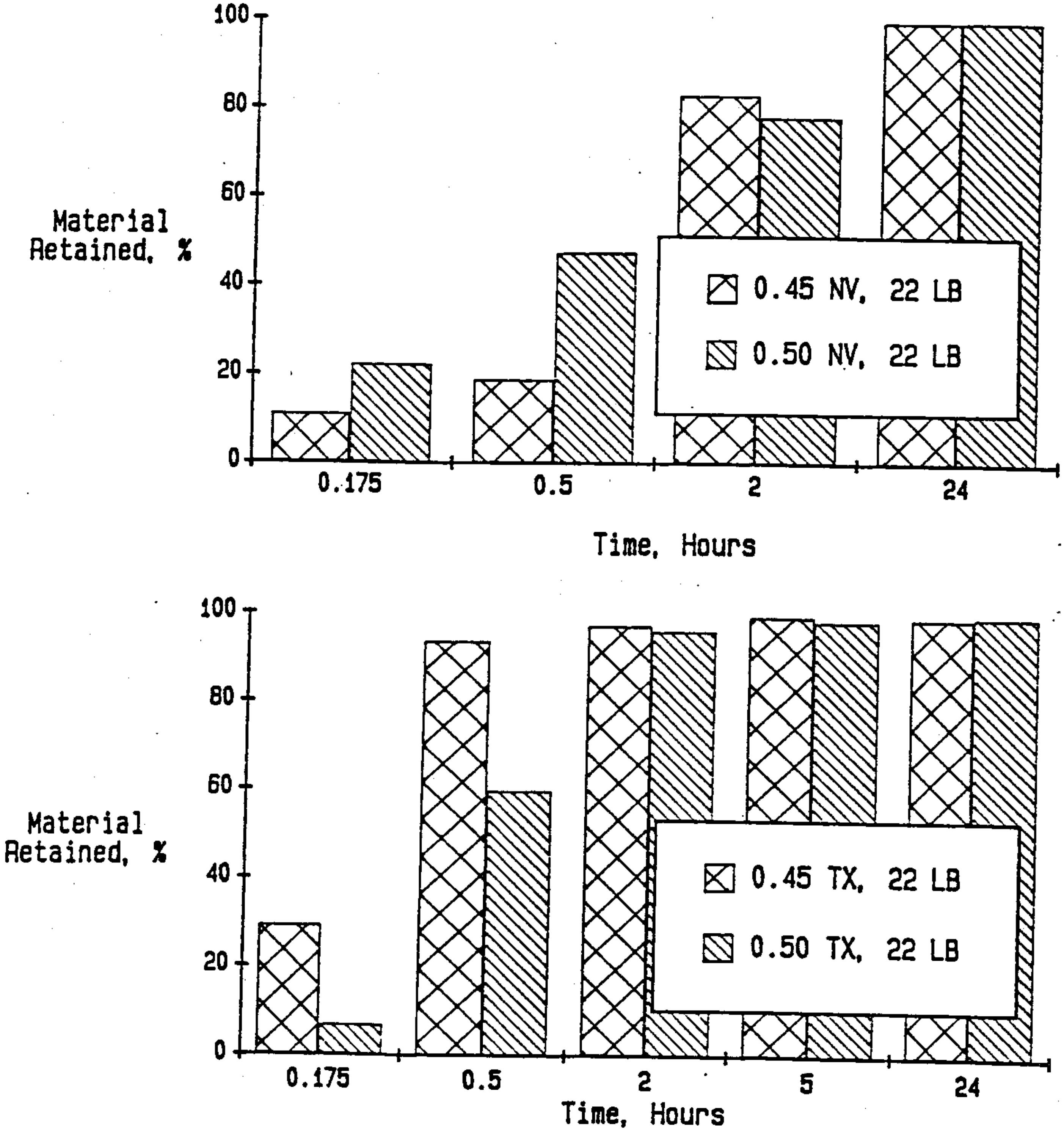
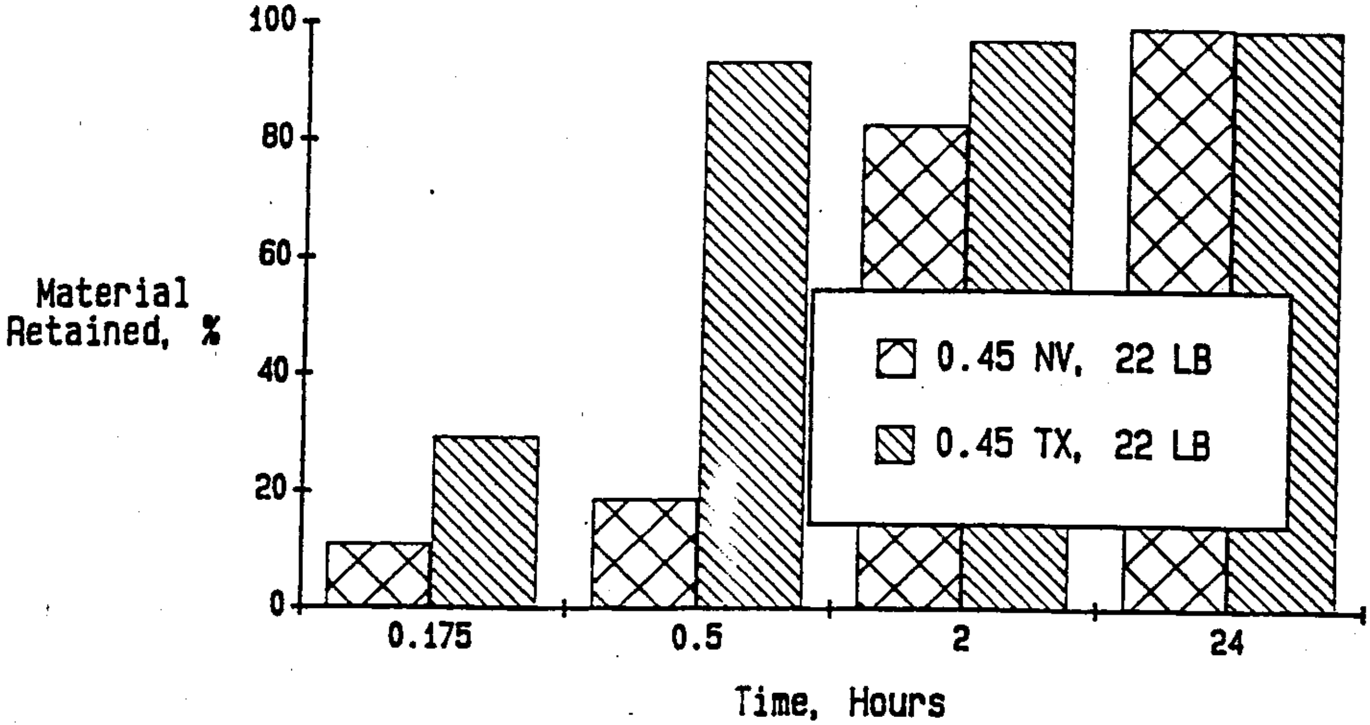


FIGURE 20 Comparison of 0.45 High Float Emulsion and 0.50 High Float Emulsion using Texas and Nevada Aggregates

HIGH FLOAT EMULSION



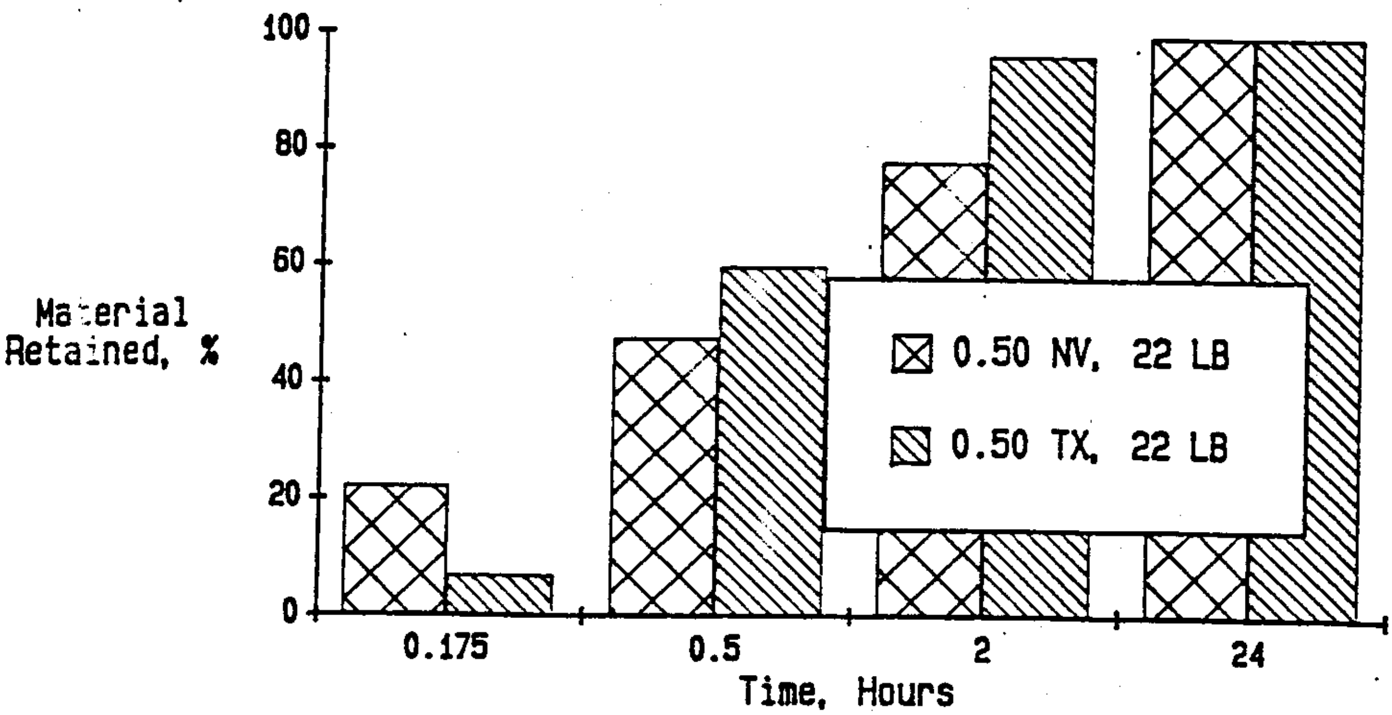


FIGURE 21 Comparison of Texas and Nevada Aggregates using 0.45 High Float Emulsion and 0.50 High Float Emulsion

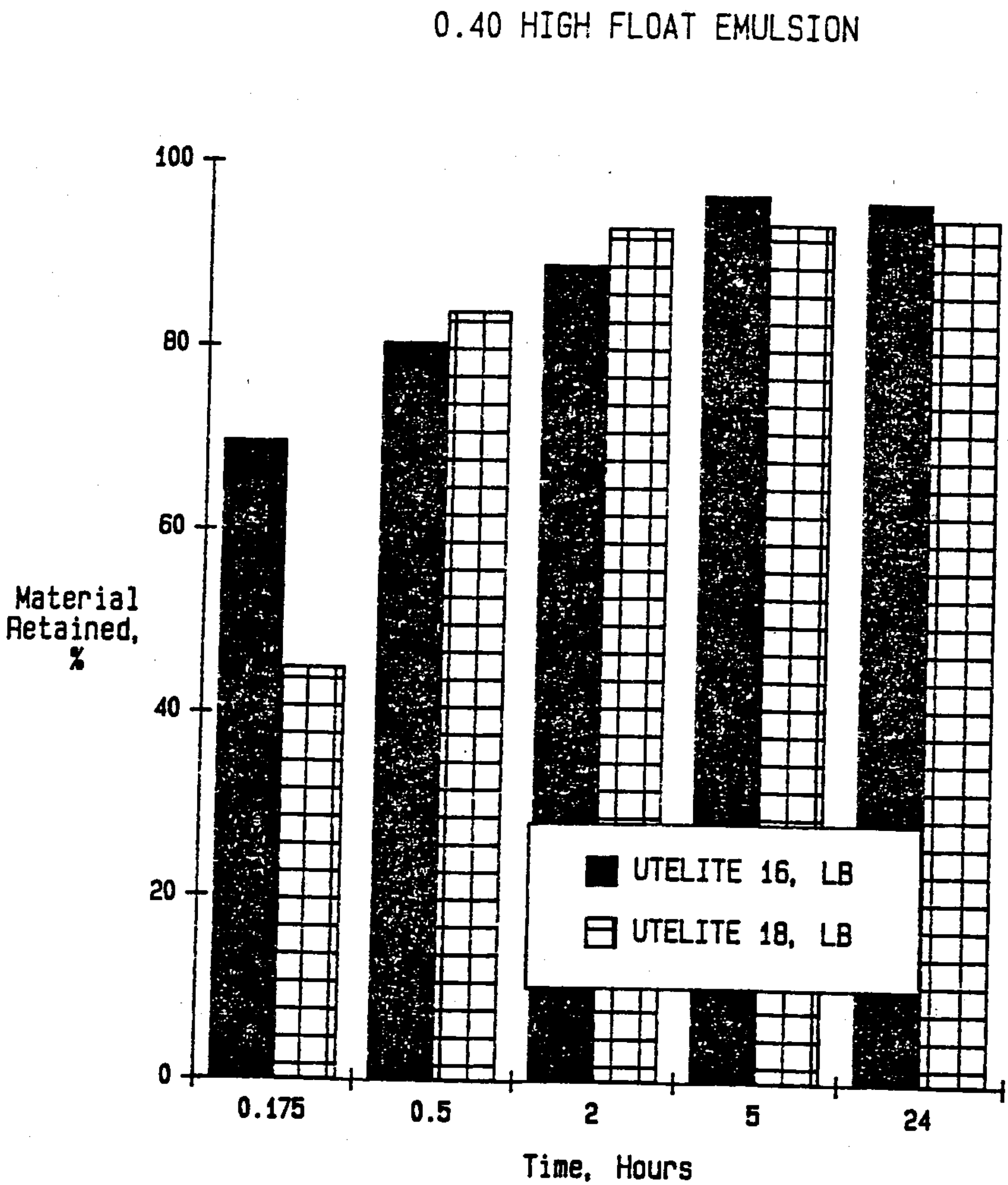


Figure 22: Comparison of Utelite 16, LB and Utelite 18, LB using High Float Emulsion

