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# Interstate Asphalt Demonstration Project NH 0762-038 (Rubblization)

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16. Abstract

This report documents the design and construction of the first rubblization project initiated by the Colorado Department of Transportation. The project was selected to demonstrate the resonant and multi-head breaker methods of rubblization of concrete pavement. Work consisted of rubblizing existing concrete pavement. The resonant breaker method rubblized 39,361 square yards of concrete, while the multi-head breaker rubblized a total of 39,498 square yards of concrete. Three two-inch lifts of a hot bituminous pavement (HBP) were placed on the rubblized concrete. Edge drains were used to control subgrade moisture. A total of 18 moisture probes were installed to evaluate the effectiveness of edge drains. A tipping bucket rain gauge was installed to record precipitation data.

This study will focus on the cost effectiveness of rubblization on jointed plain concrete pavement (JPCP) with alkali-silica reactivity (ASR). The French Rutting Tester and the Hamburg Wheel Tracking Device indicate the HBP pavement will resist rutting and moisture damage. Moisture probe data indicates moisture is being removed from pavement sections. Field performance data will be conducted each year for the 5-year study period. Evaluations will consist of crack mapping, rut measurements, falling weight deflectometer measurements and observation of edge drains. Long-term performance information provided by this study will determine the overall life cycle cost of rubblization with the asphalt overlay.

Implementation
The regions agreed that until the research is complete and the performance is fully evaluated that they will not pursue any additional rubblization projects.

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Prepared by
Colorado Department of Transportation
Research Branch

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## EXECUTIVE SUMMARY

This report documents the design and construction of the research study that was initiated to evaluate the first rubblization project built by the Colorado Department of Transportation. The project was selected to demonstrate the resonant breaker and multi-head hammer methods of rubblization of concrete pavement.

The project selected for this study is located on I-76, Sterling to Iliff in Logan County. The existing pavement on this section of highway was constructed in 1967 and consisted of a 2-inch emulsified asphalt treated base (Class 2) with 8 inches of jointed plain concrete pavement (JPCP) surface. Since the initial construction this section of highway has had limited maintenance. In 1995 this section of highway was overlaid with a 2-inch asphalt bond breaker. The asphalt bond breaker was intended to be the first phase of the unbonded portland cement concrete (PCC) overlay strategy that was scheduled to be rehabilitated in 1999.

When the decision to use the rubblization techniques on this project was made the original plans were revised. The revised plans for the project consisted of removing the existing 2-inch asphalt bond breaker, rubblizing the concrete and placing three two-inch lifts of HBP on the rubblized concrete.

The project used two methods for rubblizing the concrete pavement. The resonant breaker method rubblized 39,361 square yards of concrete. The multi-head hammer rubblized 39,498 square yards of concrete. In addition, edge drains were installed to control subgrade moisture.

Since this was a new method to Colorado, a one-day seminar was held to demonstrate the rubblization process. The seminar provided technology transfer and insight into the rubblization process. A field trip to the project site was included to provide the participants an opportunity to observe the rubblization processes.

This study will focus on the cost-effectiveness of rubblization on jointed plain concrete pavement with alkali-silica reactivity. Field performance data will be conducted each year over the 5-year study period.

Evaluations will consist of crack mapping, rut measurements, falling weight deflectometer measurements and observation of the edge drains. Long-term performance information provided by this study will determine the overall life cycle cost of rubblization with an asphalt overlay.

## Implementation Statement

No additional rubblization projects will be scoped until the research is complete and the performance is fully evaluated.

# TABLE OF CONTENTS


1.0 BACKGROUND .....1

2.0 PROJECT OVERVIEW .....2

2.1 Project Selection .....2

2.2 Project Scope .....2

2.3 Seminar/Field Demonstration .....3

3.0 DESCRIPTION OF PROJECT .....7

3.1 Initial Preparation .....7

3.2 Rubblization .....7

3.3 Resonant Breaker .....8

3.4 Multi-head Hammer .....8

3.5 Edge Drains .....9

3.6 Moisture Probes .....9

3.7 Design Thickness .....11

3.8 Construction .....11

3.9 Project Costs .....12

4.0 PROJECT TESTS .....23

4.1 Mix Design .....23

4.2 European "Torture" Test Results .....23

5.0 RESEARCH EVALUATION .....25

5.1 Crack Mapping .....25

5.2 Moisture Testing .....25

5.3 Falling Weight Deflectometer Testing .....28

6.0 FWD PAVEMENT DESIGN AND ANALYSIS .....31

7.0 SUMMARY AND RECOMMENDATIONS .....33

7.1 Construction .....33

7.2 Performance .....33

8.0 FUTURE EVALUATION .....34

APPENDIX A .....A-1

APPENDIX B .....B-1

APPENDIX C .....C-1

APPENDIX D .....D-1

APPENDIX E .....E-1

## LIST OF FIGURES


1. Location map of project ..... 4
2. Seminar provided technology and insight to the rubblization process ..... 5
3. Trip to project enabled participants to observe rubblization & crack & seat process ..... 5
4. A 4-foot by 4-foot section was excavated to verify specified rubble size ..... 6
5. Condition of joint in concrete .....13
6. Photo shows the ASR distress found in the concrete pavement .....13
7. Condition of shoulder before being broken up by the Bomag .....14
8. Location on project where resonant and multi-head hammer processes were used .....15
9. Resonant treatment process .....16
10. Resonant breaker in action .....16
11. Multi-head hammer in action .....17
12. Steel vibratory roller with "Z" pattern grid on drum face was used to seat pavement .....17
13. Trencher used for installing underdrain .....18
14. Preparation of trench for underdrain installation .....18
15. Close-up of perforated drain pipe & geotextile .....19
16. Geotextile, perforated pipe & filter material for edgedrain .....19
17. Locations of TDR soil moisture sensors .....20
18. Installation of the moisture sensors .....21
19. Installation of sensors and close-up of storage block .....21
20. ATE 525WS rain gauge with 8" collector .....22
21. The Campbell Scientific CR21 datalogger is used to measure hourly rainfall .....22
22. Moisture data .....27


## LIST OF TABLES


1. French Rutting Test Results .....24
2. Hamburg Wheel-Tracking Device Test Results .....25
3. Average and Standard Deviations for FWD .....29
4. Resilient Moduli and Pavement ( Eastbound) .....31
5. Resilient Moduli and Pavement (Westbound) .....32
6. DARWin Pavement Design .....32

## 1.0 BACKGROUND

Colorado currently has 1700 lane miles of portland cement concrete (PCC) pavement of which 33% are in need of rehabilitation. Typically rehabilitation of PCC pavements consists of reconstruction, unbonded concrete overlays or hot bituminous pavement (HBP) overlays. Due to high growth rates and limited resources many of these concrete pavements have gone beyond their original design life. These concrete pavements have deteriorated and have received very little preventive maintenance over the years thus requiring extensive rehabilitation for many sections of highways.

Rehabilitation of PCC, such as rubblization and crack and seat, has been used successfully in other states. However, the Colorado Department of Transportation (CDOT) has had limited experience with the rubblization or crack and seat methods for rehabilitating concrete pavements. This research study was initiated to evaluate and document this technology for its use in Colorado.

This report documents the design and construction of CDOT's first rubblization project.

# 2.0 PROJECT OVERVIEW

## 2.1 Project Selection

The project (NH 0762-038) selected for this study is located on I-76, Sterling to Iliff in Logan County (Figure 1). The existing pavement on this section of highway was constructed in 1967 and consisted of a 2-inch emulsified asphalt treated base (Class 2) with 8 inches of jointed plain concrete pavement (JPCP) surface. Since construction this section of highway has had limited maintenance. In 1995 this section of highway was overlaid with a 2-inch asphalt bond breaker. The asphalt bond breaker was intended to be the first phase of the unbonded portland cement concrete (PCC) overlay strategy that was scheduled to be rehabilitated in 1999.

This project was selected to incorporate rubblization techniques for rehabilitation of a concrete pavement. As noted, the project was scheduled to be rehabilitated using an unbonded PCC overlay. Construction of this type would have necessitated the installation of several crossovers located at the Sterling Interchange. Utilization of the rubblization with asphalt required fewer crossovers and less traffic control. One of the benefits of rubblization is the ability for the work to be performed next to existing traffic. With rubblization the length of time traffic is in a two-way situation can be reduced when compared to a typical concrete overlay.

Another factor that led to the selection of this project was its 3-mile length, which allowed for several evaluation sections. The project is located in both the east and westbound directions of this four-lane divided highway. In 1999 this section of roadway had an average annual daily traffic of 5477; 6% were single unit trucks and 25% were combination trucks. In 1999 the ESALs in the design lane were 267,062.

## 2.2 Project Scope

Once the decision to incorporate rubblization techniques on this project was finalized the original plans were revised. The revised plans for the project consisted of removing the existing 2-inch asphalt bond breaker. The material removed was to be used as shoulder material. The existing concrete was scheduled to be rubblized using three processes, the resonant breaker, the multi-head hammer, and crack and seat.

Following the rubblization process three two-inch lifts of an HBP were to be placed on the rubblized concrete. In addition, edge drains were to be installed as part of the roadway design to remove any existing moisture in the concrete during the rubblization process and to provide drainage for moisture that gets into pavement structure.

## 2.3 Seminar/Field Demonstration

As part of this research study, a one-day seminar demonstrating the rubblization processes was held in Sterling, Colorado on June 22, 1999. The seminar was co-sponsored by the Asphalt Institute, the Colorado Asphalt Pavement Association, the Colorado Department of Transportation, the Federal Highway Administration and the National Asphalt Pavement Association. The purpose of the seminar was to provide technology transfer and insight into the rubblization processes.

Approximately 120 participants were in attendance including representation from seven western state DOTs. The seminar portion of the program included discussions on rubblization techniques along with technical presentations from several rubblization experts at the national level. (Figure 2)

In addition, a field trip to the project site to observe the rubblization and crack and seat processes was included. Figures 3 and 4 were taken during the field demonstration of the different processes.

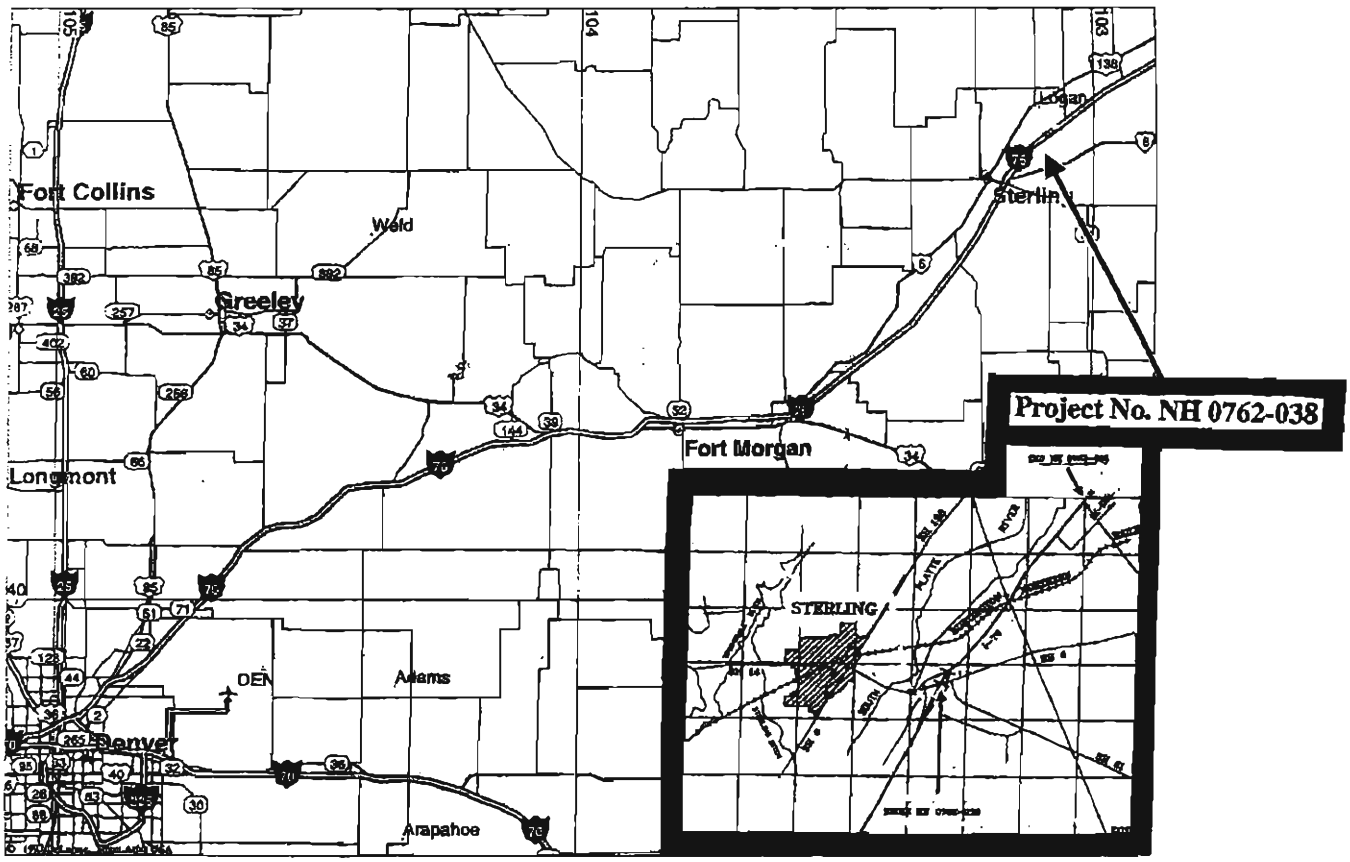


**Figure 1. Location Map of Project No. NH 0762-038**

**Figure 2. Seminar provided technology transfer and insight to the rubblization processes.**

**Figure 3. Field trip to project site enabled participants to observe the rubblization and crack & seat processes.**

**Figure 4. A 4-foot by 4-foot test section was excavated to verify specified rubble size.**

## 3.0 DESCRIPTION OF PROJECT

### 3.1 Initial Preparation

The existing 2-inch asphalt bond breaker was removed with a rotomill. The rotomilled material was stockpiled adjacent to the shoulder to be used later for shouldering next to the new overlay. Figures 5 and 6 show the condition of the concrete pavement following the removal of the asphalt bond breaker.

The existing asphalt shoulders had extensive cracking and major deterioration. A Bomag CMI 650 Reclaimer was used to break the shoulder material into sizes generally less than 1-inch. This process was used to eliminate any voids present under the old shoulders caused by erosion over the years. This material was then compacted and graded prior to placement of the asphalt overlay. Figure 7 shows the condition of the asphalt shoulders before they were broken up with the Bomag CMI 650 Reclaimer.

### 3.2 Rubblization

Initially three methods of rubblizing were to be demonstrated on this project: the resonant breaker, the multi-head hammer and crack and seat. However, due to extensive alkali-silica reactivity (ASR) deterioration in the existing pavement, the crack and seat process was not effective and unable to crack the pavement full depth. The use of the crack and seat process was discontinued on the project. Half of the area that was initially to use the crack and seat process was rubblized using the resonant breaker. The other half was rubblized with the multi-head hammer. Figure 8 shows the location on the project where the resonant breaker and the multi-head hammer processes were used.

Note: Although the crack and seat process was discontinued the contractor did provide an opportunity for the seminar participants to view the crack and seat process during the field presentation.

## 3.3 Resonant Breaker

Approximately half of each direction of roadway was rubblized using the resonant breaker. A total of 39,361 square yards of concrete was rubblized using this method.

The specifications for this type of process required that the concrete pavement be broken up with a self-contained, self-propelled, resonant frequency pavement-breaking unit capable of producing low-amplitude 2,000-pound force blows at a rate not less than 44 cycles-per-section. The majority of the rubblized concrete pieces should be 1 to 3 inches nominal size. (Specification in Appendix A)

At the beginning of the rubblization operations, a 4-foot by 4-foot test section was excavated. The excavated material was visually inspected to verify that the resonant breaker was producing the specified sizes.

Following the rubblization process and prior to placing the first HBP lift, a smooth drum 10-ton steel roller operating in the vibratory mode was used to seat the rubblized pavement.

The resonant breaker process can be seen in Figures 9 and 10.

## 3.4 Multi-head Hammer

The remainder of the pavement was rubblized using the multi-head hammer. This was approximately 1.4 miles in each direction. A total of 39,498 square yards of concrete was rubblized using this method.

With this process the concrete pavement is broken up with a self-contained, self-propelled unit with hammers mounted laterally in pairs with half the hammers in a forward row and the remainder diagonally offset in a rear row so that there is continuous breakage from side to side. The equipment was capable of rubblizing a 13-foot lane in a single pass. The existing concrete was broken into pieces ranging from sand size to pieces generally 3 inches or less in size in the top half of the concrete pavement and 9 inches or less in the bottom half of the concrete pavement. (Specification in Appendix B)

As with the resonant breaker sections, a 4-foot by 4-foot test section was excavated. The excavated material was visually inspected to verify that the multi-head hammer was producing the specified sizes. A steel vibratory roller fitted with a "Z" pattern grid on the drum face operating in the vibratory mode was used to seat the rubblized pavement.

The multi-head hammer process can be seen in Figures 11 & 12.

## 3.5 Edge Drains

Edge drains used in conjunction with rubblization are a recommended process to control subgrade moisture. Although this section of highway was built on a permeable sand subgrade, edge drains were installed as part of the roadway design in the event that there was subgrade moisture. The edge drains were installed according to CDOT specifications. The installation of the edge drains can be seen in Figures 13, 14, 15 and 16.

## 3.6 Moisture Probes

Following the rubblizing, moisture probes were installed in the rubblized concrete to determine the effectiveness of the edge drains. A total of 18 soil moisture probes was placed at the interface of the rubblized concrete and the base. Campbell Scientific Time Domain Reflectometer (TDR) moisture probes were used. These probes measure a volumetric moisture content (VMC), and when calibrated to soil types and compaction, can actually measure the soil moisture content. Changes in volumetric water content were deemed sufficient to assess migration of water in the pavement structure. Hence it was not imperative to evaluate soil densities in the base layer.

Three locations within the research test sections had moisture probes in the center of the driving lane. One additional probe was located one foot from the driving lane/shoulder joint. This location was in the general proximity of the edge drain system that was installed on the project. Sensors were placed at the center of the driving lane and covered with a minimal cover of existing basecourse material. Probe leadwires were routed through metal conduit to the edge of the shoulder. All sensor locations were referenced to the beginning of the research test sections at intervals of 125 feet, 525 feet, and 875 feet.

All sensor locations were marked with stakes identifying the locations as research projects. After completion of the installation, a quick check of the sensors was performed to verify functionality.

Ten additional TDR soilmoisture sensors were installed in the eastbound lanes. A multi-probe setup was installed in the eastbound driving lane within the resonant breaker section. The probes were placed at two feet and one foot below the fractured JPCP, at the interface of the base and the fractured JPCP, and the fourth probe at the edge drain location. Figure 17 shows the layout of these probes. A Campbell Scientific Micrologger is being used to record a continuous log of the four-probe setup on a six-hour interval since the installation was completed in September 1999. Installation of the moisture sensors can be seen in Figures 18 and 19.

