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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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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.

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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.

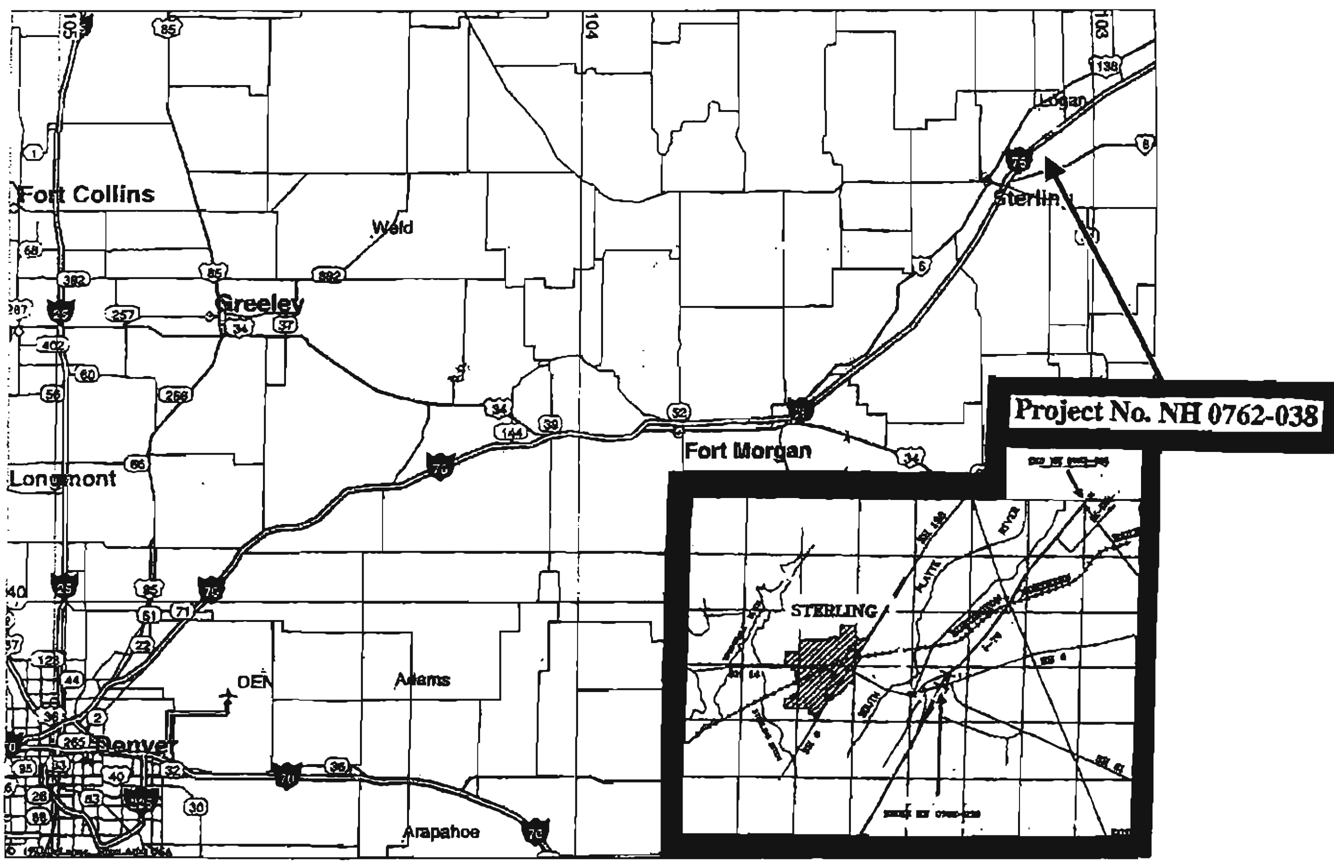


Figure 1. Location Map of Project No. NH 0762-038

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.