AC-10R

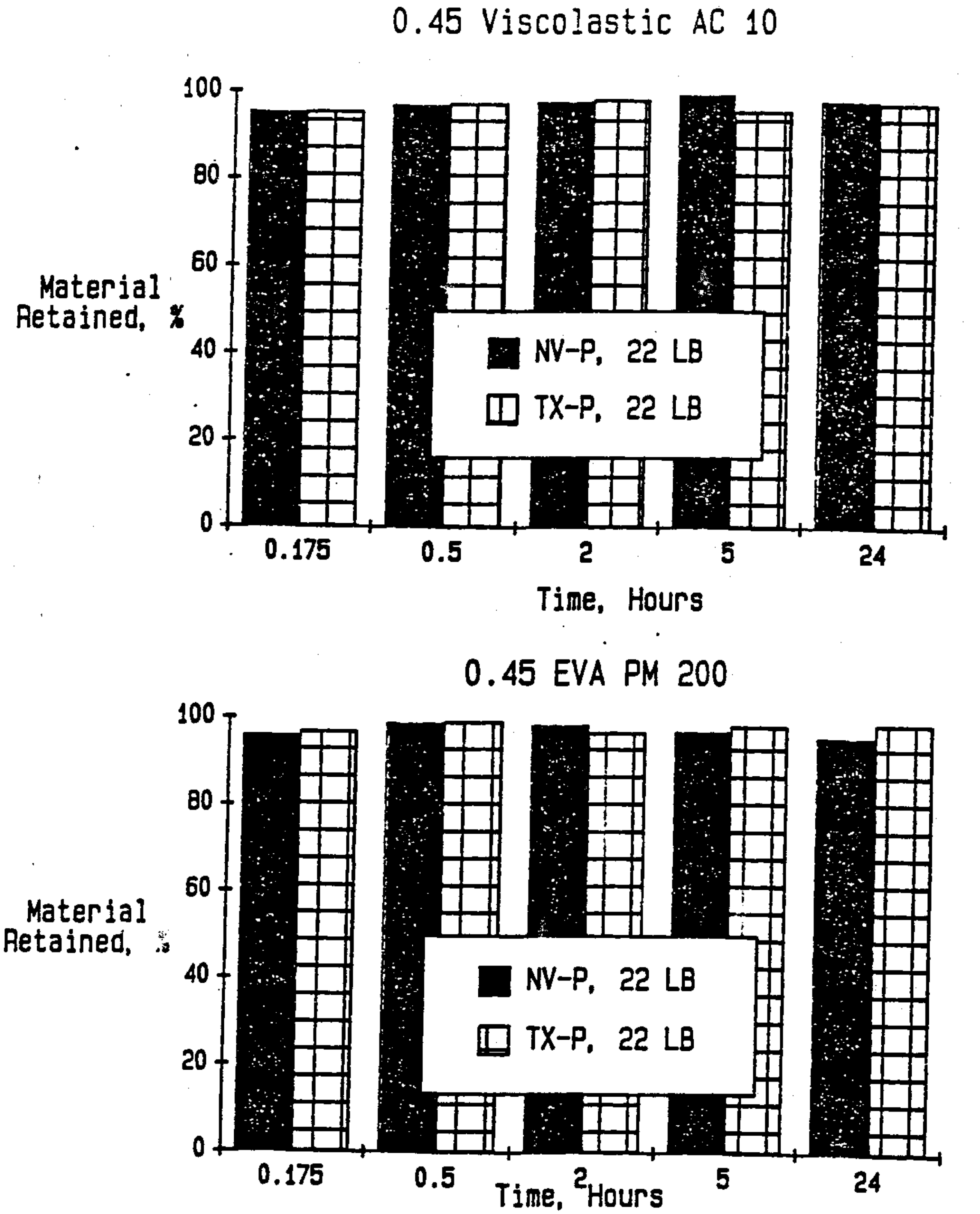
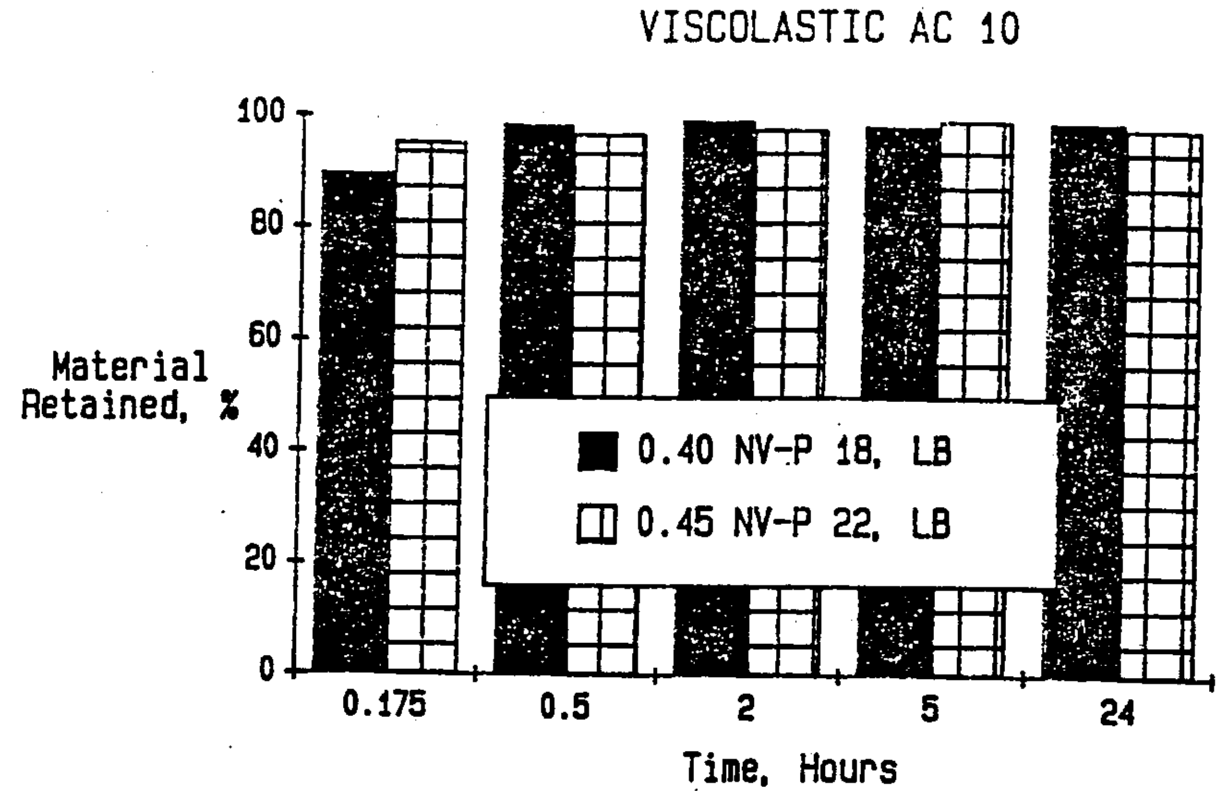


Figure 23 Comparison of EVA PM 2000, and Viscolastic AC with NVP, 22 LB Aggregate and TXP, 22 LB Aggregate

AC-10R



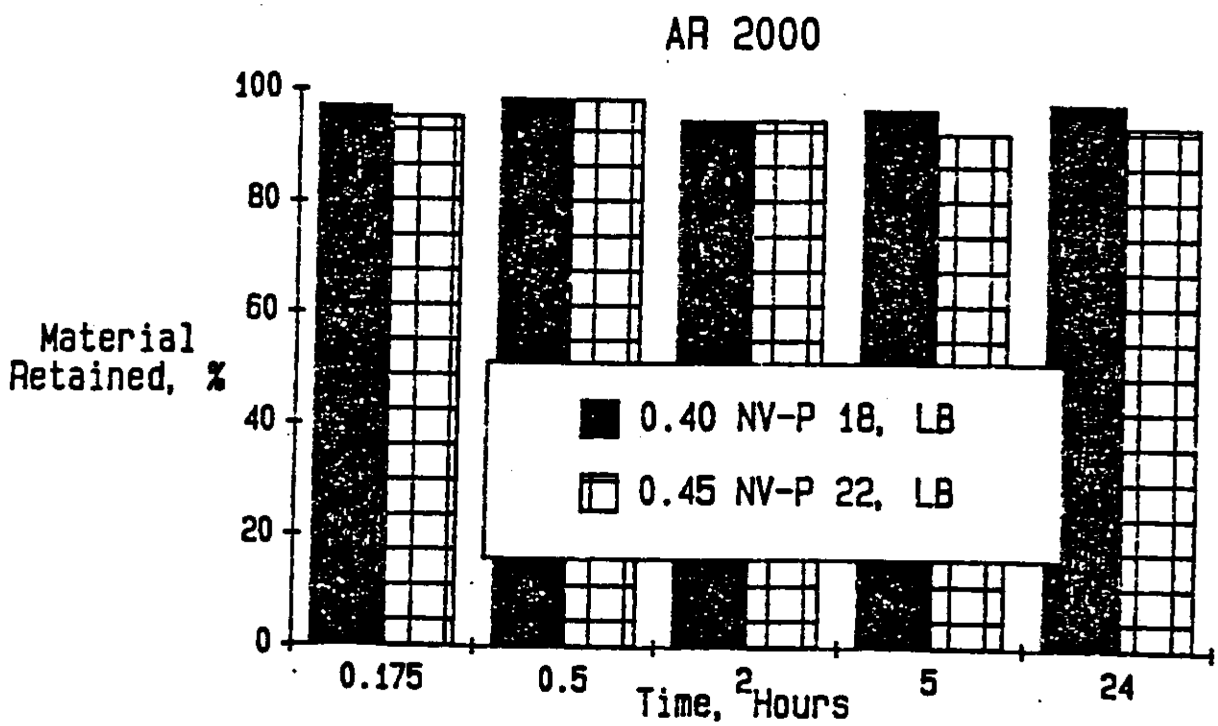


Figure 24 Comparison of NVP 18, LB Aggregate and NVP 22, Aggregate using Viscolastic AC 10 and AR 2000