In order to obtain accurate precipitation data on the rubblization project, a tipping bucket rain gauge was installed. The gauge was installed in the immediate vicinity of the moisture probes. Because of the very localized nature of storms, weather data from the local airport was not deemed accurate enough to draw conclusions from the TDR moisture probe data. A TE525WS rain gauge with an 8-inch collector, and a 0.01-inch tip was obtained from Campbell Scientific. Accuracy of the gauge is specified as –2.5% for rainfall rates of 3 inches per hour at a resolution of 0.01 inch of precipitation.

A Campbell Scientific CR21 datalogger is being used to capture hourly rainfall amounts, and store the data on a cassette recorder for later retrieval and analysis on a computer. While the CR21 has storage capacity for one week of data, the tape recorder is used to allow data to be recorded for up to two months before retrieval is necessary. This interval matches our monthly moisture data retrieval schedule very adequately. Figures 20 and 21 show the tipping rain gauge and the data recording equipment.

## 3.7 Design Thickness

Since the department's experience with rubblization was limited, the industry's involvement in the mix design was solicited. The Asphalt Institute's recommendation was to place a 6-inch minimum lift of HBP on the rubblized concrete.

Using the "Guidelines For Use of HMA Overlays to Rehabilitate PCC Pavement,"[1] and using the following variables, for H(pcc)=8", SNsb = 0 (the emulsified base was back to an A-3(0) sand), Heavy Traffic, and Good Subgrade (A-3 to A-2-4 with Modulus around 29,000 to 30,000 psi and moisture at or near optimum) a calculation of approximately 6-inch of HBP was required.

Based on the component analysis using the following values for the appropriate variable, Design 18K's = 6,000,000 (20 year), Reliability 95%, Overall deviation = 0.44, Res mod soil = 29,000 PSI, PSI loss (Traffic) = 2.00 the required structural number calculated was 2.89. The component analysis for the rubblized JPCP section was 2.0 which resulted in an overlay thickness of 2-inches.

Although the component analysis calculation was 2 inches, this value was considered low and the Asphalt Institute's recommendation of a minimum of 6-inches of HBP was incorporated into the project design plans.

## 3.8 Construction

The project consisted of removing the existing 2-inch bond breaker, rubblizing the concrete pavement and then placing three 2-inch hot bituminous pavement overlays. Although the evaluation emphasis was on the rubblized concrete pavement and how it affects the performance special care was taken in the design and placement of the hot bituminous pavement. A adequately designed HPB mix is important to the overall performance of the pavement.

A Superpave grading S with a Ndesign of 109 was used on this project. Two binders were used on the project Koch PG 70-34 and Koch PG 76-28. The job mix formulas for the mix designs can be found in Appendix C.

A Gencor continuous mixer with a capacity of 450 tons per hour was used to produce the HBP for this project. Four cold feed bins were used with a lime silo.

The HBP was delivered to the project with both end and belly dumps. The haul time from the plant to the project was approximately 6 minutes. The temperature of the mix behind the paver was 149°C (300°F).

Paving was accomplished with a Caterpillar 950 rubber track paver with a 20-foot screed. The paving was done in varying widths of 15.5 feet for the passing lane, 12.5 feet for the driving lane and 11.0 feet for the shoulder . A 10-ton Ingersol Rand roller was used for breakdown and was kept right behind the paver. A 6-ton Hyster pneumatic (rubber tire) roller and a 10-ton Ingersol Rand roller were used for finish rolling. A roller pattern study was done at the beginning of the project to establish the specified density of 92 – 96% of maximum theoretical density.

## 3.9 Project Costs

In 1995 this section of highway was overlaid with a 2-inch asphalt bond breaker. The asphalt bond breaker was intended to be the first phase of the unbonded PCC overlay strategy that was scheduled to be rehabilitated in 1999. In early 1999 CDOT's Region 4 decided to change the rehabilitation strategy from the unbonded PCC to rubblization with an HBP overlay.

The original Engineer's estimate for the roadway bid items for concrete pavement with a bond breaker was $5,675,167.20 (30-year design). The Engineer's estimate for the roadway bid items for HBP with rubblization was $4,973,901.20 (20-year design). The difference for the two methods is 14%. Although the initial cost for HBP with rubblization is lower, the long-term performance information provided by this study will determine the overall life cycle cost of rubblization with an asphalt overlay. This comparison will establish the basis for alternate life cycle costs for the two rehabilitation techniques.

The bid tabs for this project can be found in Appendix D.

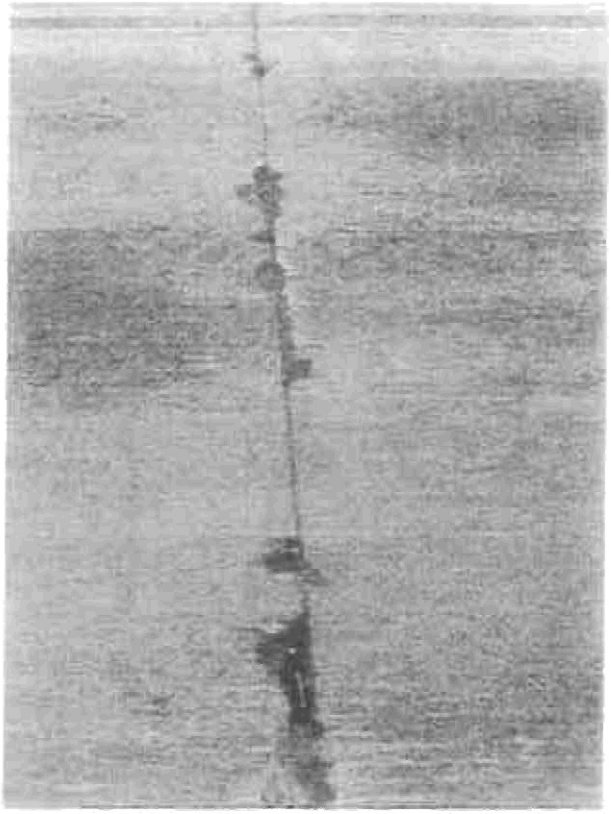

Figure 5. Condition of joint in concrete.

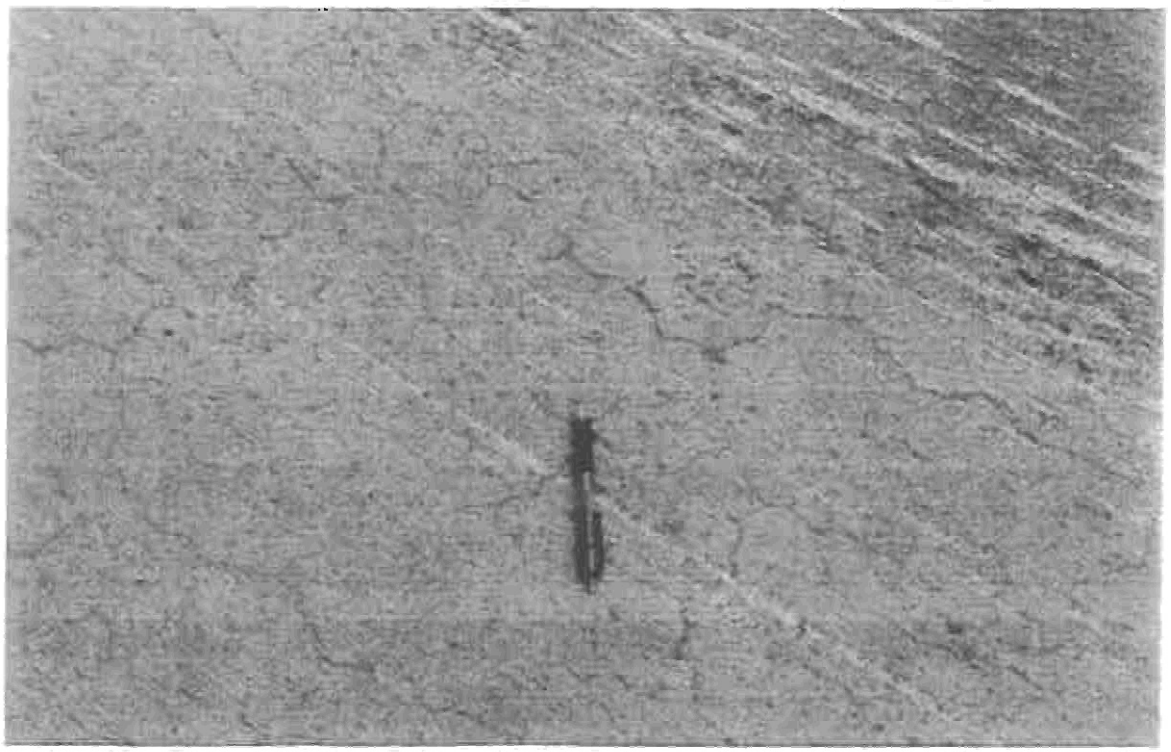

Figure 6. Photo shows the ASR distress found in the concrete pavement.

**Figure 7. Condition of shoulder before being broken up by the Bomag.**

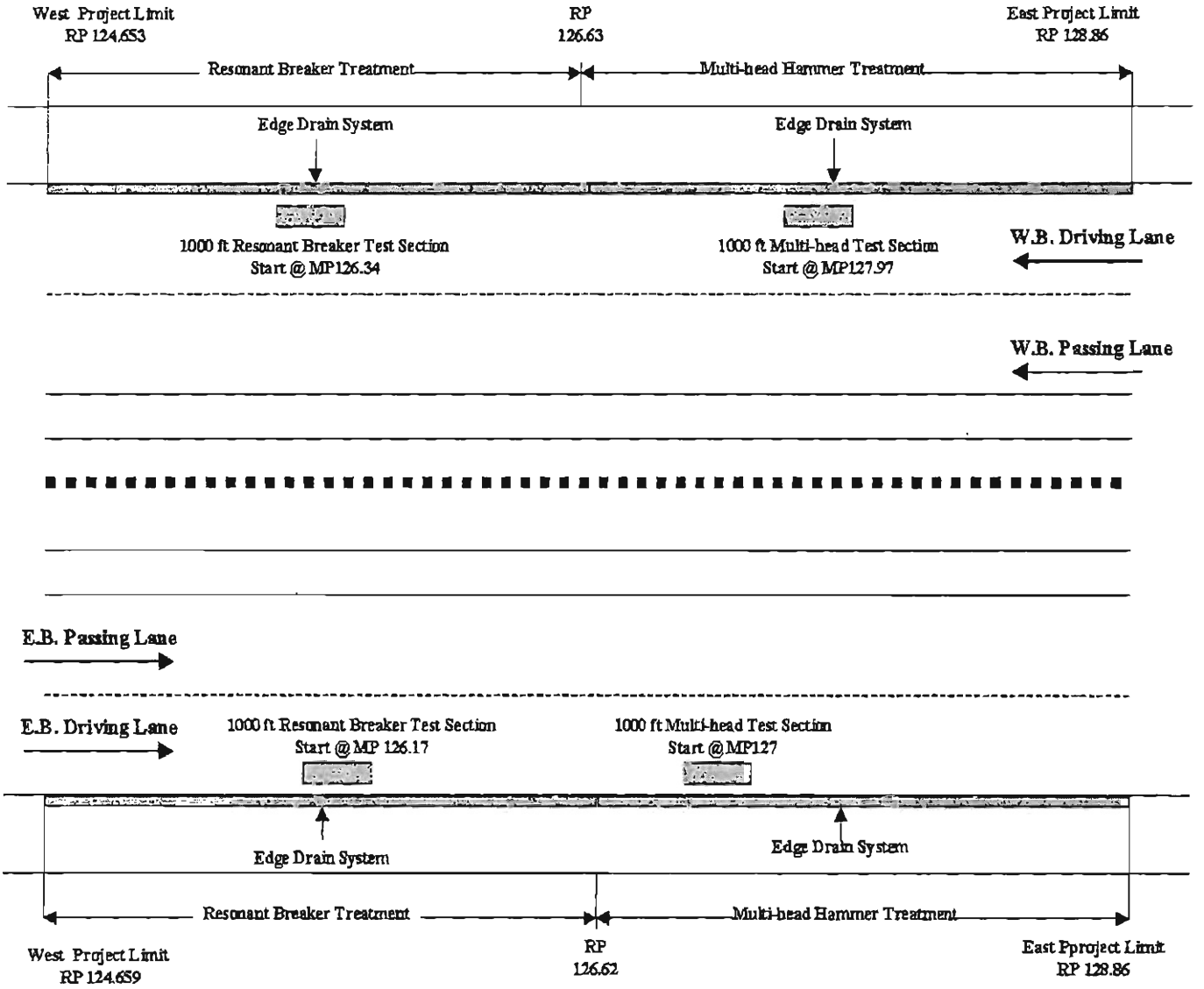


**Figure 8. Location on project where resonant breaker and multi-head hammer processes were used.**

**Figure 9. Resonant treatment process.**

**Figure 10. Resonant breaker in action.**

**Figure 11. Multi-head hammer in action.**

**Figure 12. Steel vibratory roller with "Z" pattern grid on drum face was used to seat pavement.**

**Figure 13. Trencher used for installing edge drain.**

**Figure 14. Preparation of trench for edge drain installation.**

**Figure 15. Close-up of perforated drainpipe & geotextile.**

**Figure 16. Geotextile, perforated pipe & filter material for edge drain.**

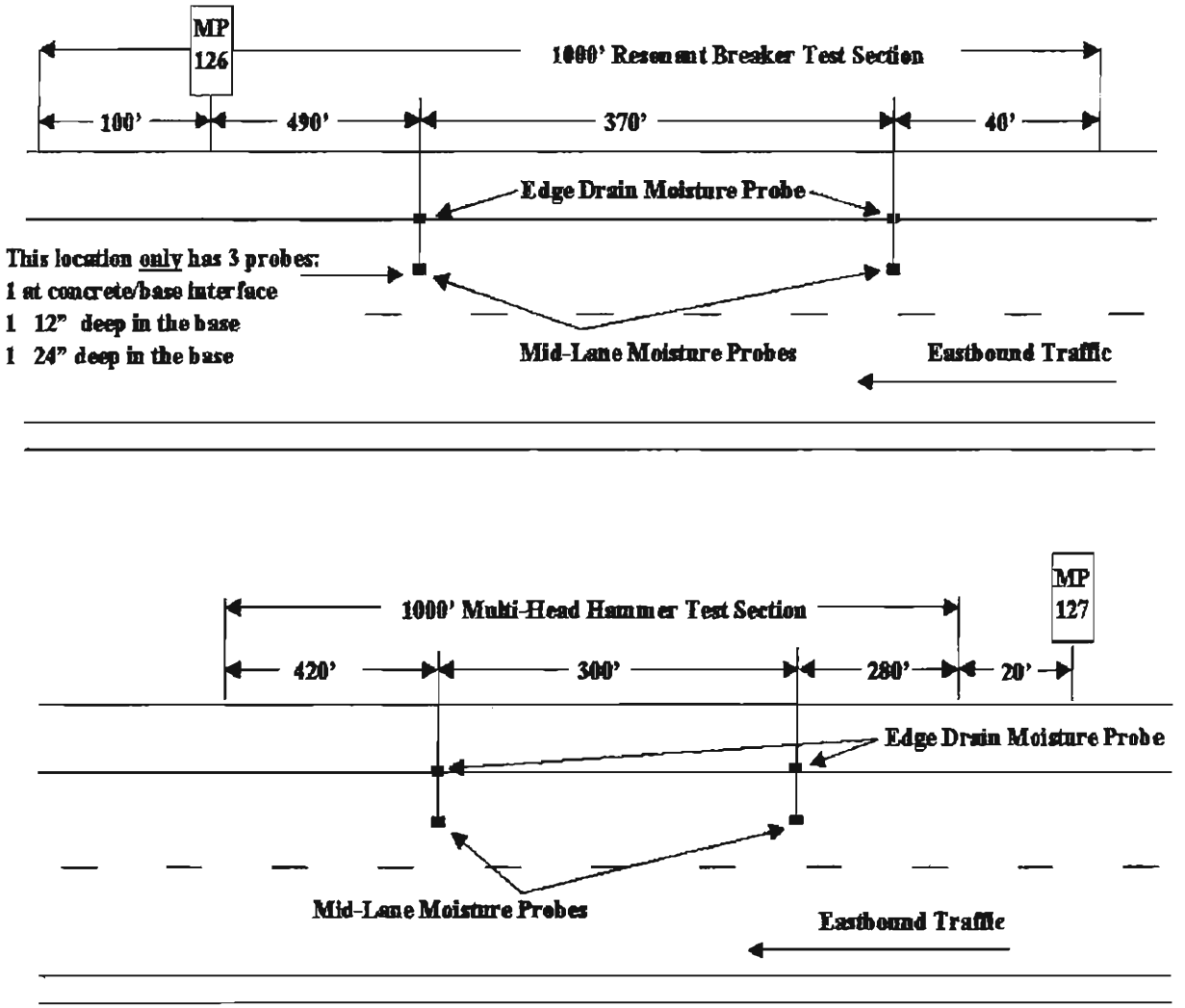


Figure 17. Locations of TDR soil moisture sensors.

**Figure 18. Installation of the moisture sensors.**

**Figure 19. Installation of sensors and close-up of storage block.**

**Figure 20. ATE 525WS rain gauge with 8-inch collector.**

**Figure 21. The Campbell Scientific CR21 datalogger is used to measure hourly rainfall.**

# 4.0 PROJECT TESTS

## 4.1 Design Mix

Two different job mix formulas were used on this project (Appendix C). The first job mix formula utilized a PG 70-34 binder with Macatee fines and sand. When the contractor began experiencing difficulty in obtaining density, a second mix design was developed. Since the time that this project was awarded, CDOT had adopted the LTPP method for selecting PG binders. The LTPP's recommendation for this project would have been a PG 70-28 binder. Because of the limited availability of the original aggregate source, the contractor switched sources, the fines were obtained from Poudre Tech and the sand from Aggregate Incorporated. In addition, the contractor switched to a PG 76-28 binder as it was more readily available than the ~~LTTP~~ LTPP recommendation of PG 70-28. The contractor did not experience difficulty in achieving density using the second mix design.

The mix was sampled from within the evaluation sections and used for mix verification. It is assumed that the change in the mix design formulas will affect the performance of the pavement or the evaluation of the rubblization.

## 4.2 European "Torture" Test Results

Laboratory tests were performed to identify the mix's resistance to permanent deformation and moisture damage. All tests were performed on plant-produced material that was sampled from the windrow. Material was taken from four locations throughout the project. Replicate samples were tested and the average were reported.

*French Rutting Tester*. The French Rutting Tester is used to evaluate the resistance of the HBP to permanent deformation. It is manufactured by the Laboratoire Central des Ponts et Chaussees (LCPC). The LCPC plate compactor is used to compact the slabs for testing in the French Rutting Tester. The slabs measuring 50 by 18 cm (19.7 by 7.1 in) are compacted to the desired air void content with a thickness ranging from 20 to 100 mm (0.8 to 3.9 in). The French Rutting Tester can test two slabs simultaneously. The slabs are placed in a temperature-controlled chamber and loaded by a pneumatic tire. Rut depth measurements are manually measured after 100, 300, 1000, 3000, 10,000, and 30,000 cycles. Additional information on the French Rutting

Tester can be found in the report titled "Description of the Demonstration of European Testing Equipment for Hot Mix Asphalt Pavement."[2] Results from the French Rutting Tester are shown in Table A.