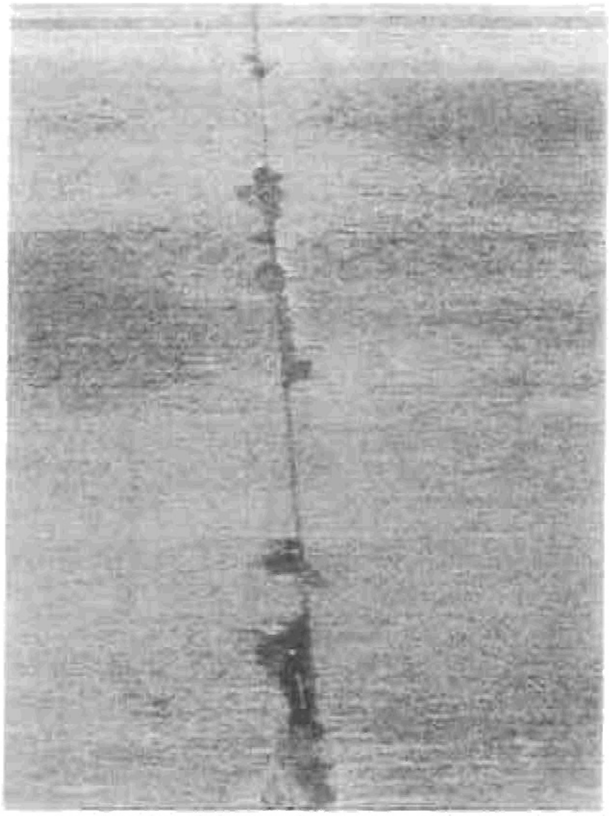


Figure 5. Condition of joint in concrete.