AC-10R

TX-P, 22 LB

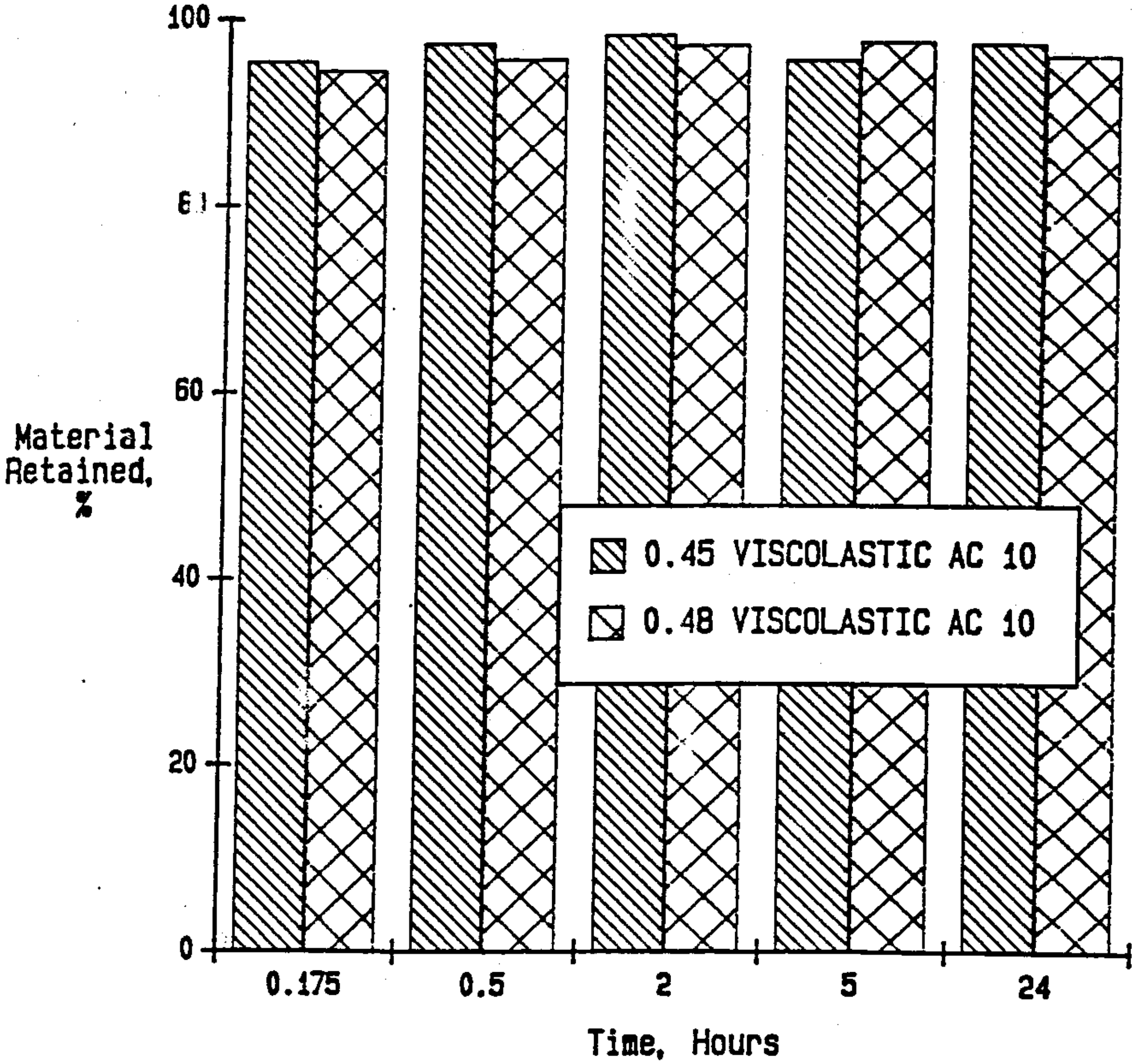
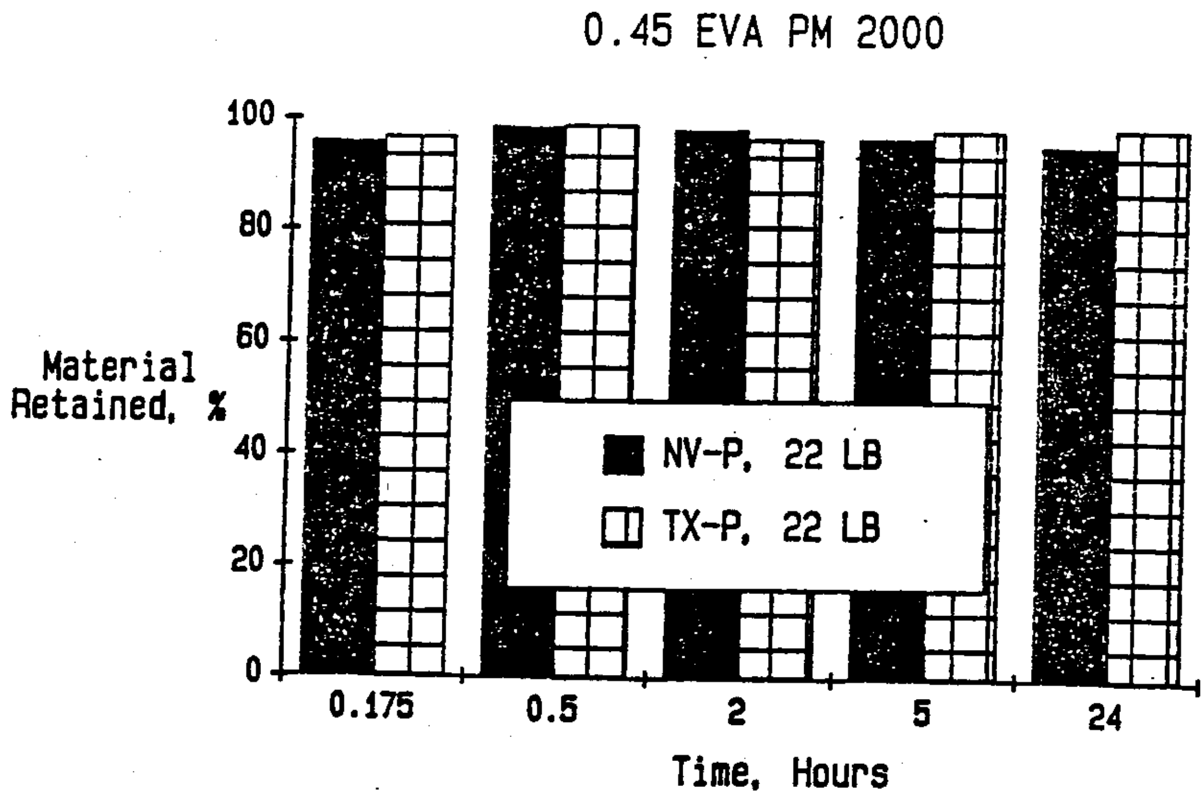


Figure 25: Comparison of 0.45 Viscolastic AC 10 and 0.48 Viscolastic AC 10 using TX-P, 22 LB Aggregate



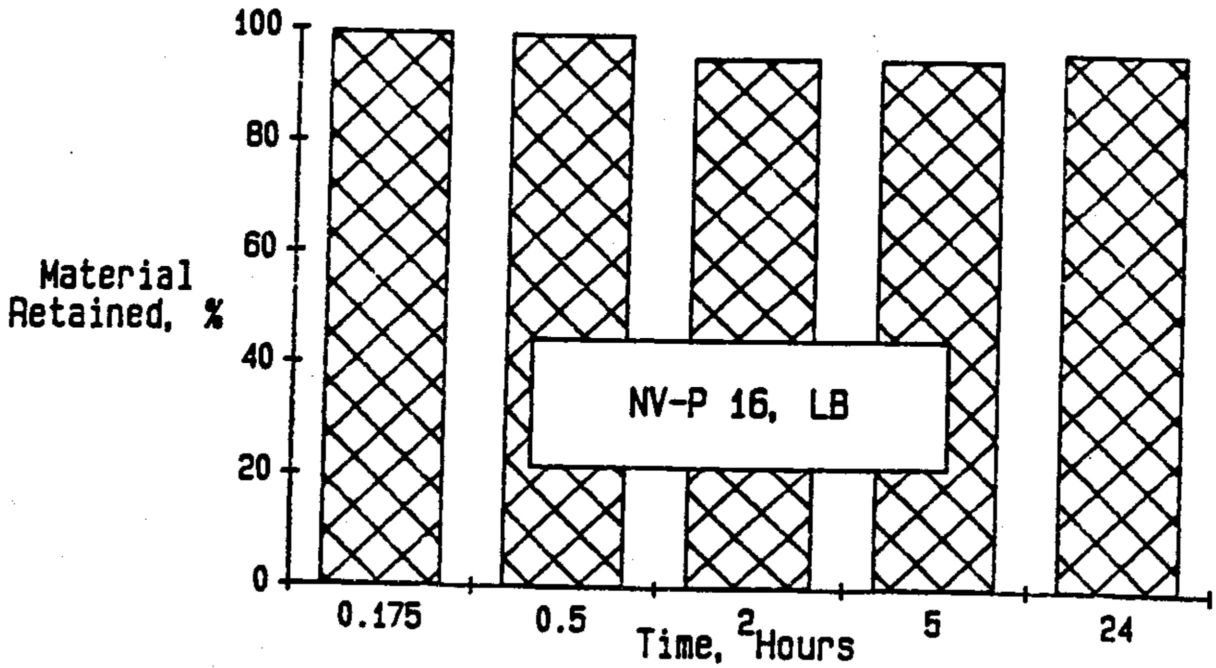


Figure 26 Comparison of Viscolastic AC 10, AR 2000, and PM 2000 with NVP, 18 LB Aggregate and NVP 22, LB Aggregate.

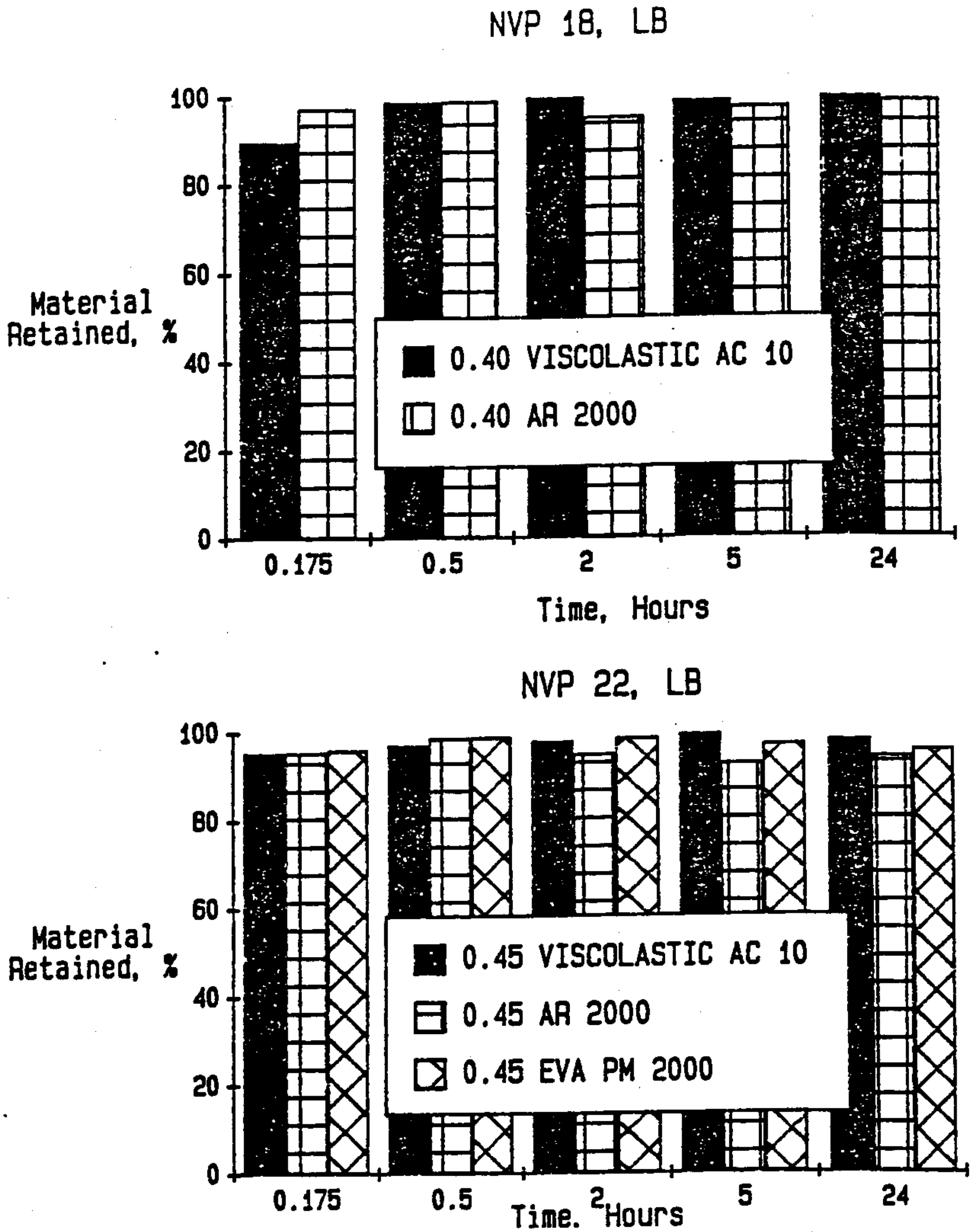


Figure 27 Comparison of Viscolastic AC 10, AR 2000, and PM 2000 with NVP, 18 LB Aggregate and NVP 22, LB Aggregate.

A = Weight of oven dry aggregate, g

9.5 Batch aggregates for individual specimens by splitting the field sample into individual sample sizes according to ASTM D 75. Place aggregate for each individual specimen (A) in a clean, 1-gal. sealable plastic bag and add additional water (W_A). Seal bag, mix aggregate and water, and store no longer than 24 hours prior to use.

10. Samples Prepared with Emulsified Asphalt Cements

10.1 *Sample Preparation*

10.1.1 Pre-heat a set of 15 plates for each binder-aggregate system to be evaluated at 140°F for a minimum of 2 hours prior to testing.

10.1.2 Pre-heat emulsified binder to 140°F. The binder should be heated in a suitable container so that the lid or other covering can be loosely placed on top of the container during heating.

10.1.3 Remove one pre-heated plate at a time from oven, obtain tare weight, and pour the amount of binder as determined in Section 8.1. Immediately rotate plate by hand in order to distribute the binder evenly on the surface of the plate (**Figure 4**).

10.1.4 Immediately place the aggregate application box over the plate with the binder. Insert the metal plate into the slot and place aggregate from one sealable plastic bag evenly on the surface of the metal application plate. Place the aggregate application pad on top of the aggregate, pad side to aggregate. Apply a firm pressure on top of the aggregate application pad with one hand while quickly pulling the metal application plate out of the aggregate application box (**Figure 5**). This will allow the aggregate to drop onto the plate.

10.1.5 Place prepared plate on smooth, solid surface, and roll plate in three passes. One pass is defined as one forward and one backward roll over the plate. Rotate the plate 90 degrees and repeat. When using the wheel barrow to roll, each pass should cover approximately one third of the plate.

10.1.6 Repeat steps 10.1.2 and 10.1.3 until all 15 plates are prepared.

10.2 *Testing*

10.2.1 Three specimens shall be tested at each of the following intervals after sample preparation is complete: 10 minutes, 30 minutes, 2 hours, 5 hours, and 24 hours (3 specimens x 5 test times = 15 specimens).

10.2.2 Obtain the initial weight of the plate, binder, and aggregate. Invert the specimen and place on three support points in Vialit test apparatus for 10 seconds. Immediately remove, turn specimen upright, and obtain weight.

10.2.3 Immediately re-invert plate, place on three support points, and drop steel ball onto the back of the specimen plate by rolling the ball down the chute. Repeat the drop three times within 10 seconds. Remove plate and obtain a final weight (**Figure 6**).

11. Samples Prepared with Paving grade Binders

11.1 *Sample Preparation*

11.1.1 Pre-heat a set of 15 plates for each binder-aggregate system to be evaluated at 300°F (or anticipated field application temperature) for a minimum of 2 hours prior to testing.