Table A. French Rutting Test Results (% Rut Depth After 30,000 Cycles)

| AC Source and Grade | Percent Rutting |
|---|---|
| Koch 70-34 | 3.76 |
| Koch 76-28 | 2.50 |
| Koch 76-28 | 4.00 |
| Koch 76-28 | 2.55 |

The testing temperature was 55°C (131°F) and was determined by the location of the project.[3] A successful test will typically have a rutting depth that is less than or equal to 10% of the slab thickness after 30,000 cycles. The test results indicate that the HBP placed on this project will be rut resistant.

*Hamburg Wheel-Tracking.* The Hamburg Wheel-Tracking Device is used to evaluate the resistance of the HBP to moisture damage. It is manufactured by Helmut-Wind Inc. in Hamburg, Germany. This device is similar to the French Rutting Tester except that the slab is immersed in a 50°C (122°F) water bath and loaded by a steel wheel. CDOT uses the linear kneading compactor to prepare samples for the Hamburg. Although the sample is not contained in a chamber the temperature in the water bath can be varied depending on the location of the pavement. The machine is automated and records the deformation after each cycle. Additional information on the Hamburg can be found in the report titled "Description of the Demonstration of European Testing Equipment for Hot Mix Asphalt Pavement."[2] Results from the Hamburg Wheel-Tracking Device are shown in Table B.

Table B. Hamburg Wheel-Tracking Device test results (mm of Deformation After 20,000 Passes)

| AC Source and Grade | mm of Deformation |
|---|---|
| Koch PG 70-34 | 4.19 |
| Koch PG 70-34 | 5.83 |
| Koch PG 76-28 | 1.99 |
| Koch PG 70-34 | 2.88 |
| Koch PG 76-28 | 2.16 |

The testing temperature was 55°C (131°F) which was determined from the asphalt type[4]. A successful test will typically have less than 10mm of deformation after 20,000 passes. The test result indicates that this HBP will be resistant to moisture damage.

# 5.0 RESEARCH EVALUATION

## 5.1 Crack Mapping

A pre-construction evaluation was performed on the existing concrete following the removal of the bond breaker. Cracks in the existing concrete pavement were identified. The major distress noted in the pavement was extensive cracking from the ASR. There was also a noticeable load-associated longitudinal crack in the right wheel path of the driving lane. However, the extent of the crack was not severe. There was minor spalling at the transverse joints. No faulting was noted at the transverse joint.

The information obtained from this evaluation will be compared to the cracking pattern during future evaluations.

## 5.2 Moisture Testing

Evaluation of moisture began immediately following installation of the probes. Heavy rainfall in the early phase of the project resulted in volumetric moisture content (VMC) readings at 28%, while during the winter season these values dropped to below 10%. Moisture readings for the probes located under the rubblized JPCP at the center of the driving lanes showed consistently higher readings than those located near the edge drains. This would suggest that moisture is

getting into the pavement section, however, the moisture is being adequately transported by the drainage system.

The graph in Figure 22 shows the moisture data that was recorded during November 1999, indicating that moisture in the pavement structure is not only very low, but also very stable. Only minor changes occurred throughout this evaluation period. The moisture profile shows the lowest value at the deepest location, followed by the probe at one foot. Base and fractured JPCP moisture is somewhat lower at the edge drain location than at midlane. This suggests that moisture does not penetrate the base, and is properly transported to the edge drain system where it is moved to the drain outlets.

The tipping bucket rain gauge described in section 3.6 will help provide an accurate measurement of precipitation on the project. This information will be compared to the data obtained from the moisture probes to help determine the effectiveness of the edge drain.

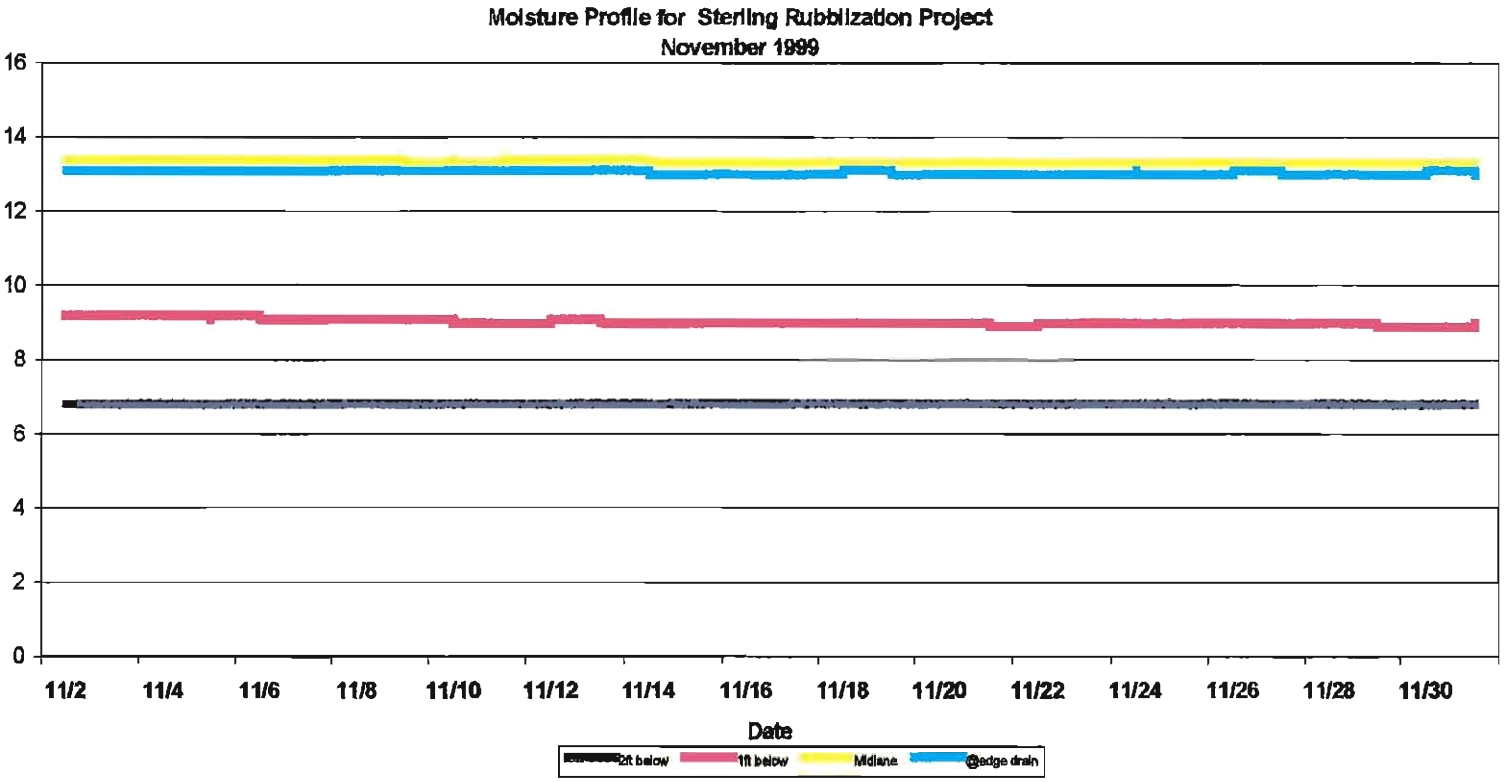


**Figure 22. Moisture data recorded during November 1999.**

## 5.3 Falling Weight Deflectometer Testing

During the construction project, CDOT personnel used a falling weight deflectometer (FWD) to assess the pavement structure response to a load value of 9,000 pounds. Initial deflection testing was performed on the JPCP prior to the rubblization process. Although this test was done for information only, it revealed that the existing JPCP exhibited surprisingly good results. The aggregate silica reactive (ASR) cracking, while rather extensive, but typically of the hair-line variety, appeared to have little effect on deflection. Average maximum deflection values were recorded at below 10 mills. A pre-rubblization pavement inspection confirmed the results of a load transfer analysis at the joints. The visual inspection found very insignificant joint defects (i.e. joint faulting and joint deterioration) which was confirmed by the deflection data. Load transfer ranged from a low of 83% to a high of 95%, which is indicative of a very good load transfer mechanism. With the exception of the eastbound pavement section (95% load transfer) which was designated to be rubblized with the multi-head hammer, the remainder of the project had load transfer between 83% to 89%.

Following the rubblizing process FWD deflection tests were performed on the fractured JPCP. The typical test involved four "drops." The initial drop was intended to "seat" the FWD and data from this drop was excluded in the analysis, while the remaining values were averaged. Table C shows the average deflections as well as sample standard deviation for all phases of the project. (i.e. fractured JPCP, bottom lift of AC, middle and top lift of AC). As can be seen in this table, the consistency of deflection values is well supported by the sample standard deviation. Only the fractured JPCP tests have a somewhat higher standard deviation. One aspect of using deflection testing on fractured JPCP is to investigate the thorough breakup of the concrete by the different methods. A load transfer analysis of the fractured JPCP could indicate if complete fracture has occurred. Load transfer values below 50% would be indicative of such complete fracture. Only one of the test sections that was treated with the multi-head hammer had a load transfer of 45%, while the other ranged from 64% to 69%. It is noted that this section was treated twice with the multi-head hammer after it was discovered that large pieces of concrete remained intact when research personnel attempted to install monitoring equipment under the fractured JPCP. A backhoe was used to dig a trench from the center of the driving lane to the shoulder.

Table C. Average and Standard Deviations for Falling Weight Deflectometer data.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| WBMH Rub | Average Deflection | 22.4 | 15.0 | 12.5 | 9.6 | 7.1 | 4.9 | 2.6 |
| | Sample Std Deviation | 3.6 | 2.4 | 1.5 | 0.9 | 1.5 | 1.0 | 0.4 |
| WBMH 1st | Average Deflection | 19.9 | 14.0 | 10.6 | 8.2 | 6.7 | 5.0 | 2.7 |
| | Sample Std Deviation | 1.9 | 1.3 | 0.9 | 0.7 | 0.6 | 0.4 | 0.2 |
| WBMH 2nd | Average Deflection | 16.9 | 12.2 | 9.7 | 7.6 | 6.0 | 4.6 | 2.6 |
| | Sample Std Deviation | 1.1 | 0.9 | 0.7 | 0.5 | 0.4 | 0.3 | 0.2 |
| WBMH 3rd | Average Deflection | 13.2 | 9.7 | 8.0 | 6.3 | 4.8 | 3.6 | 2.2 |
| | Sample Std Deviation | 0.9 | 0.7 | 0.5 | 0.4 | 0.3 | 0.2 | 0.1 |
| WBRH Rub | Average Deflection | 20.3 | 14.1 | 11.4 | 8.6 | 6.8 | 4.4 | 2.1 |
| | Sample Std Deviation | 3.0 | 1.7 | 1.3 | 1.2 | 3.5 | 1.2 | 0.3 |
| WBRH 1st | Average Deflection | 19.0 | 13.5 | 10.4 | 7.1 | 5.2 | 3.7 | 2.1 |
| | Sample Std Deviation | 0.6 | 1.2 | 0.7 | 0.6 | 0.5 | 0.4 | 0.2 |
| WBRH 2nd | Average Deflection | 19.0 | 13.6 | 10.3 | 7.1 | 5.2 | 3.8 | 2.2 |
| | Sample Std Deviation | 1.0 | 0.9 | 0.7 | 0.6 | 0.5 | 0.3 | 0.6 |
| WBRH 3rd | Average Deflection | 13.9 | 9.8 | 7.9 | 5.9 | 4.2 | 2.9 | 1.7 |
| | Sample Std Deviation | 0.7 | 0.8 | 0.5 | 0.4 | 0.3 | 0.2 | 0.2 |

| Sensor # | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| EBRH Rub | Avg. Deflection | 27.4 | 17.6 | 12.7 | 8.9 | 6.1 | 4.2 | 2.5 |
| | Sample Std Deviation | 3.8 | 4.5 | 2.6 | 1.4 | 0.8 | 1.0 | 0.6 |
| EBRH 1st | Average Deflection | 18.0 | 13.7 | 10.9 | 7.5 | 5.2 | 3.8 | 2.2 |
| | Sample Std Deviation | 1.2 | 0.8 | 0.5 | 0.4 | 0.3 | 0.2 | 0.2 |
| EBRH 2nd | Average Deflection | 14.6 | 12.0 | 10.0 | 7.6 | 5.4 | 3.7 | 2.3 |
| | Sample Std Deviation | 0.9 | 0.6 | 0.4 | 0.3 | 0.2 | 0.2 | 0.1 |
| EBRH 3rd | Average Deflection | 14.5 | 10.7 | 9.3 | 7.0 | 5.0 | 3.5 | 2.1 |
| | Sample Std Deviation | 0.8 | 0.8 | 0.4 | 0.3 | 0.2 | 0.2 | 0.1 |
| EBMH Rub | Average Deflection | 27.7 | 12.5 | 11.2 | 8.1 | 5.9 | 5.0 | 3.9 |
| | Sample Std Deviation | 5.8 | 4.1 | 3.8 | 1.8 | 1.3 | 3.2 | 5.1 |
| EBMH 1st | Average Deflection | 17.8 | 12.9 | 10.1 | 7.0 | 5.1 | 3.7 | 2.0 |
| | Sample Std Deviation | 1.4 | 1.7 | 0.8 | 0.8 | 0.6 | 0.6 | 0.5 |
| EBMH 2nd | Average Deflection | 13.7 | 11.1 | 9.3 | 7.0 | 5.1 | 3.5 | 2.0 |
| | Sample Std Deviation | 0.8 | 0.8 | 0.7 | 0.6 | 0.5 | 0.5 | 0.4 |
| EBMH 3rd | Average Deflection | 16.7 | 10.5 | 8.8 | 6.5 | 4.8 | 3.6 | 2.0 |
| | Sample Std Deviation | 1.2 | 1.2 | 0.7 | 0.6 | 0.5 | 0.5 | 0.5 |

**Legend:** EBRH – Eastbound Resonant Breaker EBMH – Eastbound Multi-head Hammer
WBRH – Westbound Resonant Breaker WBMH – Westbound Multi-head Hammer

After some considerable effort to remove the "fractured" concrete, a decision was made to re-fracture the section. A explanation for the initial failure could be attributed to possibly localized conditions. The overall observation of the fracturing potential for the two hammers is that both methods were capable of breaking the concrete adequately.

Six inches of asphalt in increments of two inches were placed on this project. Deflection tests were performed after each lift. Data from these tests were used to analyze the pavement structure at the various stages of construction.

## 6.0 FWD PAVEMENT DESIGN AND ANALYSIS

The AASHTO pavement design program DARWin 3.0 is being used to interpret the results of the deflection analysis. The table below shows the design parameters used in the analysis. Traffic loading for the 20-year design was obtained from CDOT's traffic database and other parameters from CDOT's pavement design guide. The strength coefficient for the fractured JPCP of 0.25 was selected based on the recommendation from the 1993 AASHTO design guide, and the general condition of the existing JPCP.

The pavement design computer program uses the FWD deflection data to calculate a resilient modulus by employing the method of backcalulation. Tables D and E contain the calculated resilient moduli as well as overall pavement moduli for the four test sections. (Calculations were computed for each pavement layer.)

Following are the assumptions used for analysis:

| | |
|---|---|
| 20-year 18k ESALs | 6,500,000 |
| Initial Serviceability Index | 4.5 |
| Terminal Serviceability Index | 2.5 |
| Reliability | 90% |
| Standard Deviation | 0.44 |
| Strength Coefficient for fractured JPCP (assumed) | 0.25 |
| Recommended coefficients: 0.14 to 0.30 | |

Table D. Resilient Moduli and Pavement Moduli (Eastbound)

| | Eastbound Resonant Breaker Test Section | | Eastbound Multi-head Hammer Test Section | |
|---|---|---|---|---|
| | Subgrade Resilient Modulus | Effective Pavement Modulus | Subgrade Resilient Modulus | Effective Pavement Modulus |
| Rubblized | 15,112 | 51,477 | 22,827 | 43,457 |
| 1st Lift | 15,925 | 88,865 | 17,460 | 83,278 |
| Middle Lift | 15,456 | 110,789 | 16,773 | 115,641 |
| Top Lift | 16,374 | 86,926 | 18,224 | 61,481 |

Table E. Resilient Moduli and Pavement Moduli (Westbound)

| | Westbound Multi-head Hammer Test Section | | Westbound Resonant Breaker Test Section | |
|---|---|---|---|---|
| | Subgrade Resilient Modulus | Effective Pavement Modulus | Subgrade Resilient Modulus | Effective Pavement Modulus |
| Rubblized | 16,069 | 84,136 | 15,367 | 100,396 |
| 1st Lift | 16,041 | 66,457 | 16,548 | 68,643 |
| Middle Lift | 15,487 | 78,069 | 17,246 | 63,221 |
| Top Lift | 17,354 | 99,195 | 19,991 | 79,665 |

The results outlined in Table D indicate that the resilient moduli are relatively similar, except for the eastbound multi-head hammer test section. The rubblized JPCP section shows a significantly higher modulus, which in turn as can be seen later on in the structural number requirement computation. Table F is a summary of the DARWin calculation. Some anomalies were encountered in the DARWin analysis for the top lift. This could possibly be attributable to the timing of the FWD testing, which was done shortly after the pavement was placed. Another round of testing is scheduled to ascertain the validity of the test results. The required overlay thickness is a nominal 3-1/2 inches for both westbound test sections as well as the eastbound resonant breaker section. Further analyses for each addition AC lift indicate that a four-inch overlay would satisfy the overlay strength requirement for the 20-year traffic. The DARWin analyses can be found in (Appendix E).

Table F. DARWin Pavement Design for I-76 @ Sterling Rubblization Project
(Analysis for fractured JPCP)

| Treatment | Required Structural No. | Existing Structural No. | Overlay Structural No. | Required Thickness | Load Transfer (Rubblized) |
|---|---|---|---|---|---|
| Multi-head Hammer (WB) | 3.41 | 2.00 | 1.41 | 3-1/2" | 67% |
| Resonant Breaker (WB) | 3.47 | 2.00 | 1.47 | 3-1/2" | 69% |
| Multi-head Hammer (EB) | 3.01 | 2.00 | 1.01 | 2-1/2" | 45% |
| Resonant Breaker (WB) | 3.49 | 2.00 | 1.49 | 3-1/2" | 64% |

Note: The calculations in the table reflect input values for 20-year design parameters. Projected ESAL figures of 6.5 million were obtained from the CDOT Traffic Analysis database. A strength coefficient of 0.25 was used as an estimate as per the 1993/1996 AASHTO design guide. DARWin uses the backcalculation approach for computing the resilient modulus from the falling weight deflectometer readings obtained on the project.

# 7.0 SUMMARY AND RECOMMENDATIONS

The rubblization techniques used on Project No. NH 0762-038 on Interstate 76, from Sterling east were CDOT's first attempt to use rubblization as a method to rehabilitate concrete pavement. The project initially was to demonstrate three methods: resonant breaker, multi-head hammer and the crack and seat method.

## 7.1 Construction

1) The existing concrete pavement had extensive alkali-silica reactivity (ASR). Because of the severity of the ASR cracking the energy from the crack and seat process was dissipated and this method was unable to effectively break the pavement full depth. The crack and seat process is not recommended as a rehabilitation method on concrete with this type of distress. Except for an isolated area it did not appear that the other rubblization methods had difficulty breaking the concrete to the specified sizes.