11.1.2 Pre-heat binder to 300°F (or anticipated field application temperature).

11.1.3 Proceed with steps 10.1.3 through 10.1.6.

11.2 *Testing*

11.2.1 Prepared specimens shall be stored at 25°C (77°F) (± 2.8°C (5°F)) for a minimum of 15 hours up to a maximum of 24 hours after preparation.

11.2.2 Sets of three specimens will then be placed in separate environmental chambers capable of maintaining -18°C (0°F), 0°C (32 °F), 10°C (50°F), 25°C (77°F), and 40°C (104°F) for 24 hours (± 4 hours).

11.2.3 Specimens will then be tested according to the procedure described in Sections 10.2.2 and 10.2.3.

12. Calculations

12.1 *Excess Material Present on Surface of Prepared Specimen*

$$P_{ex} = 100 - \frac{(A-B) - (C-B)}{(A-B)} \times 100$$

Where:

P_{ex} = Percent of excess material

A = Original weight of sample plate, binder, and aggregate, grams

B = Weight of sample plate, grams

C = Weight of sample plate, binder, and aggregate after inverting for the first time, grams

12.2 *Percent Material Retained After Impact*

$$P = 100 - \frac{(A-B) - (D-B)}{(A-B)} \times 100$$

Where:

P = Percent material retained on plate after impact, grams

D = Weight of sample plate, binder, and aggregate after dropping ball three times, grams.

13. Report

12.1 The report shall include the following:

12.2 Binder source and grade, and quantity used to prepare specimens.

12.3 Aggregate source, and quantity used to prepare specimens.

12.4 Whether Section 10. or 11 was followed for testing.

12.5 Method of rolling used to prepare samples.

12.6 Test Temperature.

12.7 Relative humidity during curing and at time of test.

12.7 The percent of excess material, P_{ex}.

12.8 The percent of material retained after impact, P.

14. **Precision**

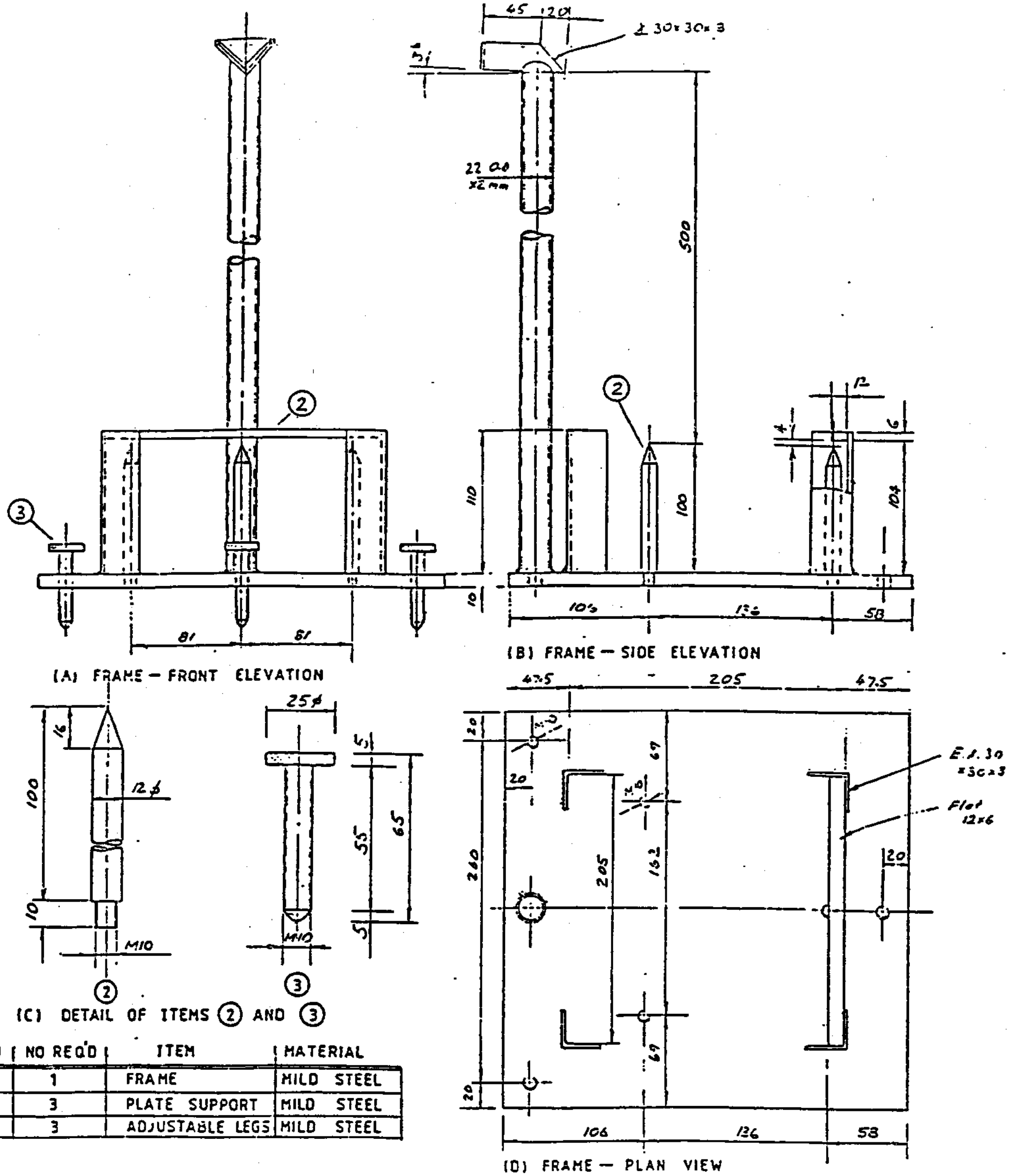
14.1 Limited work in one laboratory suggests that samples prepared with emulsified asphalt cements have the following standard deviations within a set of three samples:

Single Operator

Test Time	Standard Deviation (%)
Determination of Excess Material	
10 minutes	9.8
30 minutes	13.8
2 hours	8.5
5 hours	1.3
24 hours	2.2
Material Retained After Impact	
10 minutes	11.5
30 minutes	8.6
2 hours	5.6
5 hours	0.8
24 hours	2.0

14.2 Preliminary analysis shows that the standard deviations for specimens prepared with paving grade binders at a test temperature of 25°C (77°F) is similar to that of the 24 hour standard deviation for samples prepared with emulsified binders.

Note 3: These estimates of precision are based on samples prepared with the wheel barrow roller.

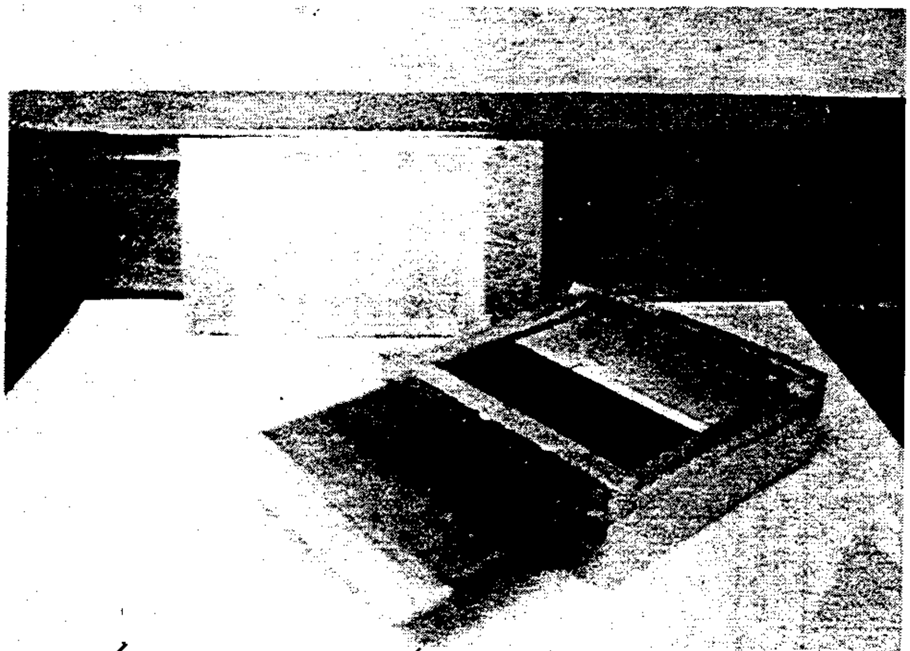


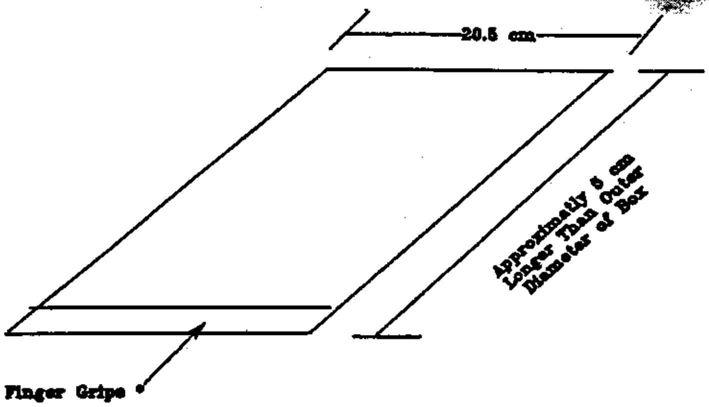
NO	NO REQ'D	ITEM	MATERIAL
1	1	FRAME	MILD STEEL
2	3	PLATE SUPPORT	MILD STEEL
3	3	ADJUSTABLE LEGS	MILD STEEL

FIGURE 1 VIALIT DROP-TEST UNIT

DIMENSIONS: MM

TOLERANCES: ± 0.5 MM





* (Note: Several Layers of Masking Tape Have Been Found To Work Well.)

FIGURE : METAL PLATE

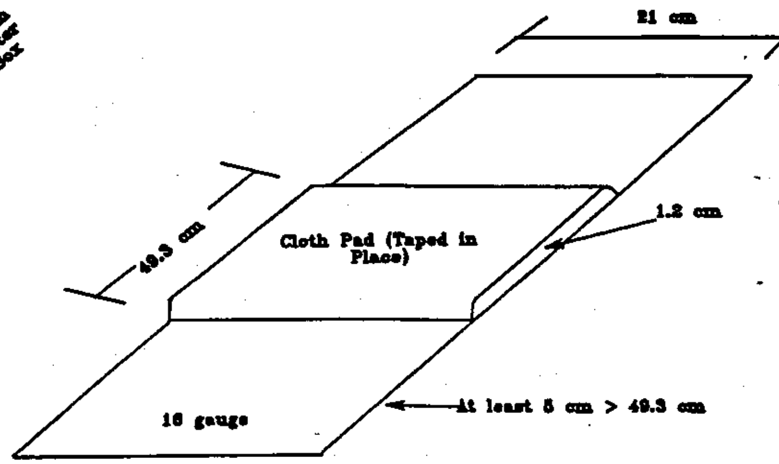
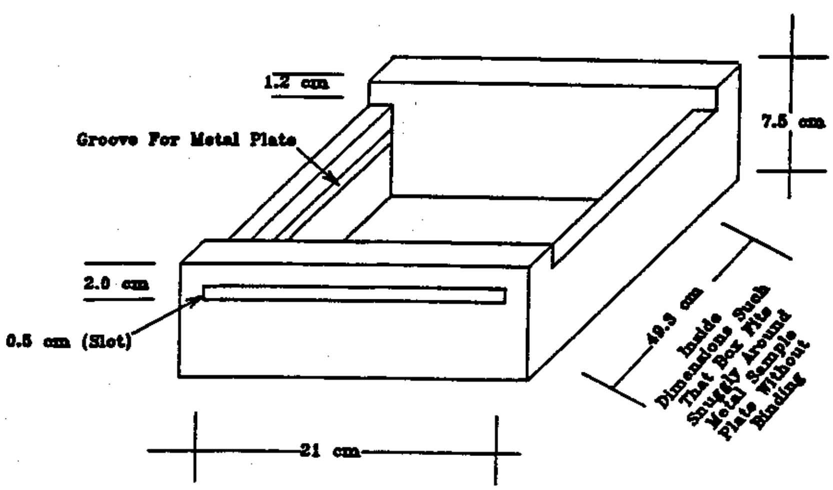


FIGURE : PADDED PLATE

Constructed of Conventional Dimension Wood Stock (Approximatly 2 cm Width)



Dimensions not indicated are not critical to the accuracy of the test.
Tolerances + 2.0mm