2) Based on project observation, the rubblization process caused very little disruption to traffic. This technique could eliminate the need for expensive traffic control and reduce the problems associated with detours when used on appropriate projects.

## 7.2 Performance

1) The major distress in the existing concrete was ASR. Since other types of distress on this project were minimal (longitudinal cracking, joint faulting and spalling), this study will focus on the cost-effectiveness of rubblization on a JPCP with ASR.

2) The test results using the French Rutting Tester and the Hamburg Wheel Tracking Device indicate that the HBP pavement will be resistant to rutting and moisture damage.

3) Initial data obtained from the moisture probes indicates moisture is being removed from the pavement section. Continued evaluation will help determine the effectiveness of the edge drains.

## 8.0 FUTURE EVALUATION

A field evaluation will be conducted each year over the 5-year study period. The evaluation will include crack mapping, rut measurements, FWD measurements and visual observations of pavement edge drains. Field notes will be written following each evaluation. A final report will be prepared documenting the performance of this method of rehabilitation at the conclusion of this study.

The initial cost analysis for this project, with the rubblization with an asphalt overlay was 14% lower than the initial cost analysis using a concrete overlay without rubblizing. Long term performance information provided by this study using actual quantities and costs will determine the overall life cycle cost of rubblization with an asphalt overlay. This comparison will establish the basis for alternate life cycle costs for the two rehabilitation techniques (concrete without rubblization versus rubblization with an asphalt overlay).

## REFERENCES


1. National Asphalt Pavement Association, "Guidelines for Use of HMA Overlays to Rehabilitate PCC." Information Series 117, Prepared by Pavement Consultancy Services, 1994.

2. Aschenbrener, Timothy and Stuart, Kevin. " Description of the Demonstration of European Testing Equipment for Hot Mix Asphalt Pavement," Colorado Department of Transportation, CDOT-DTD-R-92-10, October 1992.

3. Aschenbrener, Timothy. "Comparison of the Results Obtained from the French Rutting Tester with Pavements of Known Field Performance," Colorado Department of Transportation, CDOT-DTD-R-92-11, October 1992.

4. Aschenbrener, Timothy and Currier, Gray. "Influence of Testing Variables on the Results from the Hamburg Wheel-tracking Device," Colorado Department of Transportation, CDOT-DTD-R-93-22, December 1993.

# APPENDIX A

## Rubblization Specification (Resonant Breaker)

Colorado Project No. NH 0762-038 October 20, 1998
Construction Subaccount 11204

## Revision of Section 412
## Rubbilization of Concrete Pavement (Resonant Breaker)

Section 412 of the Standard Specifications is hereby revised for this project to include the following:

### DESCRIPTION

This work shall consist of rubbilization and settling and seating of the existing reinforced or non- reinforced portland cement concrete pavement as shown on the plans or as directed by the Engineer. The work shall be accomplished in accordance with the Standard Specifications, this special provision and the details shown in the plans.

### CONSTRUCTION REQUIREMENTS

General.
Rubbilization of the portland cement concrete pavement shall be accomplished across the full depth and panel width of the pavement. The rubbilization shall be done in partial widths when necessary to maintain traffic. When rubbilizing in a lane adjacent to a lane that is open to traffic, measures shall be taken to prevent debris from entering the traffic lane. The Contractor shall exercise care during the rubbilization operation to protect and prevent damage to underground and drainage facilities.

Equipment.
Pavement Breaker. Breaking of the concrete pavement shall be accomplished with a self-contained, self-propelled, resonant frequency pavement breaking unit capable of producing low-amplitude 2,000 pound force blows at a rate not less than 44 cycles per second. The Contractor shall minimize the dispersion of dust from the rubbilizing operation, until the rubbilized surface is overlaid with pavement, by the application of non-excessive water or other approved method. The breaking unit shall be capable of delivering such energy as may be necessary to satisfactorily break the pavement. The breaker shall be equipped with a screen to protect vehicles in the adjacent lane from flying chips during the fracturing process when necessary.

Roller. A smooth drum steel vibratory roller having a gross weight of not less than 10 tons, operated in vibratory mode, shall be used to settle and seat the rubbilized pavement.

Any other equipment needed for rubbilization shall have prior approval from the Engineer.

Rubbilization

A joint shall be cut full depth at an existing joint on ramps or mainline where rubbilization abuts concrete which is to remain in place. The existing concrete pavement shall be broken into pieces ranging from sand size to pieces generally 6 inches or less in size. No individual pieces shall exceed 8 inches in any dimension. The majority of rubbilized concrete volume shall be nominal 1 to 3 inches in size. At the beginning of the rubbilization operations, a 4-foot by 4-foot test section shall be excavated from the edge to the middle of a lane at a location selected by the Engineer to determine if the breaker is producing pieces of the specified sizes. Additional test sections may required if the Engineer determines that they are necessary. The test section material shall be removed from the project and the hole shall be filled using Item 403 Hot Bituminous Pavement (Patching) (Asphalt).

The breaker shall be operated with a maximum amplitude of one inch to avoid damaging the base and underlying structures. If damage occurs to the base or underlying structures, the contractor shall repair any damage at his expense.

## Revision of Section 412
## Rubbilization of Concrete Pavement (Resonant Breaker)

Rubbilization shall begin at a free edge or previously broken edge and progress toward the opposite shoulder or longitudinal centerline of the road. In areas where the roadway must be overlaid one lane at a time, initial rubbilization will extend a minimum of 6 inches beyond the width of the pavement to be overlaid. Reinforcement in the rubbilized pavement, if any, shall be left in place. However, any reinforcement exposed at the surface during rubbilization or compacting operations shall be cut off below the surface and removed.

The Contractor shall continuously monitor the rubbilization operation and shall make adjustments in the striking pattern, striking energy, number of passes or other factors as necessary to continually achieve acceptable breaking throughout the project.

If unstable areas occur due to expansion of the existing pavement, these areas will be removed to a maximum length of 4 feet in length and 12 feet in width and replaced full depth with Item 403 Hot Bituminous Pavement (Patching) (Asphalt). Patching of unstable areas and test section holes shall conform to the requirements of Section 403 Hot Bituminous Pavements.

Settle and Seating.
The rubbilized pavement shall be settled and seated with a minimum of three passes over the entire width of the pavement with a steel drum vibratory roller. For this operation a pass is defined as forward and back over the entire surface area. The Engineer may require additional passes if necessary to satisfactorily settle and seat the rubbilized pavement. The roller shall be operated at a speed not to exceed 6 feet per second.

### METHOD OF MEASUREMENT

Rubbilization of Concrete Pavement (Resonant Breaker) will be measured by the square yard. Hot Bituminous Pavement (Patching) (Asphalt) will be measured as prescribed in subsection 401.21.

### BASIS OF PAYMENT

The accepted quantities will be paid at the contract unit price for the pay item listed below:

Payment will be made under:

| Pay Item | | Pay Unit |
|---|---|---|
| 412 | Rubbilization of Concrete Pavement (Resonant Breaker) | Square Yard |
| 403 | Hot Bituminous Pavement (Patching) (Asphalt) | Ton |

Payment will be full compensation for all work and materials required to complete the item. This will include, but not be limited to, full compensation for all labor, equipment, tools, incidentals necessary to rubbilize and settle and seat the existing concrete pavement, full depth saw cutting, removal and replacement of the test section, removal of the existing reinforcement, clean up and waste disposal.

# APPENDIX B

## Rubblization Secification (Multi-Head Breaker)

Colorado Project No. NH 0762-038 October 20, 1998
Construction Subaccount 11204

## Revision of Section 412
## Rubbilization of Concrete Pavement (Multi-Head Breaker)

Section 412 of the Standard Specifications is hereby revised for this project to include the following:

### DESCRIPTION

This work shall consist of rubbilization and compaction of the existing reinforced or non- reinforced portland cement concrete pavement as shown on the plans or as directed by the Engineer. The work shall be accomplished in accordance with the Standard Specifications, this special provision and the details shown in the plans.

### CONSTRUCTION REQUIREMENTS

General

Rubbilization of the portland cement concrete pavement shall be accomplished across the full depth and panel width of the pavement. The rubbilization shall be done in partial widths when necessary to maintain traffic. When rubbilizing in a lane adjacent to a lane that is open to traffic, measures shall be taken to prevent debris from entering the traffic lane. The Contractor shall exercise care during the rubbilization operation to protect and prevent damage to underground and drainage facilities.

Equipment

Pavement Breaker: Breaking of the concrete pavement shall be accomplished with a self-contained, self-propelled, unit with hammers mounted laterally in pairs with half the hammers in a forward row and the remainder diagonally offset in a rear row so that there is continuous breakage from side to side. The lift height of the hammers shall be independently adjustable. The equipment shall have the capability of rubbilizing a 13 foot lane in a single pass. The Contractor shall minimize the dispersion of dust from the rubbilizing operation, until the rubbilized surface is overlaid with pavement by the application of non-excessive water or other approved method. The breaking unit shall be capable of delivering such energy as may be necessary to satisfactorily break the pavement. The breaker shall be equipped with a screen to protect vehicles in the adjacent lane from flying chips during the fracturing process when necessary.

Roller: A steel vibratory roller fitted with a "Z" pattern grid on the drum face having a gross weight of not less than 10 tons, operated in vibratory mode, shall be used to settle and seat the rubbilized pavement.

Pneumatic roller; A pneumatic roller having a gross weight of not less than 25 tons shall be used to settle and seat the rubbilized pavement.

Any other equipment needed for rubbilization shall have prior approval from the Engineer.

Rubbilization

A joint shall be cut full depth at an existing joint on ramps or mainline where rubbilization abuts concrete which is to remain in place. The existing concrete pavement shall be broken into pieces ranging from sand size to pieces generally 3 inches or less in size in the top half of the concrete pavement and 9 inches or less in the bottom half of the concrete pavement. No individual pieces shall exceed 9 inches in any dimension. The vibrator roller shall reduce the flaky type surface particles to 1 to 2 inches in size. At the beginning of the rubbilization operations, a 4-foot by 4-foot test section shall be excavated in the middle of a lane at a location selected by the Engineer to determine if the breaker is producing pieces of the specified sizes. Additional test sections may be required if the Engineer determines that they are necessary. The test section material shall be removed from the project and the hole shall be filled using Item 403 Hot Bituminous Pavement (Patching)

The breaker shall be operated to avoid damaging the base and underlying structures. If damage occurs to the base or underlying structures, the contractor shall repair any damage at his expense.

In areas where the roadway must be overlaid one lane at a time, initial rubbilization will extend a minimum of 6 inches beyond the width of the pavement to be overlaid. Reinforcement in the rubbilized pavement, if any, shall be left in place. However, any reinforcement exposed at the surface during rubbilization or compacting operations shall be cut off below the surface and removed. Any loose joint fillers, expansion materials, or other similar items shall also be removed.

The Contractor shall continuously monitor the rubbilization operation and shall make adjustments in the striking pattern, striking energy, or other factors as necessary to continually achieve acceptable breaking throughout the project.

If unstable areas occur due to expansion of the existing pavement, these areas will be removed to a maximum length of 4 feet in length by 12 feet in width and replaced full depth with Item 403 Hot Bituminous Pavement (Patching) (Asphalt). Patching of unstable areas and test section holes shall conform to the requirements of Section 403 Hot Bituminous Pavements.

Settle and Seat.

The rubbilized pavement shall be settled and seated with a vibratory steel wheel and a pneumatic roller in the following sequence or as approved by the Engineer:

After Rubbilization:

1. 2 passes with a vibratory roller fitted with a •Z• pattern grid on the roller face.
2. 1 pass with a pneumatic roller.

Immediately prior to overlay:

1. 1 pass with a vibratory roller.

For this operation a pass is defined as forward and back over the entire surface area.

## METHOD OF MEASUREMENT

Rubbilization of Concrete Pavement (Multi-head Breaker) will be measured by the square yard. Hot Bituminous Pavement (Patching) (Asphalt) will be measured as prescribed in subsection 401.21.

## BASIS OF PAYMENT

The accepted quantities will be paid at the contract unit price for the pay item listed below:

Payment will be made under:

| Pay Item | | Pay Unit |
|---|---|---|
| 412 | Rubbilization of Concrete Pavement (Multi-Head Breaker) | Square Yard |
| 403 | Hot Bituminous Pavement (Patching) (Asphalt) | Ton |

Payment will be full compensation for all work and materials required to complete the item. This will include, but not be limited to, full compensation for all labor, equipment, tools, incidentals necessary to rubbilize and settle and seat the existing concrete pavement, full depth saw cutting, removal of the test section, removal of the existing reinforcement, clean up and waste disposal.

# APPENDIX C

## Job Mix Formulas

**Colorado Department of Transportation**
**JOB MIX FORMULA**

Region: 4
Project: NH 0762-038
Location: Sterling to Iliff I-76
S.A.: 11204
From Project:
From Project S. A.:

Form 43 Serial #: 17
Mix Design: 106025
Date: 08/31/1999

This Job Mix Formula defines the specified gradation, asphalt cement content and addmixture dosage for the grading and project shown.

Contractor: Asphalt Paving Co.
Supplier: Asphalt Paving Co.
Plant: Asphalt Paving Co.

Item: 403 Top & Bottom Layers
Grading - Compaction: S 109
% RAP: 0 % Lime: 1

**Components**

1: 18% 3/4 Rock (Asphalt Paving)
2: 54% Crushed Fines (McAtee)
3: 10% Natural Sand (McAtee)
4: 17% 1/2 Rock (Asphalt Paving)
5:
6:
7:

Remarks: Change Max. Sp. Gr. according to CP56

**Gradation** Voids Acceptance

| Seive | Virgin Agg. w/o RAP %Passing | Aggregate with RAP %Passing | Tolerance +/- |
|---|---|---|---|
| 2" (50mm) | | | - |
| 1 1/2" (37.5mm) | | | - |
| 1" (25mm) | 100 | | 100 |
| 3/4" (19.0mm) | 90-100 | | - |
| 1/2' (12.5mm) | 88 | | 6 |
| 3/8" (9.5mm) | 79 | | 6 |
| #4 | 61 | | 5 |
| #8 | 49 | | 5 |
| #16 | | | - |
| #30 | 21 | | 4 |
| #50 | | | - |
| #100 | | | - |
| #200 | 4.6 | | 2.0 |

☐ Mix Design Based On Ndes

Hveem Stability @ Optimum %AC: 32

Percent AC: 4.7 +/-0.3

Grade of A.C.: PG 70-34

Source of A.C.: Koch

Max Specific Gravity at % A.C.: 2.472

Bulk Sp. Gr. of Combined Agg.: 2.658

Bulk Sp. Gr. of Fine Agg.: 2.685

Angularity (CPL 5113): 46.6

Stability for Information

| Voids Data at N (Design) | | |
|---|---|---|
| Property | Target Value | Tolerance |
| Stability: | 42 | Minimum |
| % Voids: | 3.9 | +/- 1.2 |
| % VMA: | 14.2 | +/- 1.2 |

☑ New mix design with no change

☐ Staff Materials called and concurs with change or reapproval

Staff Materials Representative

Signed: Jeff Decker Date: 9/1/99

Project Engineer

Signed: [signature] Date: 8/31/99

Region Materials Engineer

Signed: _____ Date:

Contractor Representative

Distribution:
Staff Materials
Region Materials Engineer
Resident Engineer (2)
Contractor
CDOT FORM # 43 v1.00a

**Colorado Department of Transportation**
**JOB MIX FORMULA**

Region: 4
Project: NH 0762-038
Location: Sterling to Iliff I-76
S.A.: 11204
From Project:
From Project S. A.:

Form 43 Serial #: 17
Mix Design: Westest 15399 A
Date: 10/05/1999

*This Job Mix Formula defines the specified gradation, asphalt cement content and addmixture dosage for the grading and project shown.*

Contractor: Asphalt Paving Co.
Supplier: Asphalt Paving Co.
Plant: Asphalt Paving Co.

Item: 403 Top & Bottom Layers
Grading - Compaction: S 109
% RAP: 0 % Lime: 1

**Components**

1: 17% 3/4" Rock (Asphalt Paving)
2: 55% Crushed Fines (Poudre Tech)
3: 11% Sand (Ag. Inc.)
4: 16% 1/2" Rock (Asphalt Paving)
5:
6:
7:

Remarks: Adjust target AC content to align with target VTM. Max Sp Gr adjusted as per CP 56.

**Gradation** Voids Acceptance

| Seive | Virgin Agg. w/o RAP %Passing | Aggregate with RAP %Passing | Tolerance +/- |
|---|---|---|---|
| 2" (50mm) | | | - |
| 1 1/2" (37.5mm) | | | - |
| 1" (25mm) | 100 | | 100 |
| 3/4" (19.0mm) | 90-100 | | - |
| 1/2' (12.5mm) | 89 | | 6 |
| 3/8" (9.5mm) | 80 | | 6 |
| #4 | 60 | | 5 |
| #8 | 45 | | 5 |
| #16 | | | - |
| #30 | 23 | | 4 |
| #50 | | | - |
| #100 | | | - |
| #200 | 5.9 | | 2.0 |

☐ Mix Design Based On Ndes

Hveem Stability @ Optimum %AC: 44

Percent AC: 5.0 +/-0.3
Grade of A.C.: PG 76-28
Source of A.C.: Koch
Max Specific Gravity at % A.C: 2.490
Bulk Sp. Gr. of Combined Agg.: 2.677
Bulk Sp. Gr. of Fine Agg.: 2.623
Angularity (CPL 5113): 47.7

☑ New mix design with no change

☐ Staff Materials called and concurs with change or reapproval

Stability for Information

| Voids Date at N (Design) Property | Target Value | Tolerance |
|---|---|---|
| Stability: | 42 | Minimum |
| % Voids: | 4.0 | +/- 1.2 |
| % VMA: | 14.0 | +/- 1.2 |

Distribution:
Staff Materials
Region Materials Engineer
Resident Engineer (2)
Contractor
CDOT FORM # 43 v1.00a

Staff Materials Representative
Signed: [signature] Date: 10/7/99

MATERIALS Project Engineer
Signed: [signature] Date: 10/05/99

Project ~~Region Materials~~ Engineer
Signed: [signature] Date: 10/5/99

Contractor Representative

# APPENDIX D

## Tabulation of Bids

TABULATION OF BIDS

LETTING NO. : 98111901
LETTING DATE : 11/19/98
LETTING TIME : 10:00 AM

CONTRACT ID : C11204
REGION : 4
CONTRACT TIME :
TERRAIN : PLAINS

COUNTIES : LOGAN

PROJECT(S) : NH 0762-038

CONTRACT DESCRIPTION :
PROJECT NH 0762-038
LOCATED ON INTERSTATE 76 BEGINNING EAST OF THE STERLING
INTERCHANGE AND EXTENDING APPROXIMATELY 3 MILES NORTH EAST

CONSISTING OF H.B.P. OVERLAY AND BRIDGE WIDENING WHICH
INCLUDES: REMOVAL OF PORTIONS OF PRESENT STRUCTURE,
GUARD RAIL, DETOURS, RUBBILIZATION OF CONCRETE PAVEMENT,
TRAFFIC SIGNALS AND STRIPING.

| RANK | VENDOR NO./NAME | | TOTAL BID | % OF LOW BID | % OF EST |
|---|---|---|---|---|---|
| 0 | -EST- | ENGINEER'S ESTIMATE | $ 4,973,901.20 | 135.2323% | 100.0000% |
| 1 | 017A | ASPHALT PAVING CO. | $ 3,678,040.68 | 100.0000% | 73.9467% |
| 2 | 159C | KIEWIT WESTERN CO. | $ 4,032,865.30 | 109.6471% | 81.0805% |
| 3 | 417A | PCL CIVIL CONSTRUCTORS, INC. | $ 4,109,418.48 | 111.7284% | 82.6196% |
| 4 | 163D | WESTERN-MOBILE, INC. DBA WESTERN-MOBILE NORTHERN | $ 4,304,135.68 | 117.0225% | 86.5344% |
| 5 | 071A | COULSON EXCAVATING COMPANY INCORPORATED | $ 4,483,429.15 | 121.8972% | 90.1390% |

| ITEM CODE | ITEM DESCRIPTION | QUANTITY | (0) -EST- ENGINEER'S ESTIMATE UNIT PRICE | (0) -EST- ENGINEER'S ESTIMATE AMOUNT | (1) 017A ASPHALT PAVING CO. UNIT PRICE | (1) 017A ASPHALT PAVING CO. AMOUNT | (2) 159C KIEWIT WESTERN CO UNIT PRICE | (2) 159C KIEWIT WESTERN CO AMOUNT |
|---|---|---|---|---|---|---|---|---|
| SECTION 0001 | BID ITEMS | | | | | | | |
| 202-00001 | REM STRUCTURE | 8.000 EACH | 1000.0000 | 8000.00 | 607.4000 | 4859.20 | 500.0000 | 4000.00 |
| 202-00026 | REM S AND D PAVE | 31.000 SY | 12.0000 | 372.00 | 47.7000 | 1478.70 | 90.0000 | 2790.00 |
| 202-00240 | REM ASPHALT MAT (PLANING) | 126081.000 SY | 2.0000 | 252162.00 | 0.5300 | 66822.93 | 0.9000 | 113472.90 |
| 202-00250 | REM PAVEMENT MARKING | 1000.000 SF | 1.7500 | 1750.00 | 3.2000 | 3200.00 | 2.0000 | 2000.00 |
| 202-00425 | REM BRIDGE RAILING | 778.000 LF | 8.5000 | 6613.00 | 10.6000 | 8246.80 | 10.0000 | 7780.00 |
| 202-00495 | REM PORT PRESENT STR | 1.000 L S | 50000.0000 | 50000.00 | 63600.0000 | 63600.00 | 45000.0000 | 45000.00 |
| 202-00700 | REM LIGHT STANDARD | 1.000 EACH | 500.0000 | 500.00 | 204.6000 | 204.60 | 185.0000 | 185.00 |
| 202-01130 | REM GDRAIL TY 3 | 1137.500 LF | 3.0000 | 3412.50 | 2.3000 | 2616.25 | 2.5000 | 2843.75 |
| 202-01300 | REM END ANCHORAGE | 8.000 EACH | 125.0000 | 1000.00 | 90.1000 | 720.80 | 85.0000 | 680.00 |
| 202-06000 | REM DETOUR | 1.000 L S | 50000.0000 | 50000.00 | 5679.9000 | 5679.90 | 20000.0000 | 20000.00 |
| 206-00000 | STR EXCAV | 538.000 CY | 11.0000 | 5918.00 | 13.8000 | 7424.40 | 11.0000 | 5918.00 |
| 206-00100 | STR BKFL (CL 1) | 270.000 CY | 20.0000 | 5400.00 | 11.7000 | 3159.00 | 25.0000 | 6750.00 |
| 206-00200 | STR BKFL (CL 2) | 135.000 CY | 14.0000 | 1890.00 | 51.9000 | 7006.50 | 30.0000 | 4050.00 |
| 212-00006 | SEEDING (NATIVE) | 2.000 ACRE | 650.0000 | 1300.00 | 954.0000 | 1908.00 | 950.0000 | 1900.00 |
| 213-00003 | MULCHING (WEED FREE) | 2.000 ACRE | 600.0000 | 1200.00 | 1240.0000 | 2480.00 | 1200.0000 | 2400.00 |
| 213-00061 | MULCH TACKIFIER | 200.000 LB | 3.0000 | 600.00 | 4.2000 | 840.00 | 4.0000 | 800.00 |
| 310-00400 | PROCESS ASPHALT MAT FOR BA | 46402.000 SY | 1.1000 | 51042.20 | 1.5000 | 69603.00 | 1.8000 | 83523.60 |

TABULATION OF BIDS

LETTING NO. : 98111901
LETTING DATE : 11/19/98
LETTING TIME : 10:00 AM

CONTRACT ID : C11204
REGION : 4

COUNTIES : LOGAN

| ITEM CODE | ITEM DESCRIPTION | QUANTITY | | (0) -EST- ENGINEER'S ESTIMATE UNIT PRICE | (0) -EST- ENGINEER'S ESTIMATE AMOUNT | (1) 017A ASPHALT PAVING CO. UNIT PRICE | (1) 017A ASPHALT PAVING CO. AMOUNT | (2) 159C KIEWIT WESTERN CO UNIT PRICE | (2) 159C KIEWIT WESTERN CO AMOUNT |
|---|---|---|---|---|---|---|---|---|---|
| 403-00720 | HBP (PATCHING) (ASPH) | 100.000 | TON | 120.0000 | 12000.00 | 98.1000 | 9810.00 | 100.0000 | 10000.00 |
| 403-35300 | HBP (GR S) (109) | 46866.000 | TON | 34.0000 | 1593444.00 | 26.5000 | 1241949.00 | 27.0000 | 1265382.00 |
| 411-03344 | ASPH CEM (PG 70-34) | 2350.000 | TON | 280.0000 | 658000.00 | 244.9000 | 575515.00 | 225.0000 | 528750.00 |
| 412-18010 | RUBBIL OF CONC PVMT (CRACK | 20377.000 | SY | 2.0000 | 40754.00 | 0.3000 | 6113.10 | 0.2500 | 5094.25 |
| 412-18020 | RUBBIL OF CONC PVMT (RESON | 30857.000 | SY | 2.0000 | 61714.00 | 1.7000 | 52456.90 | 1.6000 | 49371.20 |
| 412-18030 | RUBBIL OF CONC PVMT (MULTI | 28372.000 | SY | 2.0000 | 56744.00 | 1.7000 | 48232.40 | 1.5000 | 42558.00 |
| 502-00460 | PILE TIP | 8.000 | EACH | 90.0000 | 720.00 | 212.0000 | 1696.00 | 51.0000 | 408.00 |
| 502-08330 | SP PILE (12-3/4X0.330) | 347.000 | LF | 35.0000 | 12145.00 | 47.7000 | 16551.90 | 15.0000 | 5205.00 |
| 506-00209 | RIPRAP (9 IN) | 13.000 | CY | 75.0000 | 975.00 | 83.4000 | 1084.20 | 140.0000 | 1820.00 |
| 507-00000 | CONC S AND D PAVE | 31.000 | CY | 300.0000 | 9300.00 | 333.9000 | 10350.90 | 540.0000 | 16740.00 |
| 507-00400 | BIT S AND D PAVE (ASPH) | 36.000 | TON | 150.0000 | 5400.00 | 147.0000 | 5292.00 | 150.0000 | 5400.00 |
| 509-00000 | STR STEEL | 25120.000 | LB | 2.0000 | 50240.00 | 1.4000 | 35168.00 | 1.0000 | 25120.00 |
| 509-08010 | ALTER-ERECT STR STEEL | 1.000 | L S | 100000.0000 | 100000.00 | 21412.0000 | 21412.00 | 60000.0000 | 60000.00 |
| 509-90001 | PAINT EXISTING STRUCTURE | 1.000 | EACH | 40000.0000 | 40000.00 | 16430.0000 | 16430.00 | 30000.0000 | 30000.00 |
| 513-00606 | BRIDGE DRAIN (6 IN) | 2.000 | EACH | 2000.0000 | 4000.00 | 1272.0000 | 2544.00 | 1500.0000 | 3000.00 |
| 515-00120 | WATERPROOFING (MEMBRANE) | 804.000 | SY | 8.0000 | 6432.00 | 9.0000 | 7236.00 | 8.0000 | 6432.00 |
| 518-01004 | EXPAN DEVICE (0-4 IN) | 100.000 | LF | 125.0000 | 12500.00 | 116.6000 | 11660.00 | 160.0000 | 16000.00 |
| 518-03000 | SAW AND SEAL BR JOINT | 100.000 | LF | 15.0000 | 1500.00 | 6.4000 | 640.00 | 12.0000 | 1200.00 |
| 601-03040 | CONCRETE CL D (BRIDGE) | 456.000 | CY | 325.0000 | 148200.00 | 318.0000 | 145008.00 | 440.0000 | 200640.00 |
| 601-40200 | CLASS 5 FINISH | 6151.000 | SF | 1.5000 | 9226.50 | 1.5000 | 9226.50 | 0.7000 | 4305.70 |
| 602-00000 | REINF STEEL | 20005.000 | LB | 0.5000 | 10002.50 | 0.7000 | 14003.50 | 0.5000 | 10002.50 |
| 602-00020 | REINF STEEL (EPOXY) | 79060.000 | LB | 0.6000 | 47436.00 | 0.7000 | 55342.00 | 0.6000 | 47436.00 |
| 605-00040 | 4 IN PP UN-DR | 29794.000 | LF | 11.0000 | 327734.00 | 3.9000 | 116196.60 | 8.0000 | 238352.00 |
| 605-84000 | SUBSURFACE DRAIN OUTLET | 1331.000 | LF | 16.0000 | 21296.00 | 13.4000 | 17835.40 | 11.0000 | 14641.00 |
| 606-00301 | GDRAIL TY 3 (6-3) | 888.000 | LF | 13.0000 | 11544.00 | 12.4000 | 11011.20 | 12.0000 | 10656.00 |
| 606-01340 | END ANCHOR TY 3D | 1.000 | EACH | 500.0000 | 500.00 | 413.4000 | 413.40 | 390.0000 | 390.00 |
| 606-01370 | END ANCHOR TY 3G | 6.000 | EACH | 750.0000 | 4500.00 | 784.4000 | 4706.40 | 760.0000 | 4560.00 |
| 606-01380 | END ANCHOR TY 3H | 1.000 | EACH | 600.0000 | 600.00 | 530.0000 | 530.00 | 540.0000 | 540.00 |
| 606-02001 | END ANCHOR (SRT) | 7.000 | EACH | 2000.0000 | 14000.00 | 2098.8000 | 14691.60 | 1420.0000 | 9940.00 |
| 606-11000 | BRDG RAIL TY 10 | 387.000 | LF | 80.0000 | 30960.00 | 55.7000 | 21555.90 | 78.0000 | 30186.00 |
| 606-11010 | BRDG RAIL TY 10R | 389.000 | LF | 90.0000 | 35010.00 | 56.2000 | 21861.80 | 70.0000 | 27230.00 |
| 607-11580 | FENCE (TEMP) | 800.000 | LF | 2.0000 | 1600.00 | 5.3000 | 4240.00 | 3.0000 | 2400.00 |
| 609-60011 | CURB TY 6 M | 4981.000 | LF | 4.5000 | 22414.50 | 5.8000 | 28889.80 | 9.0000 | 44829.00 |
| 612-00001 | DELINEATOR (TY I) | 216.000 | EACH | 18.0000 | 3888.00 | 18.6000 | 4017.60 | 18.0000 | 3888.00 |
| 612-00003 | DELINEATOR (TY III) | 4.000 | EACH | 20.0000 | 80.00 | 19.1000 | 76.40 | 19.0000 | 76.00 |
| 613-00200 | 2 IN ELEC COND | 495.000 | LF | 10.0000 | 4950.00 | 6.6000 | 3267.00 | 21.0000 | 10395.00 |
| 613-00300 | 3 IN ELEC COND | 300.000 | LF | 13.0000 | 3900.00 | 10.4000 | 3120.00 | 31.0000 | 9300.00 |
| 613-00301 | 3 IN ELEC COND (JACKED) | 700.000 | LF | 25.0000 | 17500.00 | 19.1000 | 13370.00 | 64.0000 | 44800.00 |
| 613-10000 | WIRING | 1.000 | L S | 2000.0000 | 2000.00 | 1664.2000 | 1664.20 | 2000.0000 | 2000.00 |
| 613-50410 | LIGHT STD (TEMP) | 4.000 | EACH | 5000.0000 | 20000.00 | 2586.4000 | 10345.60 | 3400.0000 | 13600.00 |
| 614-72860 | PED PUSH BUTTON | 8.000 | EACH | 250.0000 | 2000.00 | 120.8000 | 966.40 | 100.0000 | 800.00 |
| 614-72886 | INTERSECTION DETECT SYS (C | 1.000 | EACH | 65000.0000 | 65000.00 | 23832.0000 | 23832.00 | 30000.0000 | 30000.00 |

LETTING TIME : 10:00 AM

| ITEM CODE | ITEM DESCRIPTION | QUANTITY | (0) -EST- ENGINEER'S ESTIMATE UNIT PRICE | (0) -EST- ENGINEER'S ESTIMATE AMOUNT | (1) 017A ASPHALT PAVING CO. UNIT PRICE | (1) 017A ASPHALT PAVING CO. AMOUNT | (2) 159C KIEWIT WESTERN CO UNIT PRICE | (2) 159C KIEWIT WESTERN CO AMOUNT |
|---|---|---|---|---|---|---|---|---|
| 614-79217 | FURNISH PED SIG (16) | 8.000 EACH | 1000.0000 | 8000.00 | 749.4000 | 5995.20 | 1700.0000 | 13600.00 |
| 614-79336 | FURN TRAF SIG (12-12-12) | 14.000 EACH | 1200.0000 | 16800.00 | 1334.5000 | 18683.00 | 2100.0000 | 29400.00 |
| 614-81010 | SIG-LIGHT POLE S (1) | 4.000 EACH | 8000.0000 | 32000.00 | 14492.3000 | 57969.20 | 11500.0000 | 46000.00 |
| 614-86112 | FURN CONTROLLER | 1.000 EACH | 5000.0000 | 5000.00 | 11092.9000 | 11092.90 | 11500.0000 | 11500.00 |
| 614-86722 | WIM STATION (TYPE 2) | 1.000 L S | 80000.0000 | 80000.00 | 38847.9000 | 38847.90 | 65000.0000 | 65000.00 |
| 615-00030 | EMB PROT TY 3 | 16.000 EACH | 600.0000 | 9600.00 | 212.0000 | 3392.00 | 275.0000 | 4400.00 |
| 617-00012 | 12 IN CULVERT PIPE | 1215.000 LF | 18.0000 | 21870.00 | 21.2000 | 25758.00 | 25.0000 | 30375.00 |
| 619-50960 | 12 IN PLASTIC PIPE | 33.000 LF | 100.0000 | 3300.00 | 31.8000 | 1049.40 | 15.0000 | 495.00 |
| 620-00002 | FIELD OFFICE (CL 2) | 1.000 EACH | 12000.0000 | 12000.00 | 5300.0000 | 5300.00 | 15000.0000 | 15000.00 |
| 620-00012 | FIELD LABORATORY (CL 2) | 1.000 EACH | 10000.0000 | 10000.00 | 15900.0000 | 15900.00 | 15000.0000 | 15000.00 |
| 620-00020 | SANITARY FACILITY | 1.000 EACH | 1000.0000 | 1000.00 | 795.0000 | 795.00 | 2500.0000 | 2500.00 |
| 621-00450 | DETOUR PAVEMENT | 4995.000 SY | 25.0000 | 124875.00 | 20.7000 | 103396.50 | 20.0000 | 99900.00 |
| 625-00000 | CONSTRUCTION SURVEYING | 1.000 L S | 50000.0000 | 50000.00 | 37100.0000 | 37100.00 | 12000.0000 | 12000.00 |
| 626-00000 | MOBILIZATION | 1.000 L S | 375000.0000 | 375000.00 | 205000.0000 | 205000.00 | 244000.0000 | 244000.00 |
| 627-00001 | PVMT MKG PAINT | 519.000 GAL | 26.0000 | 13494.00 | 29.7000 | 15414.30 | 42.0000 | 21798.00 |
| 627-00002 | THERMOPLASTIC PVMT MKG | 25532.000 SF | 1.5000 | 38298.00 | 1.5000 | 38298.00 | 1.7000 | 43404.40 |
| 627-00030 | RAISED PVMT MARKER (TEMP) | 1000.000 EACH | 4.0000 | 4000.00 | 4.2000 | 4200.00 | 2.0000 | 2000.00 |
| 627-01003 | PREFORM PLASTIC PVMT MKG ( | 3192.000 SF | 16.0000 | 51072.00 | 9.5000 | 30324.00 | 8.0000 | 25536.00 |
| 630-00000 | FLAGGING | 1000.000 HOUR | 21.0000 | 21000.00 | 24.4000 | 24400.00 | 23.0000 | 23000.00 |
| 630-00002 | TRAF CONTROL SUPERVISOR | 162.000 DAY | 300.0000 | 48600.00 | 371.0000 | 60102.00 | 350.0000 | 56700.00 |
| 630-00007 | TRAF CONTROL INSPECTION | 30.000 DAY | 175.0000 | 5250.00 | 159.0000 | 4770.00 | 150.0000 | 4500.00 |
| 630-80001 | FLASHING BEACON (PORTABLE) | 8.000 EACH | 1500.0000 | 12000.00 | 848.0000 | 6784.00 | 800.0000 | 6400.00 |
| 630-80336 | BARRICADE (3 M-B) (TEMP) | 3.000 EACH | 350.0000 | 1050.00 | 318.0000 | 954.00 | 300.0000 | 900.00 |
| 630-80338 | BARRICADE (3 M-D) (TEMP) | 1.000 EACH | 600.0000 | 600.00 | 742.0000 | 742.00 | 700.0000 | 700.00 |
| 630-80341 | CONST TRAF SIGN (A) | 12.000 EACH | 75.0000 | 900.00 | 84.8000 | 1017.60 | 80.0000 | 960.00 |
| 630-80342 | CONST TRAF SIGN (B) | 77.000 EACH | 105.0000 | 8085.00 | 106.0000 | 8162.00 | 100.0000 | 7700.00 |
| 630-80343 | CONST TRAF SIGN (C) | 36.000 EACH | 135.0000 | 4860.00 | 127.2000 | 4579.20 | 120.0000 | 4320.00 |
| 630-80344 | CONST TRAF SIGN (SPECIAL) | 577.000 SF | 14.0000 | 8078.00 | 19.1000 | 11020.70 | 18.0000 | 10386.00 |
| 630-80358 | FLASH ARROW PANEL (C TY) | 2.000 EACH | 1800.0000 | 3600.00 | 2650.0000 | 5300.00 | 2500.0000 | 5000.00 |
| 630-80359 | PORTABLE MESSAGE PANEL | 60.000 DAY | 300.0000 | 18000.00 | 238.5000 | 14310.00 | 225.0000 | 13500.00 |
| 630-80360 | DRUM CHANNELIZING DEVICE | 250.000 EACH | 60.0000 | 15000.00 | 53.0000 | 13250.00 | 50.0000 | 12500.00 |
| 630-80363 | DRUM DEVICE (LIGHT) (F) | 20.000 EACH | 75.0000 | 1500.00 | 84.8000 | 1696.00 | 80.0000 | 1600.00 |
| 630-80370 | CONCRETE BARRIER (TEMP) | 700.000 LF | 22.0000 | 15400.00 | 37.1000 | 25970.00 | 25.0000 | 17500.00 |
| 630-80380 | TRAFFIC CONE | 350.000 EACH | 13.0000 | 4550.00 | 15.9000 | 5565.00 | 15.0000 | 5250.00 |
| 630-80391 | CHANNELIZING DEVICE (FIXED | 130.000 EACH | 50.0000 | 6500.00 | 106.0000 | 13780.00 | 100.0000 | 13000.00 |
| 630-80401 | DELIN (TY I) (TEMP) | 50.000 EACH | 25.0000 | 1250.00 | 21.2000 | 1060.00 | 30.0000 | 1500.00 |
| 630-85005 | IMPACT ATTEN (G-R-E-A-T) ( | 2.000 EACH | 15000.0000 | 30000.00 | 7950.0000 | 15900.00 | 14000.0000 | 28000.00 |
| | SECTION TOTALS | | | $ 4,973,901.20 | | $ 3,678,040.68 | | $ 4,032,865.30 |
| | CONTRACT TOTALS | | | $ 4,973,901.20 | | $ 3,678,040.68 | | $ 4,032,865.30 |