FIGURE : APPLICATION BOX

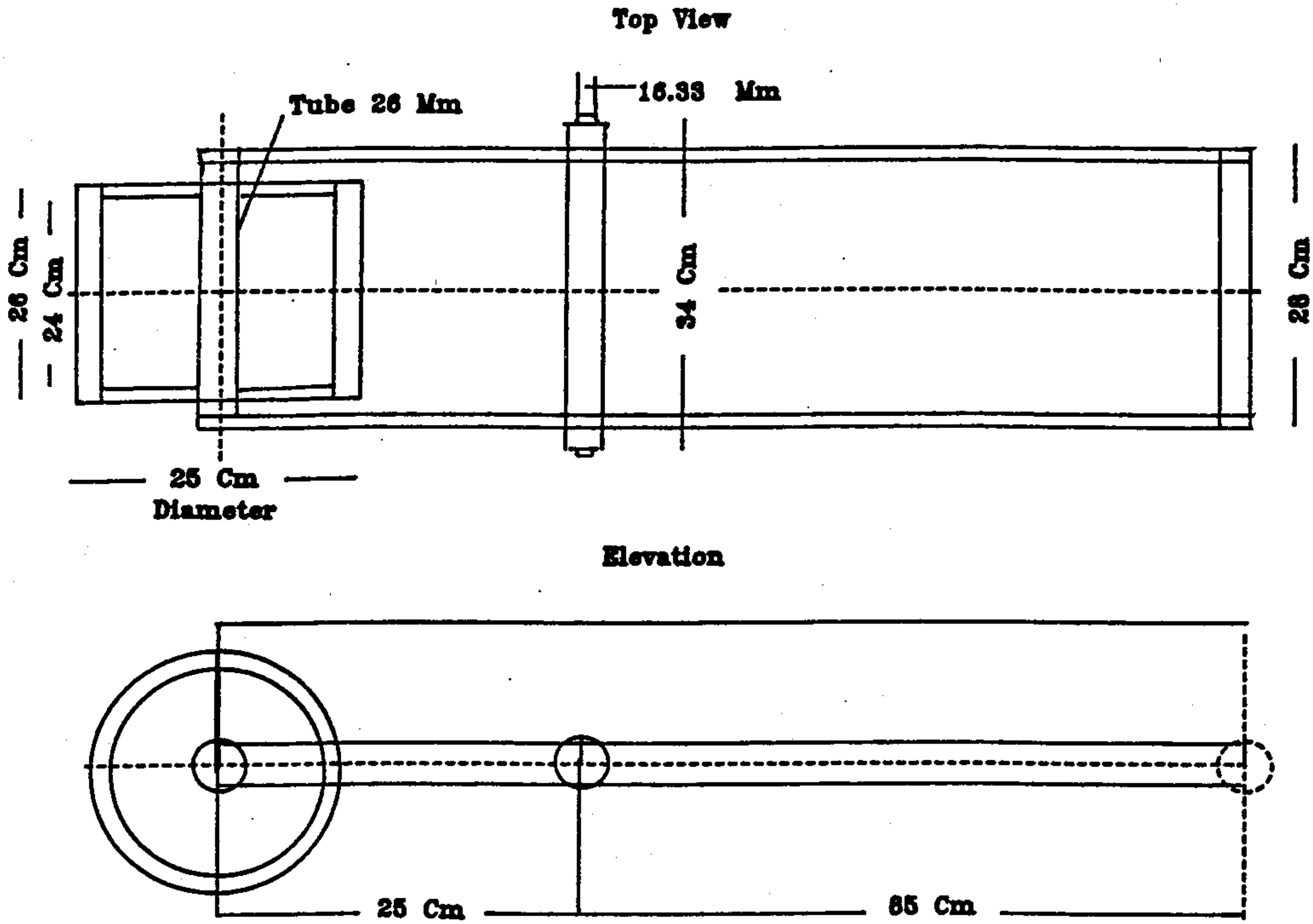


FIGURE 3 : Steel Roller

(Reproduced from R. Langois Draft)

Figure 4: Preparation of Sample

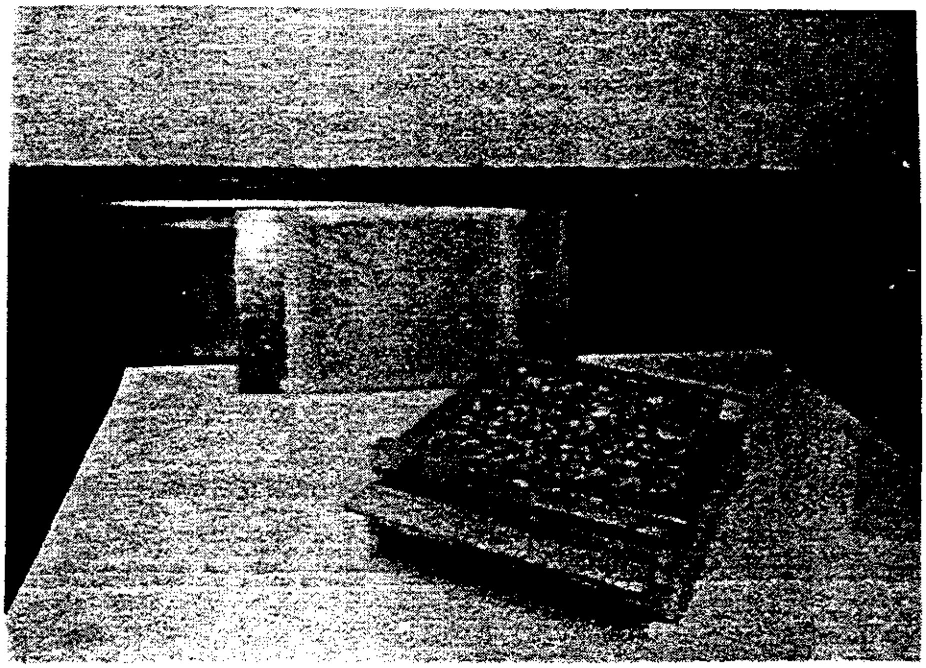


Figure 5a: Aggregate Application Box Over Sample Plate After Binder Has Been Applied

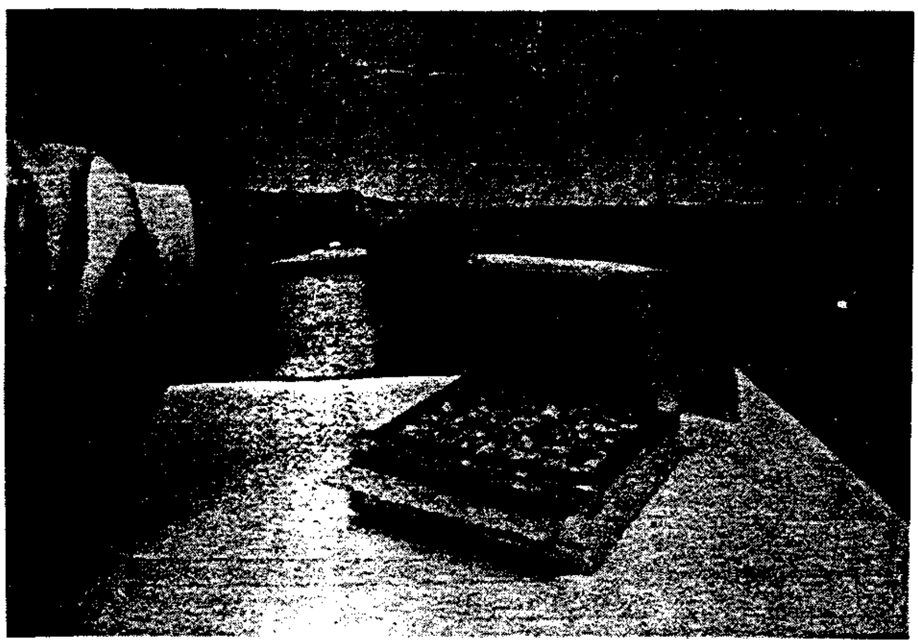


Figure 5b: Preparing To Drop Aggregate On Binder

Figure 5c: Pulling Metal Plate Out So Chips Will Fall Evenly Onto Binder Surface

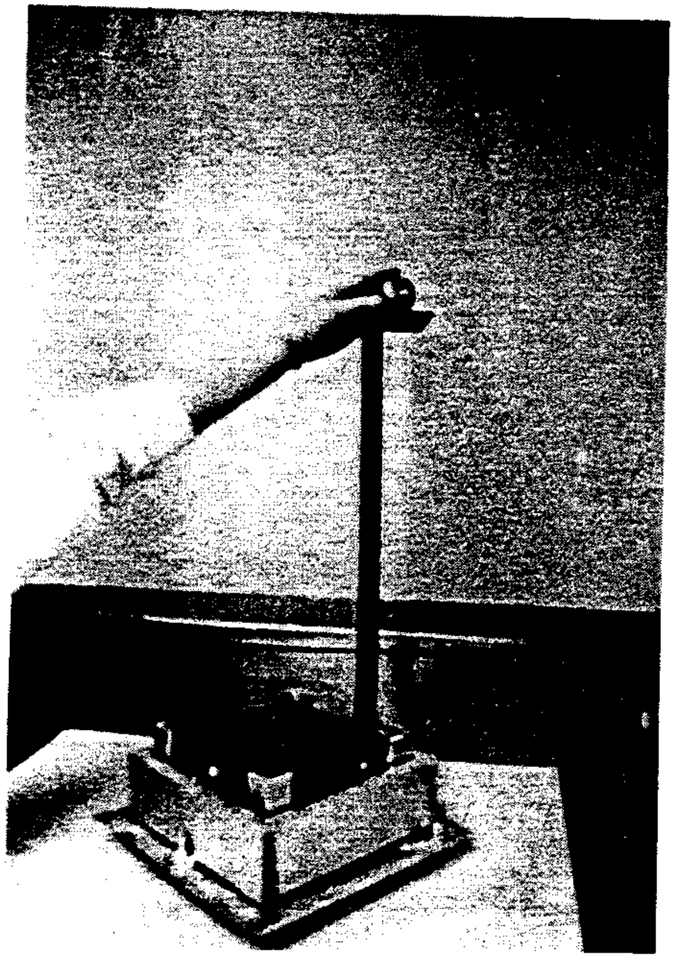


Figure 6: Preparing to Test Cured Specimen

APPENDIX B

Field Condition Survey Results One Month After Construction

TABLE B1: FIELD CONDITION SURVEY RESULTS ONE MONTH AFTER CONSTRUCTION OF LMCRS-2H SECTION (Date 10-21-88, Section Numbers 1-22)

ASPHALT/EMULSION		AGGREGATE RETENTION (scale 1-10)		CONDITION (scale 1-10)
Quan,Agg,Section		Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Overall Section Condition
LMCRS-2H				
0.39 NVP 22 (13)		10 / 10	9 / 9	7
0.44 TXP 22 (14)		10 / 10	9 / 9	4
0.47 NV 16 (16)		10 / 10	9 / 9	7
TX 22 (19)		9 / 9	7 / 7	4
(19)	S	10 / 10	10 / 10	7
TXP 22 (3)		10 / 10	9 / 9	2
0.48 UT 12 (15)		10 / 10	9 / 9	7
0.50 NV 16 (12)		10 / 10	9 / 9	6
(17)		10 / 10	9 / 9	7
NV 22 (18)		10 / 10	9 / 9	5
TX 22 (20)		9 / 9	6 / 6	4
(20)	S	10 / 10	9 / 9	7
0.51 TX 16 (2)		9 / 9	6 / 7	2
TX 22 (8)		9 / 9	8 / 8	5
0.52 TX 22 (1)		9 / 9	5 / 5	2
(21)		9 / 9	6 / 6	3
(21)	S	10 / 10	10 / 10	7
0.54 TX 22 (22)	D	10 / 10	8 / 8	5
0.55 NV 22 (11)		10 / 10	9 / 9	5
0.56 TX 16 (10)		9 / 9	7 / 7	3
TX 22 (9)				3
0.57 TX 22 (7)		9 / 9	7 / 7	5

F - fog seal   S - sand seal   D - dry   DC - double chip

TABLE B1: FIELD CONDITION SURVEY RESULTS ONE MONTH AFTER CONSTRUCTION OF HIGH FLOAT EMULSION SECTION (Date 10-21-88, Section Numbers 31-35)

ASPHALT/EMULSION	AGGREGATE RETENTION (scale 1-10)		CONDITION (scale 1-10)
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Overall Section Condition
HIGH FLOAT EMULSION			
0.48 UL 16 (33)	10 / 10	10 / 10	7
NV 22 (34)	10 / 10	9 / 9	7
TX 22 (32)	10 / 10	8 / 8	5
(32) F	10 / 10	9 / 9	8
0.52 TX 22 (31)	10 / 10	8 / 8	8
TX 22 (31) F	10 / 10	9 / 9	8
0.56 NV 22 (35)	10 / 10	9 / 9	8

F - fog seal S - sand seal D - dry DC - double chip

TABLE B1: FIELD CONDITION SURVEY RESULTS ONE MONTH AFTER CONSTRUCTION OF AR 2000 SECTION (Date 10-21-88, Section Numbers 23, 24, 27, and 28)

ASPHALT/EMULSION	AGGREGATE RETENTION (scale 1-10)		CONDITION (scale 1-10)
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Overall Section Condition
AR 2000			
0.44 NVP 18 (24)	10 / 10	9 / 9	9
0.46 NVP 22 (23)	10 / 10	9 / 9	9
TXP 22 (28)	10 / 10	10 / 10	9
0.47 TXP 22 (27)	10 / 10	9 / 9	8

F - fog seal S - sand seal D - dry DC - double chip

TABLE B1: FIELD CONDITION SURVEY RESULTS ONE MONTH AFTER CONSTRUCTION OF AC 10R SECTION (Date 10-21-88, Section Numbers 25, 26, 29 and 30)

ASPHALT/EMULSION	AGGREGATE RETENTION (scale 1-10)		CONDITION (scale 1-10)
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Overall Section Condition
AC 10R			
0.40 TXP 22 (29)	10 / 10	9 / 9	8
0.41 NVP 18 (26)	10 / 10	10 / 10	8.5
0.44 NVP 22 (25)	10 / 10	9 / 9	8.5
TXP 22 (30)	10 / 10	9 / 9	8.5

F - fog seal   S - sand seal   D - dry   DC - double chip

TABLE B1: FIELD CONDITION SURVEY RESULTS ONE MONTH AFTER CONSTRUCTION OF PM 2000 SECTION (Date 10-21-88, Section Numbers 36-49)