COLORADO DEPARTMENT OF TRANSPORTATION

TABULATION OF BIDS



LETTING NO. : 98111901
LETTING DATE : 11/19/98
LETTING TIME : 10:00 AM

CONTRACT ID : C11204
REGION : 4

COUNTIES : LOGAN

| (3) 417A PCL CIVIL CONSTRUCTORS, I | (4) 163D WESTERN-MOBILE NORTHERN, | (5) 071A COULSON EXCAVATING CO. IN |
|---|---|---|

| ITEM CODE | ITEM DESCRIPTION | QUANTITY | | UNIT PRICE | AMOUNT | UNIT PRICE | AMOUNT | UNIT PRICE | AMOUNT |
|---|---|---|---|---|---|---|---|---|---|
| SECTION 0001 | BID ITEMS | | | | | | | | |
| 202-00001 | REM STRUCTURE | 8.000 | EACH | 100.0000 | 800.00 | 600.0000 | 4800.00 | 100.0000 | 800.00 |
| 202-00026 | REM S AND D PAVE | 31.000 | SY | 200.0000 | 6200.00 | 40.0000 | 1240.00 | 100.0000 | 3100.00 |
| 202-00240 | REM ASPHALT MAT (PLANING) | 126081.000 | SY | 0.6000 | 75648.60 | 0.5500 | 69344.55 | 1.7000 | 214337.70 |
| 202-00250 | REM PAVEMENT MARKING | 1000.000 | SF | 1.7500 | 1750.00 | 1.8500 | 1850.00 | 2.3000 | 2300.00 |
| 202-00425 | REM BRIDGE RAILING | 778.000 | LF | 9.1000 | 7079.80 | 10.5000 | 8169.00 | 10.5000 | 8169.00 |
| 202-00495 | REM PORT PRESENT STR | 1.000 | L S | 35000.0000 | 35000.00 | 60000.0000 | 60000.00 | 63000.0000 | 63000.00 |
| 202-00700 | REM LIGHT STANDARD | 1.000 | EACH | 200.0000 | 200.00 | 275.0000 | 275.00 | 305.0000 | 305.00 |
| 202-01130 | REM GDRAIL TY 3 | 1137.500 | LF | 2.1500 | 2445.63 | 2.2500 | 2559.38 | 2.5000 | 2843.75 |
| 202-01300 | REM END ANCHORAGE | 8.000 | EACH | 85.0000 | 680.00 | 90.0000 | 720.00 | 98.7500 | 790.00 |
| 202-06000 | REM DETOUR | 1.000 | L S | 25000.0000 | 25000.00 | 30000.0000 | 30000.00 | 16100.0000 | 16100.00 |
| 206-00000 | STR EXCAV | 538.000 | CY | 20.0000 | 10760.00 | 13.5000 | 7263.00 | 13.6500 | 7343.70 |
| 206-00100 | STR BKFL (CL 1) | 270.000 | CY | 35.0000 | 9450.00 | 11.5000 | 3105.00 | 12.6500 | 3415.50 |
| 206-00200 | STR BKFL (CL 2) | 135.000 | CY | 15.0000 | 2025.00 | 45.0000 | 6075.00 | 52.0000 | 7020.00 |
| 212-00006 | SEEDING (NATIVE) | 2.000 | ACRE | 900.0000 | 1800.00 | 1400.0000 | 2800.00 | 2200.0000 | 4400.00 |
| 213-00003 | MULCHING (WEED FREE) | 2.000 | ACRE | 1170.0000 | 2340.00 | 1400.0000 | 2800.00 | 2200.0000 | 4400.00 |
| 213-00061 | MULCH TACKIFIER | 200.000 | LB | 4.0000 | 800.00 | 6.0000 | 1200.00 | 6.6000 | 1320.00 |
| 310-00400 | PROCESS ASPHALT MAT FOR BA | 46402.000 | SY | 1.7500 | 81203.50 | 1.5000 | 69603.00 | 3.0000 | 139206.00 |
| 403-00720 | HBP (PATCHING) (ASPH) | 100.000 | TON | 150.0000 | 15000.00 | 100.0000 | 10000.00 | 150.0000 | 15000.00 |
| 403-35300 | HBP (GR S) (109) | 46866.000 | TON | 30.0000 | 1405980.00 | 39.1500 | 1834803.90 | 28.0000 | 1312248.00 |
| 411-03344 | ASPH CEM (PG 70-34) | 2350.000 | TON | 260.0000 | 611000.00 | 247.0000 | 580450.00 | 250.0000 | 587500.00 |
| 412-18010 | RUBBIL OF CONC PVMT (CRACK | 20377.000 | SY | 0.4000 | 8150.80 | 0.8000 | 16301.60 | 1.5000 | 30565.50 |
| 412-18020 | RUBBIL OF CONC PVMT (RESON | 30857.000 | SY | 2.0000 | 61714.00 | 1.6000 | 49371.20 | 2.9000 | 89485.30 |
| 412-18030 | RUBBIL OF CONC PVMT (MULTI | 28372.000 | SY | 1.6500 | 46813.80 | 1.6000 | 45395.20 | 2.9000 | 82278.80 |
| 502-00460 | PILE TIP | 8.000 | EACH | 100.0000 | 800.00 | 150.0000 | 1200.00 | 210.0000 | 1680.00 |
| 502-08330 | SP PILE (12-3/4X0.330) | 347.000 | LF | 50.0000 | 17350.00 | 50.0000 | 17350.00 | 47.2500 | 16395.75 |
| 506-00209 | RIPRAP (9 IN) | 13.000 | CY | 65.0000 | 845.00 | 140.0000 | 1820.00 | 100.0000 | 1300.00 |
| 507-00000 | CONC S AND D PAVE | 31.000 | CY | 300.0000 | 9300.00 | 425.0000 | 13175.00 | 330.7500 | 10253.25 |
| 507-00400 | BIT S AND D PAVE (ASPH) | 36.000 | TON | 200.0000 | 7200.00 | 100.0000 | 3600.00 | 200.0000 | 7200.00 |
| 509-00000 | STR STEEL | 25120.000 | LB | 1.0000 | 25120.00 | 1.2500 | 31400.00 | 1.4000 | 35168.00 |
| 509-08010 | ALTER-ERECT STR STEEL | 1.000 | L S | 35000.0000 | 35000.00 | 20000.0000 | 20000.00 | 21210.0000 | 21210.00 |
| 509-90001 | PAINT EXISTING STRUCTURE | 1.000 | EACH | 30000.0000 | 30000.00 | 7000.0000 | 7000.00 | 10000.0000 | 10000.00 |
| 513-00606 | BRIDGE DRAIN (6 IN) | 2.000 | EACH | 1600.0000 | 3200.00 | 850.0000 | 1700.00 | 1260.0000 | 2520.00 |
| 515-00120 | WATERPROOFING (MEMBRANE) | 804.000 | SY | 8.0000 | 6432.00 | 9.0000 | 7236.00 | 9.2000 | 7396.80 |
| 518-01004 | EXPAN DEVICE (0-4 IN) | 100.000 | LF | 115.0000 | 11500.00 | 105.0000 | 10500.00 | 115.5000 | 11550.00 |
| 518-03000 | SAW AND SEAL BR JOINT | 100.000 | LF | 10.0000 | 1000.00 | 6.0000 | 600.00 | 6.9000 | 690.00 |
| 601-03040 | CONCRETE CL D (BRIDGE) | 456.000 | CY | 325.0000 | 148200.00 | 300.0000 | 136800.00 | 315.0000 | 143640.00 |
| 601-40200 | CLASS 5 FINISH | 6151.000 | SF | 1.0000 | 6151.00 | 1.4000 | 8611.40 | 1.5000 | 9226.50 |
| 602-00000 | REINF STEEL | 20005.000 | LB | 0.5000 | 10002.50 | 0.6500 | 13003.25 | 0.6700 | 13403.35 |
| 602-00020 | REINF STEEL (EPOXY) | 79060.000 | LB | 0.6000 | 47436.00 | 0.6500 | 51389.00 | 0.6900 | 54551.40 |
| 605-00040 | 4 IN PP UN-DR | 29794.000 | LF | 7.0000 | 208558.00 | 3.2500 | 96830.50 | 6.5000 | 193661.00 |



COLORADO DEPARTMENT OF TRANSPORTATION

TABULATION OF BIDS



LETTING NO. : 98111901
LETTING DATE : 11/19/98
LETTING TIME : 10:00 AM

CONTRACT ID : C11204
REGION : 4

COUNTIES - LOGAN

| ITEM CODE | ITEM DESCRIPTION | QUANTITY | | (3) 417A PCL CIVIL CONSTRUCTORS, I UNIT PRICE | (3) 417A PCL CIVIL CONSTRUCTORS, I AMOUNT | (4) 163D WESTERN-MOBILE NORTHERN, UNIT PRICE | (4) 163D WESTERN-MOBILE NORTHERN, AMOUNT | (5) 071A COULSON EXCAVATING CO. IN UNIT PRICE | (5) 071A COULSON EXCAVATING CO. IN AMOUNT |
|---|---|---|---|---|---|---|---|---|---|
| 605-84000 | SUBSURFACE DRAIN OUTLET | 1331.000 | LF | 7.0000 | 9317.00 | 5.0000 | 6655.00 | 25.0000 | 33275.00 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 606-00301 | GDRAIL TY 3 (6-3) | 888.000 | LF | 11.7000 | 10389.60 | 15.0000 | 13320.00 | 13.4500 | 11943.60 |
| 606-01340 | END ANCHOR TY 3D | 1.000 | EACH | 390.0000 | 390.00 | 450.0000 | 450.00 | 450.0000 | 450.00 |
| 606-01370 | END ANCHOR TY 3G | 6.000 | EACH | 740.0000 | 4440.00 | 750.0000 | 4500.00 | 850.0000 | 5100.00 |
| 606-01380 | END ANCHOR TY 3H | 1.000 | EACH | 500.0000 | 500.00 | 500.0000 | 500.00 | 575.0000 | 575.00 |
| 606-02001 | END ANCHOR (SRT) | 7.000 | EACH | 1380.0000 | 9660.00 | 2000.0000 | 14000.00 | 1587.0000 | 11109.00 |
| 606-11000 | BRDG RAIL TY 10 | 387.000 | LF | 35.0000 | 13545.00 | 50.0000 | 19350.00 | 40.1000 | 15518.70 |
| 606-11010 | BRDG RAIL TY 10R | 389.000 | LF | 55.0000 | 21395.00 | 58.0000 | 22562.00 | 63.6000 | 24740.40 |
| 607-11580 | FENCE (TEMP) | 800.000 | LF | 3.0000 | 2400.00 | 1.5000 | 1200.00 | 3.0000 | 2400.00 |
| 609-60011 | CURB TY 6 M | 4981.000 | LF | 5.5000 | 27395.50 | 3.6000 | 17931.60 | 5.5000 | 27395.50 |
| 612-00001 | DELINEATOR (TY I) | 216.000 | EACH | 17.0000 | 3672.00 | 18.0000 | 3888.00 | 25.0000 | 5400.00 |
| 612-00003 | DELINEATOR (TY III) | 4.000 | EACH | 20.0000 | 80.00 | 19.0000 | 76.00 | 30.0000 | 120.00 |
| 613-00200 | 2 IN ELEC COND | 495.000 | LF | 6.2500 | 3093.75 | 11.5000 | 5692.50 | 12.6500 | 6261.75 |
| 613-00300 | 3 IN ELEC COND | 300.000 | LF | 10.0000 | 3000.00 | 12.0000 | 3600.00 | 13.2500 | 3975.00 |
| 613-00301 | 3 IN ELEC COND (JACKED) | 700.000 | LF | 18.0000 | 12600.00 | 13.0000 | 9100.00 | 14.4000 | 10080.00 |
| 613-10000 | WIRING | 1.000 | L S | 1570.0000 | 1570.00 | 7200.0000 | 7200.00 | 8280.0000 | 8280.00 |
| 613-50410 | LIGHT STD (TEMP) | 4.000 | EACH | 2440.0000 | 9760.00 | 3800.0000 | 15200.00 | 4255.0000 | 17020.00 |
| 614-72860 | PED PUSH BUTTON | 8.000 | EACH | 114.0000 | 912.00 | 210.0000 | 1680.00 | 230.0000 | 1840.00 |
| 614-72886 | INTERSECTION DETECT SYS (C | 1.000 | EACH | 22500.0000 | 22500.00 | 26000.0000 | 26000.00 | 26250.0000 | 26250.00 |
| 614-79217 | FURNISH PED SIG (16) | 8.000 | EACH | 707.0000 | 5656.00 | 840.0000 | 6720.00 | 920.0000 | 7360.00 |
| 614-79336 | FURN TRAF SIG (12-12-12) | 14.000 | EACH | 1260.0000 | 17640.00 | 1425.0000 | 19950.00 | 1565.0000 | 21910.00 |
| 614-81010 | SIG-LIGHT POLE S (1) | 4.000 | EACH | 13700.0000 | 54800.00 | 16500.0000 | 66000.00 | 16800.0000 | 67200.00 |
| 614-86112 | FURN CONTROLLER | 1.000 | EACH | 10500.0000 | 10500.00 | 12800.0000 | 12800.00 | 12350.0000 | 12350.00 |
| 614-86722 | WIM STATION (TYPE 2) | 1.000 | L S | 36650.0000 | 36650.00 | 50000.0000 | 50000.00 | 50000.0000 | 50000.00 |
| 615-00030 | EMB PROT TY 3 | 16.000 | EACH | 600.0000 | 9600.00 | 220.0000 | 3520.00 | 1200.0000 | 19200.00 |
| 617-00012 | 12 IN CULVERT PIPE | 1215.000 | LF | 17.0000 | 20655.00 | 20.0000 | 24300.00 | 35.0000 | 42525.00 |
| 619-50960 | 12 IN PLASTIC PIPE | 33.000 | LF | 17.0000 | 561.00 | 33.0000 | 1089.00 | 100.0000 | 3300.00 |
| 620-00002 | FIELD OFFICE (CL 2) | 1.000 | EACH | 30000.0000 | 30000.00 | 8600.0000 | 8600.00 | 8000.0000 | 8000.00 |
| 620-00012 | FIELD LABORATORY (CL 2) | 1.000 | EACH | 15000.0000 | 15000.00 | 10000.0000 | 10000.00 | 20000.0000 | 20000.00 |
| 620-00020 | SANITARY FACILITY | 1.000 | EACH | 1000.0000 | 1000.00 | 1500.0000 | 1500.00 | 1000.0000 | 1000.00 |
| 621-00450 | DETOUR PAVEMENT | 4995.000 | SY | 18.0000 | 89910.00 | 13.0000 | 64935.00 | 18.0000 | 89910.00 |
| 625-00000 | CONSTRUCTION SURVEYING | 1.000 | L S | 30000.0000 | 30000.00 | 21000.0000 | 21000.00 | 20000.0000 | 20000.00 |
| 626-00000 | MOBILIZATION | 1.000 | L S | 360852.0000 | 360852.00 | 305000.0000 | 305000.00 | 410000.0000 | 410000.00 |
| 627-00001 | PVMT MKG PAINT | 519.000 | GAL | 20.0000 | 10380.00 | 20.0000 | 10380.00 | 46.0000 | 23874.00 |
| 627-00002 | THERMOPLASTIC PVMT MKG | 25532.000 | SF | 1.2500 | 31915.00 | 1.3000 | 33191.60 | 1.9000 | 48510.80 |
| 627-00030 | RAISED PVMT MARKER (TEMP) | 1000.000 | EACH | 2.0000 | 2000.00 | 2.0000 | 2000.00 | 2.3000 | 2300.00 |
| 627-01003 | PREFORM PLASTIC PVMT MKG ( | 3192.000 | SF | 9.0000 | 28728.00 | 9.2500 | 29526.00 | 9.1000 | 29047.20 |
| 630-00000 | FLAGGING | 1000.000 | HOUR | 23.0000 | 23000.00 | 28.0000 | 28000.00 | 26.5000 | 26500.00 |
| 630-00002 | TRAF CONTROL SUPERVISOR | 162.000 | DAY | 350.0000 | 56700.00 | 400.0000 | 64800.00 | 405.0000 | 65610.00 |
| 630-00007 | TRAF CONTROL INSPECTION | 30.000 | DAY | 150.0000 | 4500.00 | 200.0000 | 6000.00 | 175.0000 | 5250.00 |
| 630-80001 | FLASHING BEACON (PORTABLE) | 8.000 | EACH | 800.0000 | 6400.00 | 820.0000 | 6560.00 | 920.0000 | 7360.00 |
| 630-80336 | BARRICADE (3 M-B) (TEMP) | 3.000 | EACH | 300.0000 | 900.00 | 325.0000 | 975.00 | 350.0000 | 1050.00 |



COLORADO DEPARTMENT OF TRANSPORTATION

TABULATION OF BIDS



LETTING NO. : 98111901
LETTING DATE : 11/19/98
LETTING TIME : 10:00 AM

CONTRACT ID : C11204
REGION : 4

COUNTIES : LOGAN

| ITEM CODE | ITEM DESCRIPTION | QUANTITY | | (3) 417A PCL CIVIL CONSTRUCTORS, I UNIT PRICE | (3) 417A PCL CIVIL CONSTRUCTORS, I AMOUNT | (4) 163D WESTERN-MOBILE NORTHERN, UNIT PRICE | (4) 163D WESTERN-MOBILE NORTHERN, AMOUNT | (5) 071A COULSON EXCAVATING CO. IN UNIT PRICE | (5) 071A COULSON EXCAVATING CO. IN AMOUNT |
|---|---|---|---|---|---|---|---|---|---|
| 630-80338 | BARRICADE (3 M-D) (TEMP) | 1.000 | EACH | 700.0000 | 700.00 | 750.0000 | 750.00 | 810.0000 | 810.00 |
| 630-80341 | CONST TRAF SIGN (A) | 12.000 | EACH | 80.0000 | 960.00 | 100.0000 | 1200.00 | 95.0000 | 1140.00 |
| 630-80342 | CONST TRAF SIGN (B) | 77.000 | EACH | 100.0000 | 7700.00 | 160.0000 | 12320.00 | 115.0000 | 8855.00 |
| 630-80343 | CONST TRAF SIGN (C) | 36.000 | EACH | 120.0000 | 4320.00 | 160.0000 | 5760.00 | 140.0000 | 5040.00 |
| 630-80344 | CONST TRAF SIGN (SPECIAL) | 577.000 | SF | 18.0000 | 10386.00 | 19.0000 | 10963.00 | 20.7000 | 11943.90 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 630-80358 FLASH ARROW PANEL (C TY) | 2.000 | EACH | 2500.0000 | 5000.00 | 3000.0000 | 6000.00 | 2900.0000 | 5800.00 |
| 630-80359 PORTABLE MESSAGE PANEL | 60.000 | DAY | 225.0000 | 13500.00 | 300.0000 | 18000.00 | 260.0000 | 15600.00 |
| 630-80360 DRUM CHANNELIZING DEVICE | 250.000 | EACH | 50.0000 | 12500.00 | 55.0000 | 13750.00 | 60.0000 | 15000.00 |
| 630-80363 DRUM DEVICE (LIGHT) (F) | 20.000 | EACH | 80.0000 | 1600.00 | 90.0000 | 1800.00 | 95.0000 | 1900.00 |
| 630-80370 CONCRETE BARRIER (TEMP) | 700.000 | LF | 18.0000 | 12600.00 | 11.0000 | 7700.00 | 40.0000 | 28000.00 |
| 630-80380 TRAFFIC CONE | 350.000 | EACH | 15.0000 | 5250.00 | 17.0000 | 5950.00 | 17.5000 | 6125.00 |
| 630-80391 CHANNELIZING DEVICE (FIXED | 130.000 | EACH | 100.0000 | 13000.00 | 115.0000 | 14950.00 | 115.0000 | 14950.00 |
| 630-80401 DELIN (TY I) (TEMP) | 50.000 | EACH | 20.0000 | 1000.00 | 18.0000 | 900.00 | 30.0000 | 1500.00 |
| 630-85005 IMPACT ATTEN (G-R-E-A-T) ( | 2.000 | EACH | 18500.0000 | 37000.00 | 12000.0000 | 24000.00 | 18500.0000 | 37000.00 |
| SECTION TOTALS | | | | $ 4,109,418.48 | | $ 4,304,135.68 | | $ 4,483,429.15 |
| CONTRACT TOTALS | | | | $ 4,109,418.48 | | $ 4,304,135.68 | | $ 4,483,429.15 |

# APPENDIX E

## DARWin Pavement Design and Analysis System

1993 AASHTO Pavement Design

# DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
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CDOT
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Denver, CO
USA

## Overlay Design Module

WB I-76 Multihead Rubblized Section

## AC Overlay of Fractured PCC Slab

| | |
|---|---|
| Structural Number for Future Traffic | 3.41 in |

| Design Method | Effective Existing Structural Number (in) | Overlay Structural Number (in) |
|---|---|---|
| Component Analysis | 2 | 1.41 |

## Structural Number for Future Traffic

| | |
|---|---|
| Future 18-kip ESALs Over Design Period | 6,500,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2.5 |
| Reliability Level | 90 % |
| Overall Standard Deviation | 0.44 |
| Subgrade Resilient Modulus | 16,069 psi |
| Calculated Structural Number for Future Traffic | 3.41 in |

## Effective Pavement Thickness - Component Analysis Method

| Layer | Material Description | Structural Coefficient | Drainage Coefficient | Thickness (in) |
|---|---|---|---|---|
| 1 | Rubblized PCC | 0.25 | 1 | 8 |

Milling Thickness - in

Calculated Results

| | |
|---|---|
| Calculated Pavement Structural Number Before Milling | 2.00 in |
| Calculated Effective Pavement Structural Number | 2.00 in |

## Backcalculation - WBMHRub

| | |
|---|---|
| Total Pavement Thickness | 8 in |
| Resilient Modulus Correction Factor, C | 1 |
| Existing AC Thickness | - in |
| Base Type | Granular |

| | |
|---|---|
| Data Evaluation Basis | Mean |

Calculated Results

| | |
|---|---|
| Subgrade Resilient Modulus (MR) | 16,069 psi |
| Effective Pavement Modulus (Ep) | 84,136 psi |
| Dynamic k-value | - psi/in |

## Effective Roadbed Soil Resilient Modulus

| Period | Description | Roadbed Resilient Modulus (psi) |
|---|---|---|
| Calculated Effective Modulus | - psi* | |

*Note: This value is not represented by the inputs or an error occurred in calculation.

1993 AASHTO Pavement Design

# DARWin Pavement Design and Analysis System

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## Overlay Design Module

Bottom Lift of HBP (WB I-76 Multihead Hammer Section)

## AC Overlay of Fractured PCC Slab

| | |
|---|---|
| Structural Number for Future Traffic | 3.42 in |

| Design Method | Effective Existing Structural Number (in) | Overlay Structural Number (in) |
|---|---|---|
| Component Analysis | 2.88 | 0.54 |

## Structural Number for Future Traffic

| | |
|---|---|
| Future 18-kip ESALs Over Design Period | 6,500,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2.5 |
| Reliability Level | 90 % |
| Overall Standard Deviation | 0.44 |
| Subgrade Resilient Modulus | 16,041 psi |
| Calculated Structural Number for Future Traffic | 3.42 in |

## Effective Pavement Thickness - Component Analysis Method

| Layer | Material Description | Structural Coefficient | Drainage Coefficient | Thickness (in) |
|---|---|---|---|---|
| 1 | Rubblized PCC | 0.25 | 1 | 8 |
| 2 | HBP | 0.44 | 1 | 2 |

Milling Thickness - in

Calculated Results

| | |
|---|---|
| Calculated Pavement Structural Number Before Milling | 2.88 in |
| Calculated Effective Pavement Structural Number | 2.88 in |

## Backcalculation - WBMH1

| | |
|---|---|
| Total Pavement Thickness | 10 in |
| Resilient Modulus Correction Factor, C | 1 |
| Existing AC Thickness | - in |

| | |
|---|---|
| Base Type | Granular |
| Data Evaluation Basis | Mean |

Calculated Results

| | |
|---|---|
| Subgrade Resilient Modulus (MR) | 16,041 psi |
| Effective Pavement Modulus (Ep) | 66.457 psi |
| Dynamic k-value | - psi/in |

## Effective Roadbed Soil Resilient Modulus

| Period | Description | Roadbed Resilient Modulus (psi) |
|---|---|---|
| Calculated Effective Modulus | - psi* | |

*Note: This value is not represented by the inputs or an error occurred in calculation.

1993 AASHTO Pavement Design

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## Overlay Design Module

Middle Lift of HBP (WB I-76 Multihead Hammer Section)

## AC Overlay of Fractured PCC Slab

Structural Number for Future Traffic 3.46 in

| Design Method | Effective Existing Structural Number (in) | Overlay Structural Number (in) |
|---|---|---|
| Component Analysis | 3.76 | 0.00 |

## Structural Number for Future Traffic

| | |
|---|---|
| Future 18-kip ESALs Over Design Period | 6,500,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2.5 |
| Reliability Level | 90 % |
| Overall Standard Deviation | 0.44 |
| Subgrade Resilient Modulus | 15,487 psi |
| Calculated Structural Number for Future Traffic | 3.46 in |

## Effective Pavement Thickness - Component Analysis Method

| Layer | Material Description | Structural Coefficient | Drainage Coefficient | Thickness (in) |
|---|---|---|---|---|
| 1 | Rubblized PCC | 0.25 | 1 | 8 |
| 2 | HBP Bottom & Middle Lifts | 0.44 | 1 | 4 |

Milling Thickness - in

Calculated Results

| | |
|---|---|
| Calculated Pavement Structural Number Before Milling | 3.76 in |
| Calculated Effective Pavement Structural Number | 3.76 in |

## Backcalculation - WBMH2

| | |
|---|---|
| Total Pavement Thickness | 12 in |
| Resilient Modulus Correction Factor, C | 1 |
| Existing AC Thickness | - in |

| | |
|---|---|
| Base Type | Granular |
| Data Evaluation Basis | Mean |

Calculated Results

| | |
|---|---|
| Subgrade Resilient Modulus (MR) | 15,487 psi |
| Effective Pavement Modulus (Ep) | 78,069 psi |
| Dynamic k-value | - psi/in |

## Effective Roadbed Soil Resilient Modulus

| Period | Description | Roadbed Resilient Modulus (psi) |
|---|---|---|
| Calculated Effective Modulus | - psi* | |

*Note: This value is not represented by the inputs or an error occurred in calculation.

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## Overlay Design Module

Top Lift of HBP (WB I-76 Multihead Hammer Section)

## AC Overlay of Fractured PCC Slab

Structural Number for Future Traffic: 3.32 in

| Design Method | Effective Existing Structural Number (in) | Overlay Structural Number (in) |
|---|---|---|
| Component Analysis | 4.64 | 0.00 |

## Structural Number for Future Traffic

| | |
|---|---|
| Future 18-kip ESALs Over Design Period | 6,500,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2.5 |
| Reliability Level | 90 % |
| Overall Standard Deviation | 0.44 |
| Subgrade Resilient Modulus | 17,354 psi |
| Calculated Structural Number for Future Traffic | 3.32 in |

## Effective Pavement Thickness - Component Analysis Method

| Layer | Material Description | Structural Coefficient | Drainage Coefficient | Thickness (in) |
|---|---|---|---|---|
| 1 | Rubblized PCC | 0.25 | 1 | 8 |
| 2 | Bottom, Middle & Top Lift HBP | 0.44 | 1 | 6 |

Milling Thickness: - in

Calculated Results

| | |
|---|---|
| Calculated Pavement Structural Number Before Milling | 4.64 in |
| Calculated Effective Pavement Structural Number | 4.64 in |

## Future Simple ESAL Calculation

| | |
|---|---|
| Performance Period (years) | - |
| Two-Way Traffic (ADT) | - |
| Number of Lanes in Design Direction | - |

| | |
|---|---|
| Percent of All Trucks in Design Lane | - % |
| Percent Trucks in Design Direction | - % |
| Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater | - % |
| Average Initial Truck Factor (ESALs/truck) | - |
| Annual Truck Factor Growth Rate | - % |
| Annual Truck Volume Growth Rate | - % |
| Growth | Simple |
| Total Calculated Cumulative ESALs | * |

*Note: This value is not represented by the inputs or an error occurred in calculation.

## Future Rigorous ESAL Calculation

| | |
|---|---|
| Performance Period (years) | - |
| Two-Way Traffic (ADT) | - |
| Number of Lanes in Design Direction | - |
| Percent of All Trucks in Design Lane | - % |
| Percent Trucks in Design Direction | - % |

| Vehicle Class | Percent of ADT | Annual % Growth | Average Initial Truck Factor (ESALs/ Truck) | Annual % Growth in Truck Factor | Accumulated 18-kip ESALs over Performance Period |
|---|---|---|---|---|---|
| Total | | - | - | | - |

| | |
|---|---|
| Growth | Simple |
| Total Calculated Cumulative ESALs | - * |

*Note: This value is not represented by the inputs or an error occurred in calculation.

## Backcalculation - WBMH3

| | |
|---|---|
| Total Pavement Thickness | 14 in |
| Resilient Modulus Correction Factor, C | 1 |
| Existing AC Thickness | - in |
| Base Type | Granular |
| Data Evaluation Basis | Mean |

Calculated Results

| | |
|---|---|
| Subgrade Resilient Modulus (MR) | 17,354 psi |
| Effective Pavement Modulus (Ep) | 99,195 psi |
| Dynamic k-value | - psi/in |

## Effective Roadbed Soil Resilient Modulus

| Period | Description | Roadbed Resilient Modulus (psi) |
|---|---|---|
| Calculated Effective Modulus | - psi* | |

*Note: This value is not represented by the inputs or an error occurred in calculation.

1993 AASHTO Pavement Design

# DARWin Pavement Design and Analysis System

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USA

## Overlay Design Module

WB I-76 Resonant Hammer Rubblized Section

## AC Overlay of Fractured PCC Slab

Structural Number for Future Traffic 3.47 in

| Design Method | Effective Existing Structural Number (in) | Overlay Structural Number (in) |
|---|---|---|
| Component Analysis | 2 | 1.47 |

## Structural Number for Future Traffic

| | |
|---|---|
| Future 18-kip ESALs Over Design Period | 6,500,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2.5 |
| Reliability Level | 90 % |
| Overall Standard Deviation | 0.44 |
| Subgrade Resilient Modulus | 15,367 psi |
| Calculated Structural Number for Future Traffic | 3.47 in |

## Effective Pavement Thickness - Component Analysis Method

| Layer | Material Description | Structural Coefficient | Drainage Coefficient | Thickness (in) |
|---|---|---|---|---|
| 1 | Rubblized PCC | 0.25 | 1 | 8 |

Milling Thickness - in

Calculated Results

| | |
|---|---|
| Calculated Pavement Structural Number Before Milling | 2.00 in |
| Calculated Effective Pavement Structural Number | 2.00 in |

## Backcalculation - WBRHRub

| | |
|---|---|
| Total Pavement Thickness | 8 in |
| Resilient Modulus Correction Factor, C | 1 |
| Existing AC Thickness | - in |
| Base Type | Granular |

| | |
|---|---|
| Data Evaluation Basis | Mean |

Calculated Results

| | |
|---|---|
| Subgrade Resilient Modulus (MR) | 15,367 psi |
| Effective Pavement Modulus (Ep) | 100,396 psi |
| Dynamic k-value | - psi/in |

## Effective Roadbed Soil Resilient Modulus

| Period | Description | Roadbed Resilient Modulus (psi) |
|---|---|---|
| Calculated Effective Modulus | - psi* | |

*Note: This value is not represented by the inputs or an error occurred in calculation.

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USA

## Overlay Design Module

Bottom Lift of HBP (WB I-76 Resonant Hammer Section)

## AC Overlay of Fractured PCC Slab

Structural Number for Future Traffic 3.38 in

| Design Method | Effective Existing Structural Number (in) | Overlay Structural Number (in) |
|---|---|---|
| Component Analysis | 2.88 | 0.50 |

## Structural Number for Future Traffic

| | |
|---|---|
| Future 18-kip ESALs Over Design Period | 6,500,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2.5 |
| Reliability Level | 90 % |
| Overall Standard Deviation | 0.44 |
| Subgrade Resilient Modulus | 16,548 psi |
| Calculated Structural Number for Future Traffic | 3.38 in |

## Effective Pavement Thickness - Component Analysis Method

| Layer | Material Description | Structural Coefficient | Drainage Coefficient | Thickness (in) |
|---|---|---|---|---|
| 1 | Rubblized PCC | 0.25 | 1 | 8 |
| 2 | HBP | 0.44 | 1 | 2 |

Milling Thickness - in

Calculated Results

| | |
|---|---|
| Calculated Pavement Structural Number Before Milling | 2.88 in |
| Calculated Effective Pavement Structural Number | 2.88 in |

## Backcalculation - WBRH1

| | |
|---|---|
| Total Pavement Thickness | 10 in |
| Resilient Modulus Correction Factor, C | 1 |
| Existing AC Thickness | - in |

| | |
|---|---|
| Base Type | Granular |
| Data Evaluation Basis | Mean |

Calculated Results

| | |
|---|---|
| Subgrade Resilient Modulus (MR) | 16,548 psi |
| Effective Pavement Modulus (Ep) | 68,643 psi |
| Dynamic k-value | - psi/in |

## Effective Roadbed Soil Resilient Modulus

| Period | Description | Roadbed Resilient Modulus (psi) |
|---|---|---|
| Calculated Effective Modulus | - psi* | |

*Note: This value is not represented by the inputs or an error occurred in calculation.

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## Overlay Design Module

Middle Lift of HBP (WB I-76 Resonant Hammer Section)

## AC Overlay of Fractured PCC Slab

Structural Number for Future Traffic 3.33 in

| Design Method | Effective Existing Structural Number (in) | Overlay Structural Number (in) |
|---|---|---|
| Component Analysis | 3.76 | 0.00 |

## Structural Number for Future Traffic

| | |
|---|---|
| Future 18-kip ESALs Over Design Period | 6,500,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2.5 |
| Reliability Level | 90 % |
| Overall Standard Deviation | 0.44 |
| Subgrade Resilient Modulus | 17,246 psi |
| Calculated Structural Number for Future Traffic | 3.33 in |

## Effective Pavement Thickness - Component Analysis Method

| Layer | Material Description | Structural Coefficient | Drainage Coefficient | Thickness (in) |
|---|---|---|---|---|
| 1 | Rubblized PCC | 0.25 | 1 | 8 |
| 2 | HBP Bottom & Middle Lifts | 0.44 | | 4 |

Milling Thickness - in

Calculated Results

| | |
|---|---|
| Calculated Pavement Structural Number Before Milling | 3.76 in |
| Calculated Effective Pavement Structural Number | 3.76 in |

## Backcalculation - WBRH2

| | |
|---|---|
| Total Pavement Thickness | 12 in |
| Resilient Modulus Correction Factor, C | 1 |
| Existing AC Thickness | - in |

| | |
|---|---|
| Base Type | Granular |
| Data Evaluation Basis | Mean |

Calculated Results

| | |
|---|---|
| Subgrade Resilient Modulus (MR) | 17,246 psi |
| Effective Pavement Modulus (Ep) | 63,221 psi |
| Dynamic k-value | - psi/in |

## Effective Roadbed Soil Resilient Modulus

| Period | Description | Roadbed Resilient Modulus (psi) |
|---|---|---|
| Calculated Effective Modulus | - psi* | |

*Note: This value is not represented by the inputs or an error occurred in calculation.

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## Overlay Design Module

Top Lift of HBP (WB I-76 Resonant Hammer Section)

## AC Overlay of Fractured PCC Slab

| | |
|---|---|
| Structural Number for Future Traffic | 3.16 in |

| Design Method | Effective Existing Structural Number (in) | Overlay Structural Number (in) |
|---|---|---|
| Component Analysis | 4.64 | 0.00 |

## Structural Number for Future Traffic

| | |
|---|---|
| Future 18-kip ESALs Over Design Period | 6,500,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2.5 |
| Reliability Level | 90 % |
| Overall Standard Deviation | 0.44 |
| Subgrade Resilient Modulus | 19,991 psi |
| Calculated Structural Number for Future Traffic | 3.16 in |

## Effective Pavement Thickness - Component Analysis Method

| Layer | Material Description | Structural Coefficient | Drainage Coefficient | Thickness (in) |
|---|---|---|---|---|
| 1 | Rubblized PCC | 0.25 | 1 | 8 |
| 2 | Bottom, Middle & Top Lift HBP | 0.44 | 1 | 6 |

Milling Thickness - in

Calculated Results

| | |
|---|---|
| Calculated Pavement Structural Number Before Milling | 4.64 in |
| Calculated Effective Pavement Structural Number | 4.64 in |

## Future Simple ESAL Calculation

| | |
|---|---|
| Performance Period (years) | - |
| Two-Way Traffic (ADT) | - |
| Number of Lanes in Design Direction | - |

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## Overlay Design Module

EB Resonant Hammer Rubblized Section

## AC Overlay of Fractured PCC Slab

Structural Number for Future Traffic 3.49 in

| Design Method | Effective Existing Structural Number (in) | Overlay Structural Number (in) |
|---|---|---|
| Component Analysis | 2 | 1.49 |

## Structural Number for Future Traffic

| | |
|---|---|
| Future 18-kip ESALs Over Design Period | 6,500,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2.5 |
| Reliability Level | 90 % |
| Overall Standard Deviation | 0.44 |
| Subgrade Resilient Modulus | 15,112 psi |
| Calculated Structural Number for Future Traffic | 3.49 in |

## Effective Pavement Thickness - Component Analysis Method

| Layer | Material Description | Structural Coefficient | Drainage Coefficient | Thickness (in) |
|---|---|---|---|---|
| 1 | Rubblized PCC | 0.25 | 1 | 8 |

Milling Thickness - in

Calculated Results

| | |
|---|---|
| Calculated Pavement Structural Number Before Milling | 2.00 in |
| Calculated Effective Pavement Structural Number | 2.00 in |

## Backcalculation - EBRH1

| | |
|---|---|
| Total Pavement Thickness | 8 in |
| Resilient Modulus Correction Factor, C | 1 |
| Existing AC Thickness | - in |
| Base Type | Granular |

| | |
|---|---|
| Data Evaluation Basis | Mean |

Calculated Results*

| | |
|---|---|
| Subgrade Resilient Modulus (MR) | 15,112 psi |
| Effective Pavement Modulus (Ep) | 51,477 psi |
| Dynamic k-value | - psi/in |

*Note: These values are not represented by the inputs or an error occurred in calculation.