ASPHALT/EMULSION	AGGREGATE RETENTION (scale 1-10)		CONDITION (scale 1-10)
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Overall Section Condition
PM 2000			
0.33 NVP 22 (42)	10 / 10	9 / 9	8
(42) F	10 / 10	9 / 9	8
0.34 NVP 16 (37)	10 / 10	9 / 9	8
(37) S	10 / 10	10 / 10	8
(43)	9 / 9	6 / 6	5
NVP 22 (36)	10 / 10	9 / 9	7
(36) S	10 / 10	10 / 10	8
0.35 NV 16 (49)	10 / 10	8 / 8	2
(49) S	10 / 10	10 / 10	5
0.37 UT 12 (45)	8 / 8	6 / 6	3
(45) S	10 / 10	10 / 10	4
0.38 NVP 16 (41)	10 / 10	9 / 9	8
0.40 UT 18 (44)	10 / 10	6 / 6	2
(44) S	10 / 10	10 / 10	3
0.41 NV 22 (48)	9 / 9	7 / 7	5
(48) S	10 / 10	10 / 10	6
UT 12 (47)	8 / 8	6 / 6	3
UT 12 (47) F	10 / 10	9 / 9	6
0.43 NVP 22 (40)	10 / 10	9 / 9	8
22 (40) F	10 / 10	9 / 9	8
0.44 UT 18 (46)	8 / 8	6 / 6	4
(46) F	10 / 10	9 / 9	6
0.48 NVP 16 (39)	10 / 10	9 / 9	8
NVP 22 (38)	10 / 10	9 / 9	8

F - fog seal S - sand seal D - dry DC - double chip

TABLE B1: FIELD CONDITION SURVEY RESULTS ONE MONTH AFTER CONSTRUCTION OF PM 2000 SECTION (Date 10-21-88, Section Numbers 50-68)

ASPHALT/EMULSION	AGGREGATE RETENTION (scale 1-10)		CONDITION (scale 1-10)
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Overall Section Condition
PM 2000			
0.34 TXP 16 (63) S	10 / 10	10 / 10	5
0.35 TX 22 (64) DC	10 / 10	10 / 10	5
TXP 16 (62)	10 / 10	10 / 10	4
(61)	10 / 10	10 / 10	7
0.37 TX 16 (66)	10 / 10	10 / 10	4
TXP 22 (57)	9 / 9	7 / 7	3
(57) S	10 / 10	10 / 10	3
(58)	10 / 10	10 / 10	3
0.39 TXP 22 (53)	9 / 9	7 / 7	5
(53) F	10 / 10	9 / 9	7
0.40 TXP 22 (59)	10 / 10	9 / 9	3
(59) DC	9 / 9	8 / 8	4
(59) DC,F	10 / 10	10 / 10	8
(60)	10 / 10	9 / 10	8
(60) F	10 / 10	10 / 10	9
0.41 TX 16 (67)	7 / 7	5 / 5	3
(67) F	10 / 10	10 / 10	4
0.43 TXP 16 (54)	9 / 9	8 / 8	5
0.45 TXP 16 (56)	10 / 10	10 / 10	9
TXP 22 (55)	10 / 10	9 / 9	7
0.46 TXP 16 (52)	10 / 10	9 / 9	6
(52) F	10 / 10	9 / 9	7
TXP 22 (51) F	10 / 10	9 / 9	8
0.47 TX 22 (65)	10 / 10	9 / 9	6
0.50 TX 22 (68)	9 / 9	6 / 6	4
TX 22 (68) S	10 / 10	10 / 10	3
0.53 TXP 22 (50)	10 / 10	8 / 8	6

F - fog seal S - sand seal D - dry DC - double chip

TABLE B2: FIELD CONDITION SURVEY RESULTS ONE MONTH AFTER CONSTRUCTION OF LMCRS-2H SECTION (Date 10-21-88, Section Numbers 1-22)

ASPHALT/EMULSION	BLEEDING (scale 1-10)		AGGREGATE EMBEDMENT (%)	
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line
LMCRS-2H				
0.39 NVP 22 (13)	10 / 10	10 / 10	60 / 60	30 / 30
0.44 TXP 22 (14)	10 / 10	10 / 10	45 / 45	30 / 30
0.47 NV 16 (16)	10 / 10	10 / 10	65 / 65	35 / 35
TX 22 (19)	10 / 10	10 / 10	40 / 40	20 / 20
(19) S	10 / 10	10 / 10	75 / 75	50 / 50
TXP 22 (3)	10 / 10	10 / 10	55 / 55	55 / 55
0.48 UT 12 (15)	9 / 9	10 / 10	70 / 70	55 / 55
0.50 NV 16 (12)	10 / 10	10 / 10	40 / 40	25 / 25
NV 16 (17)	10 / 10	10 / 10	70 / 70	50 / 50
NV 22 (18)	10 / 10	10 / 10	45 / 45	25 / 25
(20)	10 / 10	10 / 10	35 / 35	20 / 20
(20) S	10 / 10	10 / 10	60 / 60	35 / 35
0.51 TX 16 (2)	10 / 10	10 / 10	25 / 25	15 / 15
TX 22 (8)	10 / 10	10 / 10	35 / 35	20 / 20
0.52 TX 22 (1)	10 / 10	10 / 10	30 / 30	15 / 15
(21)	10 / 10	10 / 10	30 / 30	15 / 15
(21) S	10 / 10	10 / 10	70 / 70	50 / 50
0.54 TX 22 (22) D	10 / 10	10 / 10	35 / 35	25 / 25
0.55 NV 22 (11)	10 / 10	10 / 10	40 / 40	25 / 25
0.56 TX 16 (10)	10 / 10	10 / 10	35 / 35	15 / 15
TX 22 (9)	6 / 10	10 / 10	35 / 35	20 / 20
0.57 TX 22 (7)	10 / 10	10 / 10	35 / 35	20 / 20

F - fog seal S - sand seal D - dry DC - double chip

TABLE B2: FIELD CONDITION SURVEY RESULTS ONE MONTH AFTER CONSTRUCTION OF HIGH FLOAT EMULSION SECTION (Date 10-21-88, Section Numbers 31-35)

ASPHALT/EMULSION	BLEEDING (scale 1-10)		AGGREGATE EMBEDMENT (%)	
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line
HIGH FLOAT EMULSION				
0.48 UL 16 (33)	10 / 10	10 / 10	40 / 40	25 / 25
NV 22 (34)	10 / 10	10 / 10	35 / 35	15 / 15
TX 22 (32)	10 / 10	10 / 10	35 / 35	20 / 20
(32) F	10 / 10	10 / 10	35 / 35	20 / 20
0.52 TX 22 (31)	10 / 10	10 / 10	40 / 40	25 / 25
(31) F	10 / 10	10 / 10	45 / 45	25 / 25
0.56 NV 22 (35)	10 / 10	10 / 10	35 / 35	25 / 25

F - fog seal S - sand seal D - dry DC - double chip

TABLE B2: FIELD CONDITION SURVEY RESULTS ONE MONTH AFTER CONSTRUCTION OF AR 2000 SECTION (Date 10-21-88, Section Numbers 23, 24, 27 and 28)

ASPHALT/EMULSION	BLEEDING (scale 1-10)		AGGREGATE EMBEDMENT (%)	
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line
AR 2000				
0.44 NVP 18 (24)	10 / 10	10 / 10	70 / 70	45 / 45
0.46 NVP 22 (23)	10 / 10	10 / 10	65 / 65	40 / 40
TXP 22 (28)	10 / 10	10 / 10	60 / 60	40 / 40
0.47 TXP 22 (27)	10 / 10	10 / 10	40 / 40	25 / 25

F - fog seal S - sand seal D - dry DC - double chip

TABLE B2: FIELD CONDITION SURVEY RESULTS ONE MONTH AFTER CONSTRUCTION OF AC 10R SECTION (Date 10-21-88, Section Numbers 25, 26, 29 and 30)

ASPHALT/EMULSION	BLEEDING (scale 1-10)		AGGREGATE EMBEDMENT (%)	
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line
AC 10R				
0.40 TXP 22 (29)	10 / 10	10 / 10	45 / 45	25 / 25
0.41 NVP 18 (26)	10 / 10	10 / 10	60 / 60	35 / 35
0.44 NVP 22 (25)	10 / 10	10 / 10	50 / 50	25 / 25
TXP 22 (30)	10 / 10	10 / 10	40 / 40	20 / 20

F - fog seal S - sand seal D - dry DC - double chip

TABLE B2: FIELD CONDITION SURVEY RESULTS ONE MONTH AFTER CONSTRUCTION OF PM 2000 SECTION (Date 10-21-88, Section Numbers 36-49)

ASPHALT/EMULSION	BLEEDING (scale 1-10)		AGGREGATE EMBEDMENT (%)	
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line
PM 2000				
0.33 NVP 22 (42)	10 / 10	10 / 10	30 / 30	20 / 20
(42) F	10 / 10	10 / 10	35 / 35	25 / 25
0.34 NVP 16 (37)	10 / 10	10 / 10	40 / 40	30 / 30
(37) S	10 / 10	10 / 10	60 / 60	50 / 50
(43)	10 / 10	10 / 10	30 / 30	20 / 20
NVP 22 (36)	10 / 10	10 / 10	40 / 40	30 / 30
(36) S	10 / 10	10 / 10	65 / 65	45 / 45
0.35 NV 16 (49)	10 / 10	10 / 10	20 / 20	20 / 20
(49) S	10 / 10	10 / 10	60 / 60	35 / 35
0.37 UT 12 (45)	10 / 10	10 / 10	35 / 35	20 / 20
(45) S	10 / 10	10 / 10	40 / 40	25 / 25
0.38 NVP 16 (41)	10 / 10	10 / 10	35 / 35	25 / 25
0.40 UT 18 (44)	10 / 10	10 / 10	30 / 30	20 / 20
(44) S	10 / 10	10 / 10	40 / 40	30 / 30
0.41 NV 22 (48)	10 / 10	10 / 10	40 / 40	25 / 25
(48) S	10 / 10	10 / 10	50 / 50	35 / 35
UT 12 (47)	10 / 10	10 / 10	30 / 30	25 / 25
(47) F	10 / 10	10 / 10	45 / 45	35 / 35
0.43 NVP 22 (40)	10 / 10	10 / 10	45 / 45	25 / 25
(40) F	10 / 10	10 / 10	45 / 45	25 / 25
0.44 UT 18 (46)	10 / 10	10 / 10	25 / 25	15 / 15
(46) F	10 / 10	10 / 10	35 / 35	25 / 25
0.48 NVP 16 (39)	10 / 10	10 / 10	40 / 40	25 / 25
NVP 22 (38)	10 / 10	10 / 10	40 / 40	30 / 30

F - fog seal S - sand seal D - dry DB - double chip

TABLE B2: FIELD CONDITION SURVEY RESULTS ONE MONTH AFTER CONSTRUCTION OF PM 2000 SECTION (Date 10-21-88, Section Numbers 50-68)

ASPHALT/EMULSION	BLEEDING (scale 1-10)		AGGREGATE EMBEDMENT (%)	
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line
PM 2000				
0.34 TXP 16 (63) S	10 / 10	10 / 10	35 / 35	25 / 25
0.35 TX 22 (64) DC	10 / 10	10 / 10	50 / 50	40 / 40
TXP 16 (62)	10 / 10	10 / 10	30 / 30	20 / 20
(61)	10 / 10	10 / 10	45 / 45	30 / 30
0.37 TX 16 (66)	10 / 10	10 / 10	70 / 70	50 / 50
TXP 22 (57)			20 / 20	20 / 20
(57) S	10 / 10	10 / 10	50 / 50	40 / 40
(58)	10 / 10	10 / 10	50 / 50	40 / 40
0.39 TXP 22 (53)	10 / 10	10 / 10	25 / 25	20 / 20
(53) F	10 / 10	10 / 10	30 / 30	30 / 30
0.40 TXP 22 (59) DC	10 / 10	10 / 10	30 / 30	25 / 25
(59)DC,F	10 / 10	10 / 10	40 / 40	35 / 35
(59)	10 / 10	10 / 10	55 / 55	40 / 45
(60)	10 / 10	10 / 10	35 / 35	25 / 25
(60) F	10 / 10	10 / 10	35 / 35	25 / 25
0.41 TX 16 (67)	10 / 10	10 / 10	25 / 25	20 / 20
(67) F	10 / 10	10 / 10	35 / 35	25 / 25
0.43 TXP 16 (54)	10 / 10	10 / 10	35 / 35	20 / 20
0.45 TXP 16 (56)	10 / 10	10 / 10	45 / 45	35 / 35
TXP 22 (55)	10 / 10	10 / 10	35 / 35	25 / 25
0.46 TXP 16 (52)	10 / 10	10 / 10	25 / 25	20 / 20
(52) F	10 / 10	10 / 10	30 / 30	25 / 25
(51) F	10 / 10	10 / 10	30 / 30	30 / 30
0.47 TX 22 (65)	10 / 10	10 / 10	75 / 75	60 / 60
0.50 TX 22 (68)			25 / 25	15 / 18
(68) S	10 / 10	10 / 10	35 / 35	25 / 25
0.53 TXP 22 (50)	10 / 10	10 / 10	30 / 30	25 / 25

F - fog seal S - sand seal D - dry DC - double chip

APPENDIX C

Field Condition Survey Results Eight Months After Construction

TABLE C1: COMMENTS MADE EIGHT MONTHS AFTER CONSTRUCTION OF LMCRS-2H SECTION (Date 5-24-89, Section Numbers 1-22)

Asphalt/Emulsion Quan, Agg, Sample			Comments
LMCRS-2H			
0.51	TX 16	(2)	more reflection cracking than section 11, loss of stone 1-2" around the crack, pick up and bleeding during construction
	TX 22	(8)	reflection cracking, aggregate loss 1-2' around cracks
0.52	TX 22	(1)	some reflection cracking
		(21)	reflection cracking, loss of aggregate 1-2" from cracks
		(21)SS	reflection cracking
0.54	TX 22	(22)D	reflection cracking, aggregate loss 1-2" around cracks
0.55	NV 22	(11)	fewer reflection cracks than section 2
0.56	TX 16	(10)	some reflection cracking
	TX 22	(9)	reflection cracking and stone loss 1-2" around crack, tendency to bleed in a short part of the section, 20-30% stone loss between wheel paths and at centerline in the first part of the section
0.57	TX 22	(7)	reflection cracking, aggregate loss 1-2" from crack

TABLE C1: COMMENTS MADE EIGHT MONTHS AFTER CONSTRUCTION OF LMCRS-2H SECTION (Date 5-24-89, Section Numbers 1-22)

Asphalt/Emulsion Quan, Agg, Sample	Comments
LMCRS-2H	
0.39 NVP 22 (13)	sanded during construction, reflection cracking, aggregate retained near cracks
0.44 TX 22 (0)	
TXP 22 (14)	reflection cracking, aggregate retention around cracks
0.47 NV 16 (16)	minor reflection cracking
TX 22 (19)	reflection cracking, loss of aggregate around cracks
(19)SS	reflection cracking, aggregate retention around cracks
(19)FS	reflection cracking but sealed, good aggregate retention near cracks
TXP 22 (3)	reflection cracking aggregate loss 1-2" from cracks
0.48 UT 12 (15)	sanded during construction, very little reflection cracking
0.50 NV 16 (12)	reflection cracking, aggregate retention near the cracks
NV 16 (17)	less reflection cracking than section 20
NV 22 (18)	minor reflection cracking, aggregate retention around cracks, less reflection cracking than section 20
0.50 TX 22 (20)	extensive reflection cracking, loss of stone around cracks
(20)SS	reflection cracking, aggregate retention around cracks

TABLE C1: COMMENTS MADE EIGHT MONTHS AFTER CONSTRUCTION OF HIGH FLOAT EMULSION 100S SECTION (Date 5-24-89, Section Numbers 31-35)

Asphalt/Emulsion Quan, Agg, Sample			Comments
HIGH FLOAT EMULSION			
0.48	UL 16	(33)	pick up during construction, minor reflection cracking, little aggregate loss around cracks
	NV 22	(34)	minor reflection cracking
	TX 22	(32)	minor reflection cracking but sealed, a little tendency to loose aggregate around cracks
		(32)FS	no reflection cracking
0.52	TX 22	(31)	more relection cracking than flush seal section, minor aggregate loss in cracks
		(31)FS	minor reflection cracking, good aggregate retention around cracks, some snow plow damage in center of lane
0.56	NV 22	(35)	minor reflection cracking but sealed

TABLE C1: COMMENTS MADE EIGHT MONTHS AFTER CONSTRUCTION OF AR 2000 SECTION (Date 5-24-89, Section Numbers 23, 24, 27 and 28)

Asphalt/Emulsion Quan,Agg,Sample	Comments
AR 2000	
0.44 NVP 18 (24)	minor reflection cracks, slightly open but sealed
0.46 NVP 22 (23)	minor reflection cracks and sealed
TXP 22 (28)	no reflection cracking
0.47 TXP 22 (27)	reflection cracking, aggregate loss around cracks

TABLE C1: COMMENTS MADE EIGHT MONTHS AFTER CONSTRCTION OF AC 10R SECTION (Date 5-24-89, Section Numbers 25, 26, 29, and 30)

Asphalt/Emulsion Quan,Agg,Sample	Comments
AC 10R	
0.40 TXP 22 (29)	minor reflection cracks but sealed
0.41 NVP 18 (26)	no reflection cracking
0.44 NVP 22 (25)	no reflection cracking
TXP 22 (30)	no reflection cracking, some snow plow damage

TABLE C1: COMMENTS MADE EIGHT MONTHS AFTER CONSTRUCTION OF PM 2000 SECTION (Date 5-24-89, Section Numbers 36-43, and 44-49)

Asphalt/Emulsion Quan,Agg,Sample	Comments
PM 2000	
0.33 NVP 22 (42)	moderate reflection cracking, minor aggregate loss around cracks
(42)FS	moderate reflection cracking, minor aggregate loss around cracks, no geysers, some snow plow damage
0.34 NVP 16 (37)	some small geysers, minor-moderate reflection cracking, less cracks on original pavement
(37)SS	less reflection cracking than (42), moderate reflection cracking, a few small geysers
(43)	moderate reflection cracking, aggregate retention around cracks, some geysers
NVP 22 (36)	reflection cracking, little aggregate loss in crack
(36)SS	minor reflection cracking
0.35 NV 16 (49)	moderate reflection cracking, 80% of original stone was lost
(49)SS	moderate reflection cracking
0.37 UT 12 (45)	moderate reflection cracking, lost 60% of original stone, last three deflection measurements are in this section
(45)SS	minor-moderate reflection cracking
0.38 NVP 16 (41)	minor reflection cracking

TABLE C1: COMMENTS MADE EIGHT MONTHS AFTER CONSTRUCTION OF PM 2000 SECTION (Date 5-24-89, Section Numbers 36-43, and 44-49)

Asphalt/Emulsion Quan,Agg,Sample			Comments
PM 2000			
0.40	UT 18	(44)	moderate reflection cracking, 50% of original stone lost, bleeding due to stone loss
		(44)SS	moderate-severe reflection cracking
0.41	NV 22	(48)	minor reflection cracking, some snow plow damage, some geysers
		(48)SS	moderate reflection cracking, few small geysers
	UT 12	(47)	moderate reflection cracking
		(47)FS	moderate reflection cracking
0.43	NVP 22	(40)	reflection cracking
		(40)FS	
0.44	UT 18	(46)	moderate reflection cracking, some geysers
0.48	NVP 16	(39)	moderate reflection cracking
	NVP 22	(38)	moderate reflection cracking

TABLE C1: COMMENTS MADE EIGHT MONTHS AFTER CONSTRUCTION OF PM 2000 SECTION (Date 5-24-89 Section Numbers 50-68)

Asphalt/Emulsion Quan,Agg,Sample	Comments
PM 2000	
0.34 TXP 16 (63)	moderate reflection cracking, stone loss 1-2" from crack, 50% original aggregate lost
(63)FS	moderate reflection cracking
0.35 TX 22 (64)	
TXP 16 (62)	moderate reflection cracking
(61)	moderate reflection cracking
0.37 TX 16 (66)DC	moderate reflection cracking
TXP 22 (57)	severe reflection cracking, bleeding due to loss of stone
(57)SS	slight-moderate relection cracking
(58)SS	slight-moderate reflection cracking, stone loss during construction
0.39 TXP 22 (53)	moderate reflection cracking, 30% original stone lost
(53)FS	slight-moderate reflection cracking
0.40 TXP 22 (59)	slight-moderate reflection cracking
(59)DC&FS	no reflection cracking
(59A)	
(60)	slight reflection cracking
DC? (60)FS	minor reflection cracking

TABLE C1: COMMENTS MADE EIGHT MONTHS AFTER CONSTRUCTION OF PM 2000 SECTION (Date 5-24-89 Section Numbers 50-68)

Asphalt/Emulsion Quan,Agg,Sample	Comments
PM 2000	
0.41 TX 16 (67)	moderate reflection cracking, 50% original aggregate lost
(67)SS	moderate reflection cracking
(67)FS	moderate reflection cracking
0.43 TXP 16 (54)	moderate reflection cracking, stone loss 1-2" from crack, 20-30% stone loss during construction
0.45 TXP 16 (56)	moderate reflection cracking, stone loss 1-2" from crack, a few geysers
TXP 22 (55)	moderate reflection cracking, streaking during construction
0.46 TXP 16 (52)FS?	slight-moderate reflection cracking
TXP 22 (51)FS	minor-moderate reflection cracking
0.47 TX 22 (65)	60% stone loss during construction
(65)DC	moderate reflection cracking
(65)FS	slight reflection cracking, 40-50% stone loss during construction
0.50 TX 22 (68)	slight-moderate reflection cracking, lost 40% of original stone during the winter
(68)SS	minor reflection cracking
(68)FS	minor reflection cracking
0.53 TXP 22 (50)	minor reflection cracking

TABLE C1: COMMENTS MADE EIGHT MONTHS AFTER CONSTRUCTION OF HIGH

TABLE C2 : FIELD CONDITION SURVEY RESULTS EIGHT MONTHS AFTER CONSTRUCTION OF LMCRS-2H SECTION (Date 5-24-89, Section Numbers 1-22)

ASPHALT/EMULSION	AGGREGATE RETENTION (scale 1-10)		CONDITION (scale 1-10)
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Overall Section Condition
LMCRS-2H			
0.39 NVP 22 (13)	10 / 10	10 / 10	8
0.44 TXP 22 (14)	10 / 10	10 / 10	6
0.47 NV 16 (16)	10 / 10	10 / 10	8.5
TX 22 (19)	10 / 10	10 / 10	4
(19) S	10 / 10	10 / 10	5
(19) F	10 / 10	10 / 10	6
TXP 22 (3)	10 / 10	10 / 10	3.5
0.48 UT 12 (15)	10 / 10	10 / 10	8
0.50 NV 16 (12)	10 / 10	10 / 10	7.5
NV 16 (17)	10 / 10	10 / 10	8
0.50 NV 22 (18)	10 / 10	10 / 10	7.5
TX 22 (20)	10 / 10	10 / 10	2.5
(20) S	10 / 10	10 / 10	6
0.51 TX 16 (2)	10 / 10	9 / 9	3.5
TX 22 (8)	10 / 10	9 / 9	4
0.52 TX 22 (1)	10 / 10	10 / 10	2
(21)	10 / 10	9 / 9	3
(21) S	10 / 10	10 / 10	6
0.54 TX 22 (22) D	10 / 10	10 / 10	4
0.55 NV 22 (11)	10 / 10	10 / 10	8.5
0.56 TX 16 (10)	10 / 10	10 / 10	3
TX 22 (9)	10 / 10	9 / 9	2
0.57 TX 22 (7)	10 / 10	10 / 10	5

F - fog seal S - sand seal D - dry DC - double chip

TABLE C2 : FIELD CONDITION SURVEY RESULTS EIGHT MONTHS AFTER CONSTRUCTION OF HIGH FLOAT EMULSION SECTION (Date 15-24-89, Section Numbers 31-35)

ASPHALT/EMULSION	AGGREGATE RETENTION (scale 1-10)		CONDITION (scale 1-10)
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Overall Section Condition
HIGH FLOAT EMULSION			
0.48 UL 16 (33)	10 / 10	10 / 10	7
NV 22 (34)	10 / 10	10 / 10	8.5
TX 22 (32)	10 / 10	10 / 10	5.5
(32) F	10 / 10	10 / 10	7
0.52 TX 22 (31)	10 / 10	10 / 10	6
(31) F	10 / 10	10 / 10	7
0.56 NV 22 (35)	10 / 10	10 / 10	8.5

F - fog seal S - sand seal D - dry DC - double chip

TABLE C2 : FIELD CONDITION SURVEY RESULTS EIGHT MONTHS AFTER CONSTRUCTION OF AR 2000 SECTION (Date 5-24-89, Section Numbers 23, 24, 27, and 28)

ASPHALT/EMULSION	AGGREGATE RETENTION (scale 1-10)		CONDITION (scale 1-10)
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Overall Section Condition
AR 2000			
0.44 NVP 18 (24)	10 / 10	10 / 10	8
0.46 NVP 22 (23)	10 / 10	10 / 10	8.5
TXP 22 (28)	10 / 10	10 / 10	8
0.47 TXP 22 (27)	10 / 10	10 / 10	6.5

TABLE C2 : FIELD CONDITION SURVEY RESULTS EIGHT MONTHS AFTER CONSTRUCTION OF AC 10R SECTION (Date 5-24-89, Section Numbers 25, 26, 29 and 30)

ASPHALT/EMULSION	AGGREGATE RETENTION (scale 1-10)		CONDITION (scale 1-10)
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Overall Section Condition
AC 10R			
0.40 TXP 22 (29)	10 / 10	10 / 10	8
0.41 NVP 18 (26)	10 / 10	10 / 10	9
0.44 NVP 22 (25)	10 / 10	10 / 10	9
TXP 22 (30)	10 / 10	10 / 10	7.5

F - fog seal S - sand seal D - dry DC - double chip

TABLE C2 : FIELD CONDITION SURVEY RESULTS EIGHT MONTHS AFTER CONSTRUCTION OF PM 2000 SECTION (Date 5-24-89, Section Numbers 36-49)

ASPHALT/EMULSION		AGGREGATE RETENTION (scale 1-10)		CONDITION (scale 1-10)
Quan,Agg,Section		Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Overall Section Condition
PM 2000				
0.33 NVP 22 (42)		10 / 10	10 / 10	5.5
(42)	F	10 / 10	10 / 10	6.5
0.34 NVP 16 (37)		10 / 10	10 / 10	7
(37)	S	10 / 10	10 / 10	6
(43)		10 / 10	10 / 10	7.5
NVP 22 (36)		10 / 10	10 / 10	4
(36)	S	10 / 10	10 / 10	
0.35 NV 16 (49)		10 / 10	10 / 10	2
(49)	S	10 / 10	10 / 10	6
0.37 UT 12 (45)		10 / 10	10 / 10	3.5
(45)	S	10 / 10	10 / 10	5
0.38 NVP 16 (41)		10 / 10	10 / 10	8.5
0.40 UT 18 (44)		10 / 10	10 / 10	1
(44)	S	10 / 10	10 / 10	4.5
0.41 NV 22 (48)		10 / 10	10 / 10	5
(48)	S	10 / 10	10 / 10	7
UT 12 (47)		10 / 10	10 / 10	6.5
UT 12 (47)	F	10 / 10	10 / 10	7
0.43 NVP 22 (40)		10 / 10	10 / 10	6
22 (40)	F	10 / 10	10 / 10	6
0.44 UT 18 (46)		10 / 10	10 / 10	6
0.48 NVP 16 (39)		10 / 10	10 / 10	8
NVP 22 (38)		10 / 10	10 / 10	8