## Backcalculation - EBRHRub

| | |
|---|---|
| Total Pavement Thickness | 8 in |
| Resilient Modulus Correction Factor, C | 1 |
| Existing AC Thickness | - in |
| Base Type | Granular |
| Data Evaluation Basis | Mean |

Calculated Results

| | |
|---|---|
| Subgrade Resilient Modulus (MR) | 15,112 psi |
| Effective Pavement Modulus (Ep) | 51,477 psi |
| Dynamic k-value | - psi/in |

## Backcalculation - EBRH2

| | |
|---|---|
| Total Pavement Thickness | - in |
| Resilient Modulus Correction Factor, C | - |
| Existing AC Thickness | - in |
| Base Type | Granular |
| Data Evaluation Basis | Mean |

Calculated Results*

| | |
|---|---|
| Subgrade Resilient Modulus (MR) | - psi |
| Effective Pavement Modulus (Ep) | - psi |
| Dynamic k-value | - psi/in |

*Note: These values are not represented by the inputs or an error occurred in calculation.

## Backcalculation - EBRH3

| | |
|---|---|
| Total Pavement Thickness | - in |
| Resilient Modulus Correction Factor, C | - |
| Existing AC Thickness | - in |
| Base Type | Granular |
| Data Evaluation Basis | Mean |

Calculated Results*

| | |
|---|---|
| Subgrade Resilient Modulus (MR) | - psi |
| Effective Pavement Modulus (Ep) | - psi |
| Dynamic k-value | - psi/in |

*Note: These values are not represented by the inputs or an error occurred in calculation.

## Effective Roadbed Soil Resilient Modulus

| Period | Description | Roadbed Resilient Modulus (psi) |
|---|---|---|
| Calculated Effective Modulus | - psi* | |

*Note: This value is not represented by the inputs or an error occurred in calculation.

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## Overlay Design Module

Bottom Lift of HBP (EB I-76 Resonant Hammer Section)

## AC Overlay of Fractured PCC Slab

Structural Number for Future Traffic 3.42 in

| Design Method | Effective Existing Structural Number (in) | Overlay Structural Number (in) |
|---|---|---|
| Component Analysis | 2.88 | 0.54 |

## Structural Number for Future Traffic

| | |
|---|---|
| Future 18-kip ESALs Over Design Period | 6,500,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2.5 |
| Reliability Level | 90 % |
| Overall Standard Deviation | 0.44 |
| Subgrade Resilient Modulus | 15,925 psi |
| Calculated Structural Number for Future Traffic | 3.42 in |

## Effective Pavement Thickness - Component Analysis Method

| Layer | Material Description | Structural Coefficient | Drainage Coefficient | Thickness (in) |
|---|---|---|---|---|
| 1 | Rubblized PCC | 0.25 | 1 | 8 |
| 2 | HBP | 0.44 | 1 | 2 |

Milling Thickness - in

Calculated Results

| | |
|---|---|
| Calculated Pavement Structural Number Before Milling | 2.88 in |
| Calculated Effective Pavement Structural Number | 2.88 in |

## Backcalculation - EBRH1

| | |
|---|---|
| Total Pavement Thickness | 10 in |
| Resilient Modulus Correction Factor, C | 1 |
| Existing AC Thickness | - in |

| | |
|---|---|
| Base Type | Granular |
| Data Evaluation Basis | Mean |

Calculated Results

| | |
|---|---|
| Subgrade Resilient Modulus (MR) | 15,925 psi |
| Effective Pavement Modulus (Ep) | 88,865 psi |
| Dynamic k-value | - psi/in |

## Effective Roadbed Soil Resilient Modulus

| Period | Description | Roadbed Resilient Modulus (psi) |
|---|---|---|
| Calculated Effective Modulus | - psi* | |

*Note: This value is not represented by the inputs or an error occurred in calculation.

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## Overlay Design Module

Middle Lift of HBP (EB I-76 Resonant Hammer Section)

## AC Overlay of Fractured PCC Slab

Structural Number for Future Traffic 3.46 in

| Design Method | Effective Existing Structural Number (in) | Overlay Structural Number (in) |
|---|---|---|
| Component Analysis | 3.76 | 0.00 |

## Structural Number for Future Traffic

| | |
|---|---|
| Future 18-kip ESALs Over Design Period | 6,500,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2.5 |
| Reliability Level | 90 % |
| Overall Standard Deviation | 0.44 |
| Subgrade Resilient Modulus | 15,456 psi |
| Calculated Structural Number for Future Traffic | 3.46 in |

## Effective Pavement Thickness - Component Analysis Method

| Layer | Material Description | Structural Coefficient | Drainage Coefficient | Thickness (in) |
|---|---|---|---|---|
| 1 | Rubblized PCC | 0.25 | 1 | 8 |
| 2 | HBP Bottom & Middle Lifts | 0.44 | 1 | 4 |

Milling Thickness - in

Calculated Results

| | |
|---|---|
| Calculated Pavement Structural Number Before Milling | 3.76 in |
| Calculated Effective Pavement Structural Number | 3.76 in |

## Backcalculation - EBRH2

| | |
|---|---|
| Total Pavement Thickness | 12 in |
| Resilient Modulus Correction Factor, C | 1 |
| Existing AC Thickness | - in |

| | |
|---|---|
| Base Type | Granular |
| Data Evaluation Basis | Mean |

Calculated Results

| | |
|---|---|
| Subgrade Resilient Modulus (MR) | 15,456 psi |
| Effective Pavement Modulus (Ep) | 110,789 psi |
| Dynamic k-value | - psi/in |

## Effective Roadbed Soil Resilient Modulus

| Period | Description | Roadbed Resilient Modulus (psi) |
|---|---|---|
| Calculated Effective Modulus | - psi* | |

*Note: This value is not represented by the inputs or an error occurred in calculation.

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## Overlay Design Module

Top Lift of HBP (EB I-76 Resonant Hammer Section)

## AC Overlay of Fractured PCC Slab

Structural Number for Future Traffic 3.39 in

| Design Method | Effective Existing Structural Number (in) | Overlay Structural Number (in) |
|---|---|---|
| Component Analysis | 4.64 | 0.00 |

## Structural Number for Future Traffic

| | |
|---|---|
| Future 18-kip ESALs Over Design Period | 6,500,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2.5 |
| Reliability Level | 90 % |
| Overall Standard Deviation | 0.44 |
| Subgrade Resilient Modulus | 16,374 psi |
| Calculated Structural Number for Future Traffic | 3.39 in |

## Effective Pavement Thickness - Component Analysis Method

| Layer | Material Description | Structural Coefficient | Drainage Coefficient | Thickness (in) |
|---|---|---|---|---|
| 1 | Rubblized PCC | 0.25 | 1 | 8 |
| 2 | Bottom, Middle & Top Lift HBP | 0.44 | 1 | 6 |

Milling Thickness - in

Calculated Results

| | |
|---|---|
| Calculated Pavement Structural Number Before Milling | 4.64 in |
| Calculated Effective Pavement Structural Number | 4.64 in |

## Future Simple ESAL Calculation

| | |
|---|---|
| Performance Period (years) | |
| Two-Way Traffic (ADT) | - |
| Number of Lanes in Design Direction | - |

| | |
|---|---|
| Percent of All Trucks in Design Lane | - % |
| Percent Trucks in Design Direction | - % |
| Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater | - % |
| Average Initial Truck Factor (ESALs/truck) | - |
| Annual Truck Factor Growth Rate | - % |
| Annual Truck Volume Growth Rate | - % |
| Growth | Simple |
| Total Calculated Cumulative ESALs | - * |

*Note: This value is not represented by the inputs or an error occurred in calculation.

## Future Rigorous ESAL Calculation

| | |
|---|---|
| Performance Period (years) | |
| Two-Way Traffic (ADT) | - |
| Number of Lanes in Design Direction | - |
| Percent of All Trucks in Design Lane | - % |
| Percent Trucks in Design Direction | - % |

| Vehicle Class | Percent of ADT | Annual % Growth | Average Initial Truck Factor (ESALs/ Truck) | Annual % Growth in Truck Factor | Accumulated 18-kip ESALs over Performance Period |
|---|---|---|---|---|---|
| Total | - | | | | - |

| | |
|---|---|
| Growth | Simple |
| Total Calculated Cumulative ESALs | - * |

*Note: This value is not represented by the inputs or an error occurred in calculation.

## Backcalculation - EBRH3

| | |
|---|---|
| Total Pavement Thickness | 14 in |
| Resilient Modulus Correction Factor, C | 1 |
| Existing AC Thickness | - in |
| Base Type | Granular |
| Data Evaluation Basis | Mean |

Calculated Results

| | |
|---|---|
| Subgrade Resilient Modulus (MR) | 16,374 psi |
| Effective Pavement Modulus (Ep) | 86,926 psi |
| Dynamic k-value | - psi/in |

## Effective Roadbed Soil Resilient Modulus

| Period | Description | Roadbed Resilient Modulus (psi) |
|---|---|---|
| Calculated Effective Modulus | - psi* | |

*Note: This value is not represented by the inputs or an error occurred in calculation.

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## Overlay Design Module

EB I-76 Multihead Rubblized Section

## AC Overlay of Fractured PCC Slab

| | |
|---|---|
| Structural Number for Future Traffic | 3.01 in |

| Design Method | Effective Existing Structural Number (in) | Overlay Structural Number (in) |
|---|---|---|
| Component Analysis | 2 | 1.01 |

## Structural Number for Future Traffic

| | |
|---|---|
| Future 18-kip ESALs Over Design Period | 6,500,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2.5 |
| Reliability Level | 90 % |
| Overall Standard Deviation | 0.44 |
| Subgrade Resilient Modulus | 22,827 psi |
| Calculated Structural Number for Future Traffic | 3.01 in |

## Effective Pavement Thickness - Component Analysis Method

| Layer | Material Description | Structural Coefficient | Drainage Coefficient | Thickness (in) |
|---|---|---|---|---|
| 1 | Rubblized PCC | 0.25 | | 8 |

Milling Thickness - in

Calculated Results

| | |
|---|---|
| Calculated Pavement Structural Number Before Milling | 2.00 in |
| Calculated Effective Pavement Structural Number | 2.00 in |

## Backcalculation - EBMHRub

| | |
|---|---|
| Total Pavement Thickness | 8 in |
| Resilient Modulus Correction Factor, C | 1 |
| Existing AC Thickness | - in |
| Base Type | Granular |

| | |
|---|---|
| Data Evaluation Basis | Mean |

Calculated Results

| | |
|---|---|
| Subgrade Resilient Modulus (MR) | 22,827 psi |
| Effective Pavement Modulus (Ep) | 43,457 psi |
| Dynamic k-value | - psi/in |

## Effective Roadbed Soil Resilient Modulus

| Period | Description | Roadbed Resilient Modulus (psi) |
|---|---|---|
| Calculated Effective Modulus | - psi* | |

*Note: This value is not represented by the inputs or an error occurred in calculation.

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## Overlay Design Module

Bottom Lift of HBP (EB I-76 Multihead Hammer Section)

## AC Overlay of Fractured PCC Slab

Structural Number for Future Traffic 3.31 in

| Design Method | Effective Existing Structural Number (in) | Overlay Structural Number (in) |
|---|---|---|
| Component Analysis | 2.88 | 0.43 |

## Structural Number for Future Traffic

| | |
|---|---|
| Future 18-kip ESALs Over Design Period | 6,500,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2.5 |
| Reliability Level | 90 % |
| Overall Standard Deviation | 0.44 |
| Subgrade Resilient Modulus | 17,460 psi |
| Calculated Structural Number for Future Traffic | 3.31 in |

## Effective Pavement Thickness - Component Analysis Method

| Layer | Material Description | Structural Coefficient | Drainage Coefficient | Thickness (in) |
|---|---|---|---|---|
| 1 | Rubblized PCC | 0.25 | | 8 |
| 2 | HBP | 0.44 | 1 | 2 |

Milling Thickness - in

Calculated Results

| | |
|---|---|
| Calculated Pavement Structural Number Before Milling | 2.88 in |
| Calculated Effective Pavement Structural Number | 2.88 in |

## Backcalculation - EBMH1

| | |
|---|---|
| Total Pavement Thickness | 10 in |
| Resilient Modulus Correction Factor, C | 1 |
| Existing AC Thickness | - in |

| | |
|---|---|
| Base Type | Granular |
| Data Evaluation Basis | Mean |

Calculated Results

| | |
|---|---|
| Subgrade Resilient Modulus (MR) | 17,460 psi |
| Effective Pavement Modulus (Ep) | 83,278 psi |
| Dynamic k-value | - psi/in |

## Effective Roadbed Soil Resilient Modulus

| Period | Description | Roadbed Resilient Modulus (psi) |
|---|---|---|
| Calculated Effective Modulus | - psi* | |

*Note: This value is not represented by the inputs or an error occurred in calculation.

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## Overlay Design Module

Middle Lift of HBP (EB I-76 Multihead Hammer Section)

## AC Overlay of Fractured PCC Slab

Structural Number for Future Traffic 3.36 in

| Design Method | Effective Existing Structural Number (in) | Overlay Structural Number (in) |
|---|---|---|
| Component Analysis | 3.76 | 0.00 |

## Structural Number for Future Traffic

| | |
|---|---|
| Future 18-kip ESALs Over Design Period | 6,500,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2.5 |
| Reliability Level | 90 % |
| Overall Standard Deviation | 0.44 |
| Subgrade Resilient Modulus | 16,773 psi |
| Calculated Structural Number for Future Traffic | 3.36 in |

## Effective Pavement Thickness - Component Analysis Method

| Layer | Material Description | Structural Coefficient | Drainage Coefficient | Thickness (in) |
|---|---|---|---|---|
| 1 | Rubblized PCC | 0.25 | 1 | 8 |
| 2 | HBP Bottom & Middle Lifts | 0.44 | . | 4 |

Milling Thickness - in

Calculated Results

| | |
|---|---|
| Calculated Pavement Structural Number Before Milling | 3.76 in |
| Calculated Effective Pavement Structural Number | 3.76 in |

## Backcalculation - EBMH2

| | |
|---|---|
| Total Pavement Thickness | 12 in |
| Resilient Modulus Correction Factor, C | 1 |
| Existing AC Thickness | - in |

| | |
|---|---|
| Base Type | Granular |
| Data Evaluation Basis | Mean |

Calculated Results

| | |
|---|---|
| Subgrade Resilient Modulus (MR) | 16,773 psi |
| Effective Pavement Modulus (Ep) | 115,641 psi |
| Dynamic k-value | - psi/in |

## Effective Roadbed Soil Resilient Modulus

| Period | Description | Roadbed Resilient Modulus (psi) |
|---|---|---|
| Calculated Effective Modulus | - psi* | |

*Note: This value is not represented by the inputs or an error occurred in calculation.

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## Overlay Design Module

Top Lift of HBP (EB I-76 Multiheadr Section)

## AC Overlay of Fractured PCC Slab

| | |
|---|---|
| Structural Number for Future Traffic | 3.26 in |

| Design Method | Effective Existing Structural Number (in) | Overlay Structural Number (in) |
|---|---|---|
| Component Analysis | 4.64 | 0.00 |

## Structural Number for Future Traffic

| | |
|---|---|
| Future 18-kip ESALs Over Design Period | 6,500,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2.5 |
| Reliability Level | 90 % |
| Overall Standard Deviation | 0.44 |
| Subgrade Resilient Modulus | 18,224 psi |
| Calculated Structural Number for Future Traffic | 3.26 in |

## Effective Pavement Thickness - Component Analysis Method

| Layer | Material Description | Structural Coefficient | Drainage Coefficient | Thickness (in) |
|---|---|---|---|---|
| 1 | Rubblized PCC | 0.25 | 1 | 8 |
| 2 | Bottom, Middle & Top Lift HBP | 0.44 | 1 | 6 |

Milling Thickness - in

Calculated Results

| | |
|---|---|
| Calculated Pavement Structural Number Before Milling | 4.64 in |
| Calculated Effective Pavement Structural Number | 4.64 in |

## Future Simple ESAL Calculation

| | |
|---|---|
| Performance Period (years) | - |
| Two-Way Traffic (ADT) | - |
| Number of Lanes in Design Direction | |

| | |
|---|---|
| Percent of All Trucks in Design Lane | - % |
| Percent Trucks in Design Direction | - % |
| Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater | % |
| Average Initial Truck Factor (ESALs/truck) | - |
| Annual Truck Factor Growth Rate | - % |
| Annual Truck Volume Growth Rate | - % |
| Growth | Simple |
| Total Calculated Cumulative ESALs | - * |

*Note: This value is not represented by the inputs or an error occurred in calculation.

## Future Rigorous ESAL Calculation

| | |
|---|---|
| Performance Period (years) | - |
| Two-Way Traffic (ADT) | |
| Number of Lanes in Design Direction | - |
| Percent of All Trucks in Design Lane | - % |
| Percent Trucks in Design Direction | - % |

| Vehicle Class | Percent of ADT | Annual % Growth | Average Initial Truck Factor (ESALs/ Truck) | Annual % Growth in Truck Factor | Accumulated 18-kip ESALs over Performance Period |
|---|---|---|---|---|---|
| Total | - | - | - | - | - |

| | |
|---|---|
| Growth | Simple |
| Total Calculated Cumulative ESALs | - * |

*Note: This value is not represented by the inputs or an error occurred in calculation.

## Backcalculation - EBMH3

| | |
|---|---|
| Total Pavement Thickness | 14 in |
| Resilient Modulus Correction Factor, C | 1 |
| Existing AC Thickness | - in |
| Base Type | Granular |
| Data Evaluation Basis | Mean |

Calculated Results

| | |
|---|---|
| Subgrade Resilient Modulus (MR) | 18,224 psi |
| Effective Pavement Modulus (Ep) | 61,481 psi |
| Dynamic k-value | - psi/in |

## Effective Roadbed Soil Resilient Modulus

| Period | Description | Roadbed Resilient Modulus (psi) |
|---|---|---|
| Calculated Effective Modulus | - psi* | |

*Note: This value is not represented by the inputs or an error occurred in calculation.