F - fog seal S - sand seal D - dry DC - double chip

TABLE C2 : FIELD CONDITION SURVEY RESULTS EIGHT MONTHS AFTER CONSTRUCTION OF PM 2000 SECTION (Date 5-24-89, Section Numbers 50-68)

ASPHALT/EMULSION Quan,Agg,Section		AGGREGATE RETENTION (scale 1-10) Outer/ Inner Wheel Path	AGGREGATE RETENTION (scale 1-10) Between Wheel Path/ Center Line	CONDITION (scale 1-10) Overall Section Condition
PM 2000				
0.34 TXP 16	(63)	10 / 10	10 / 10	3
	(63) S			
	(63) F	10 / 10	10 / 10	6.5
0.35 TX 22	(64)	10 / 10	10 / 10	7
	(64) DC	10 / 10	10 / 10	8
TXP 16	(62)	10 / 10	10 / 10	8
	(61)	10 / 10	10 / 10	8
0.37 TX 16	(66) D	10 / 10	10 / 10	7
	(66) F	10 / 10	10 / 10	5.5
TXP 22	(57)	10 / 10	10 / 10	4
	(57) S	10 / 10	10 / 10	5.5
	(58) S	10 / 10	10 / 10	5.5
0.39 TXP 22	(53)	10 / 10	10 / 10	4.5
	(53) F	10 / 10	10 / 10	5
0.40 TXP 22	(59)	10 / 10	10 / 10	6
	(59)DC,F	10 / 10	10 / 10	9
	(60)	10 / 10	10 / 10	8
	(60) F	10 / 10	10 / 10	8.5
0.41 TX 16	(67)	10 / 10	10 / 10	3
	(67) S	10 / 10	10 / 10	6
0.43 TXP 16	(54)	10 / 10	10 / 10	5
0.45 TXP 16	(56)	10 / 10	10 / 10	7.5
TXP 22	(55)	10 / 10	10 / 10	6
0.46 TXP 16	(52)	10 / 10	10 / 10	8
TXP 22	(51) F	10 / 10	10 / 10	8
0.47 TX 22	(65)	10 / 10	10 / 10	2
	(65) F	10 / 10	10 / 10	4
	(65) D	10 / 10	10 / 10	7
0.50 TX 22	(68)	10 / 10	10 / 10	3
	(68) S	10 / 10	10 / 10	7.5
	(68) F	10 / 10	10 / 10	7.5
0.53 TXP 22	(50)	10 / 10	10 / 10	8.5

F - fog seal S - sand seal D - dry DC - double chip

TABLE C3 : FIELD CONDITION SURVEY RESULTS EIGHT MONTHS AFTER CONSTRUCTION OF LMCRS-2H SECTION (Date 5-24-89, Section Numbers 1-22)

ASPHALT/EMULSION	BLEEDING (scale 1-10)		AGGREGATE EMBEDMENT (%)	
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line
LMCRS-2H				
0.39 NVP 22 (13)	10 / 10	10 / 10	65 / 65	50 / 50
0.44 TXP 22 (14)	10 / 10	10 / 10	50 / 50	30 / 30
0.47 NV 16 (16)	10 / 10	10 / 10	65 / 65	45 / 45
TX 22 (19)	10 / 10	10 / 10	45 / 45	30 / 30
(19) S	10 / 10	10 / 10	80 / 80	65 / 65
(19) F	10 / 10	10 / 10	60 / 60	40 / 40
TXP 22 (3)	10 / 10	10 / 10	40 / 40	20 / 20
0.48 UT 12 (15)	10 / 10	10 / 10	70 / 70	50 / 50
0.50 NV 16 (12)	10 / 10	10 / 10	80 / 60	40 / 40
(17)	10 / 10	10 / 10	65 / 65	50 / 50
NV 22 (18)	10 / 10	10 / 10	55 / 55	40 / 40
TX 22 (20)	10 / 10	10 / 10	30 / 30	20 / 20
(20) S	10 / 10	10 / 10	70 / 70	40 / 40
0.51 TX 16 (2)	10 / 10	10 / 10	40 / 40	25 / 25
TX 22 (8)	10 / 10	10 / 10	40 / 40	25 / 25
0.52 TX 22 (1)	10 / 10	10 / 10	30 / 30	20 / 20
(21)	10 / 10	10 / 10	30 / 30	20 / 20
(21) S	10 / 10	10 / 10	70 / 70	50 / 50
0.54 TX 22 (22) D	10 / 10	10 / 10	50 / 50	30 / 30
0.55 NV 22 (11)	10 / 10	10 / 10	45 / 45	25 / 25
0.56 TX 16 (10)	10 / 10	10 / 10	35 / 35	25 / 25
TX 22 (9)	10 / 10	10 / 10	50 / 50	30 / 30
0.57 TX 22 (7)	9 / 9	10 / 10	60 / 60	40 / 40

F - fog seal S - sand seal D - dry DC - double chip

TABLE C3 : FIELD CONDITION SURVEY RESULTS EIGHT MONTHS AFTER CONSTRUCTION OF HIGH FLOAT EMULSION (Date 5-24-89, Section Numbers 31-35)

ASPHALT/EMULSION	BLEEDING (scale 1-10)		AGGREGATE EMBEDMENT (%)	
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line
HIGH FLOAT EMULSION				
0.48 UL 16 (33)	9 / 9	9 / 9	50 / 50	35 / 35
NV 22 (34)	10 / 10	10 / 10	45 / 45	35 / 35
TX 22 (32)	10 / 10	10 / 10	40 / 40	30 / 30
(32) F	10 / 10	10 / 10	55 / 55	40 / 40
0.52 TX 22 (31)	10 / 10	10 / 10	40 / 40	30 / 30
(31) F	10 / 10	10 / 10	50 / 50	45 / 45
0.56 NV 22 (35)	10 / 10	10 / 10	50 / 50	35 / 35

F - fog seal S - sand seal D - dry DC - double chip

TABLE C3 : FIELD CONDITION SURVEY RESULTS EIGHT MONTHS AFTER CONSTRUCTION OF AC 10R SECTION (Date 5-24-89, Section Numbers 25, 26, 29 and 30)

ASPHALT/EMULSION	BLEEDING (scale 1-10)		AGGREGATE EMBEDMENT (%)	
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line
AC 10R				
0.40 TXP 22 (29)	10 / 10	10 / 10	60 / 60	40 / 40
0.41 NVP 18 (26)	10 / 10	10 / 10	70 / 70	55 / 55
0.44 NVP 22 (25)	10 / 10	10 / 10	70 / 70	50 / 50
TXP 22 (30)	10 / 10	10 / 10	40 / 40	35 / 35

F - fog seal S - sand seal D - dry DC - double chip

TABLE C3 : FIELD CONDITION SURVEY RESULTS EIGHT MONTHS AFTER CONSTRUCTION OF AC 10R SECTION (Date 5-24-89, Section Numbers 25, 26, 29 and 30)

ASPHALT/EMULSION	BLEEDING (scale 1-10)		AGGREGATE EMBEDMENT (%)	
Quan,Agg,Section	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line
AC 10R				
0.40 TXP 22 (29)	10 / 10	10 / 10	60 / 60	40 / 40
0.41 NVP 18 (26)	10 / 10	10 / 10	70 / 70	55 / 55
0.44 NVP 22 (25)	10 / 10	10 / 10	70 / 70	50 / 50
TXP 22 (30)	10 / 10	10 / 10	40 / 40	35 / 35

F - fog seal S - sand seal D - dry DC - double chip

TABLE C3 : FIELD CONDITION SURVEY RESULTS EIGHT MONTHS AFTER CONSTRUCTION OF PM 2000 SECTION (Date 5-24-89, Section Numbers 36-49)

ASPHALT/EMULSION		BLEEDING (scale 1-10)		AGGREGATE EMBEDMENT (%)	
Quan, Agg, Section		Outer/ Inner Wheel Path	Between Wheel Path/ Center Line	Outer/ Inner Wheel Path	Between Wheel Path/ Center Line
PM 2000					
0.33 NVP 22 (42)		10 / 10	10 / 10	30 / 30	20 / 20
(42)	F	10 / 10	10 / 10	35 / 35	25 / 25
0.34 NVP 16 (37)		10 / 10	10 / 10	35 / 35	30 / 30
(37)	S	10 / 10	10 / 10	70 / 70	60 / 60
(43)		10 / 10	10 / 10	45 / 45	30 / 30
NVP 22 (36)		9 / 9	9 / 9	30 / 30	20 / 20
(36)	S	10 / 10	10 / 10	60 / 60	50 / 50
0.35 NV 16 (49)		10 / 10	10 / 10	10 / 10	10 / 10
(49)	S	10 / 10	10 / 10	55 / 55	40 / 40
0.37 UT 12 (45)		5 / 5	5 / 5	40 / 40	40 / 40
(45)	S	7 / 7	7 / 7	55 / 55	40 / 40
0.38 NVP 16 (41)		10 / 10	10 / 10	40 / 40	35 / 35
0.40 UT 18 (44)		5 / 5	5 / 5	40 / 40	40 / 40
(44)	S	7 / 7	7 / 7	65 / 65	50 / 50
0.41 NV 22 (48)		10 / 10	10 / 10	35 / 35	20 / 20
(48)	S	10 / 10	10 / 10	60 / 60	40 / 40
UT 12 (47)		8.5 / 8.5	8.5 / 8.5	40 / 40	30 / 30
(47)	F	9 / 9	9 / 9	45 / 45	35 / 35
0.43 NVP 22 (40)		10 / 10	10 / 10	40 / 40	30 / 30
(40)	F	10 / 10	10 / 10	50 / 50	40 / 40
0.44 UT 18 (46)		8 / 8	8 / 8	35 / 35	20 / 20
(46)	F				
0.48 NVP 16 (39)		10 / 10	10 / 10	40 / 40	50 / 50
NVP 22 (38)		10 / 10	10 / 10	40 / 40	30 / 30

F - fog seal S - sand seal D - dry DC - double chip

TABLE C3 : FIELD CONDITION SURVEY RESULTS EIGHT MONTHS AFTER CONSTRUCTION OF PM 2000 (Date 5-24-89, Section Numbers 50-68)

ASPHALT/EMULSION Quan,Agg,Section		BLEEDING (scale 1-10) Outer/ Inner Wheel Path	BLEEDING (scale 1-10) Between Wheel Path/ Center Line	AGGREGATE EMBEDMENT (%) Outer/ Inner Wheel Path	AGGREGATE EMBEDMENT (%) Between Wheel Path/ Center Line
PM 2000					
0.34 TXP 16 (63)		5 / 5	5 / 5	40 / 40	35 / 35
(63)	F	9.5 / 9.5	9.5 / 9.5	40 / 40	35 / 35
0.35 TX 22 (64)	DC				
TXP 16 (62)		10 / 10	10 / 10	45 / 45	35 / 35
(61)		10 / 10	10 / 10	45 / 45	35 / 35
0.37 TX 16 (66)	DC	9 / 9	9 / 9	75 / 75	75 / 75
TXP 22 (57)		7 / 7	7 / 7	30 / 30	15 / 15
(57)	S	9 / 9	9 / 9	45 / 45	35 / 35
(58)					
(58)	S	10 / 10	10 / 10	50 / 50	30 / 30
0.39 TXP 22 (53)		9.5 / 9.5	9.5 / 9.5	30 / 30	25 / 25
(53)	F	9 / 9 /	9 / 9	35 / 35	30 / 30
0.40 TXP 22 (59)	DC,F				
(59A)	DC,F	10 / 10	10 / 10	60 / 60	55 / 55
(59A)	F	9.5 / 9.5	9.5 / 9.5	60 / 60	40 / 40
(60)		9.5 / 9.5	9.5 / 9.5	60 / 60	40 / 40
(60)	F	10 / 10	10 / 10	50 / 50	45 / 45
0.41 TX 16 (67)		5 / 5	5 / 5	50 / 50	40 / 40
(67)	S	9 / 9	9 / 9	60 / 60	45 / 45
(67)	F	9 / 9	9 / 9	50 / 50	30 / 30
0.43 TXP 22 (54)		8.5 / 8.5	8.5 / 8.5	35 / 35	25 / 25
0.45 TXP 16 (56)		10 / 10	10 / 10	45 / 45	30 / 30
TXP 22 (55)		10 / 10	10 / 10	40 / 40	30 / 30
0.46 TXP 16 (52)		10 / 10	10 / 10	40 / 40	30 / 30
(52)	F				
TXP 22 (51)	F	10 / 10	10 / 10	30 / 30	30 / 30
0.47 TX 22 (65)		5 / 5	5 / 5	40 / 40	40 / 40
(65)	DC	9.5 / 9.5	9.5 / 9.5	80 / 80	65 / 65
(65)	F	7.5 / 7.5	7.5 / 7.5	60 / 60	60 / 60
0.50 TX 22 (68)		5.5 / 5.5	5.5 / 5.5	40 / 40	30 / 30
(68)	F	10 / 10	10 / 10	50 / 50	35 / 35
(68)	S	9 / 9	9 / 9	75 / 75	60 / 60
0.53 TXP 22 (50)		10 / 10	10 / 10	30 / 30	30 / 30

F - fog seal S - sand seal D - dry DC - double chip

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