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

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

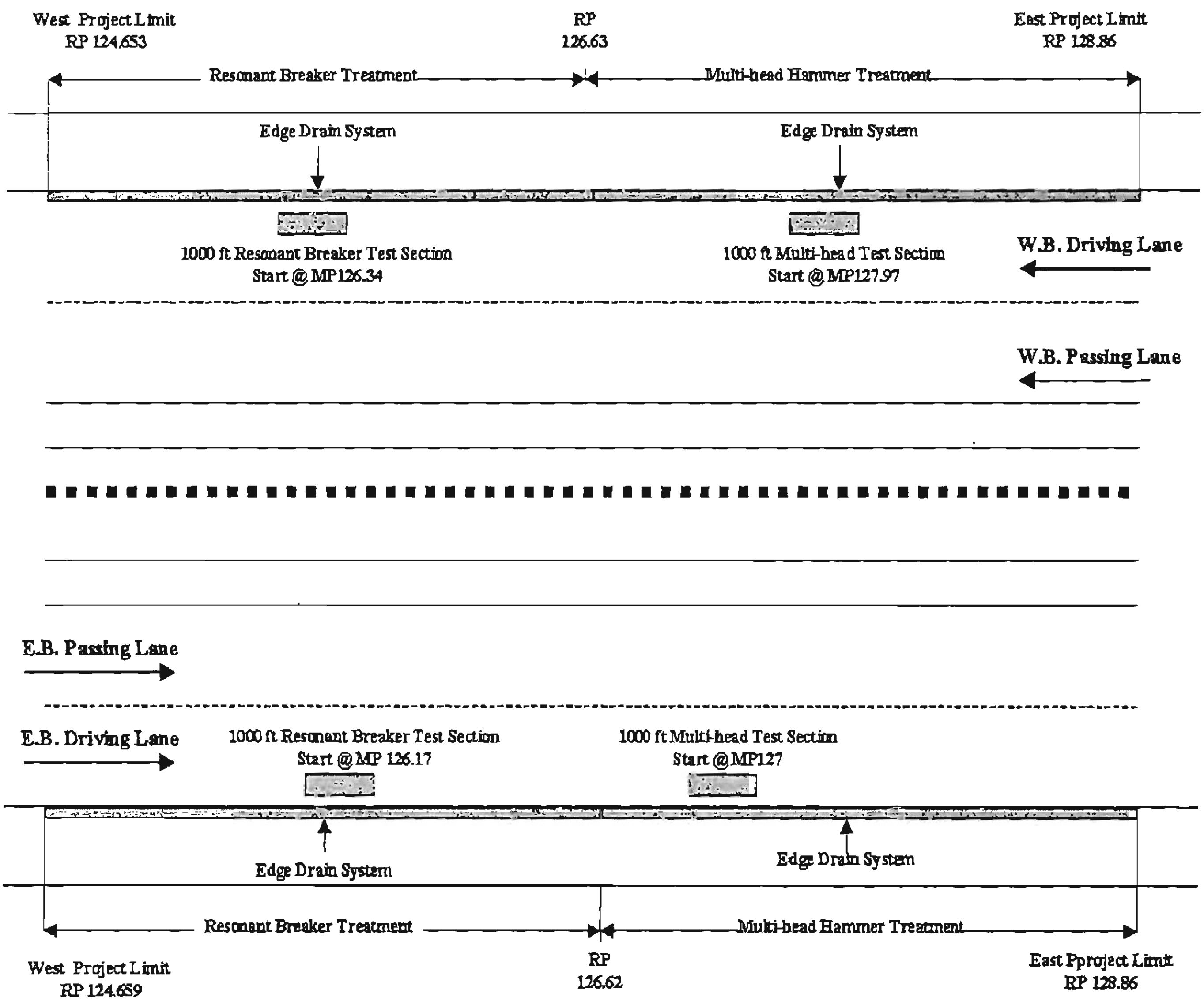


Figure 8. Location on project where resonant breaker and multi-head hammer processes were used.

Figure 9. Resonant treatment process.

Figure 10. Resonant breaker in action.

Figure 11. Multi-head hammer in action.

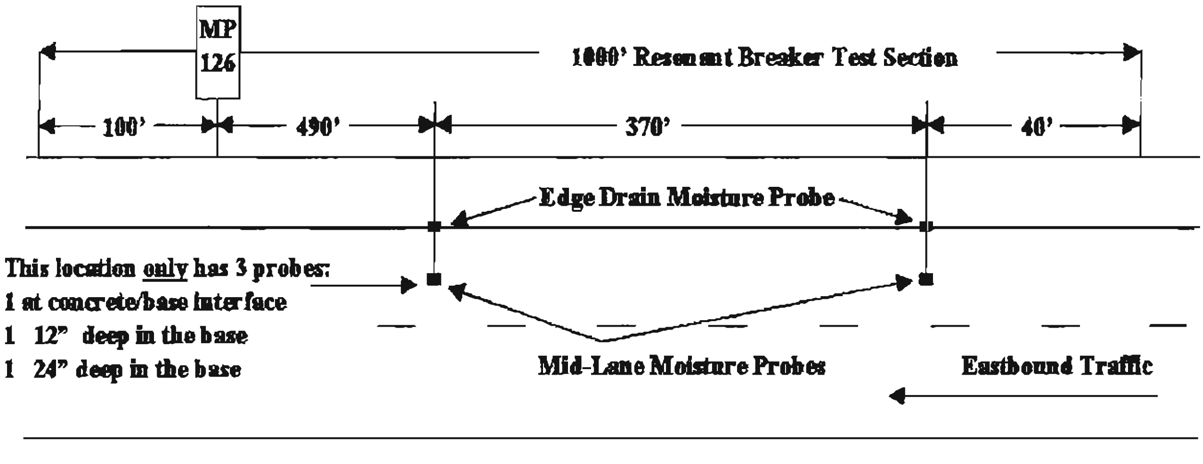
Figure 12. Steel vibratory roller with "Z" pattern grid on drum face was used to seat pavement.

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.



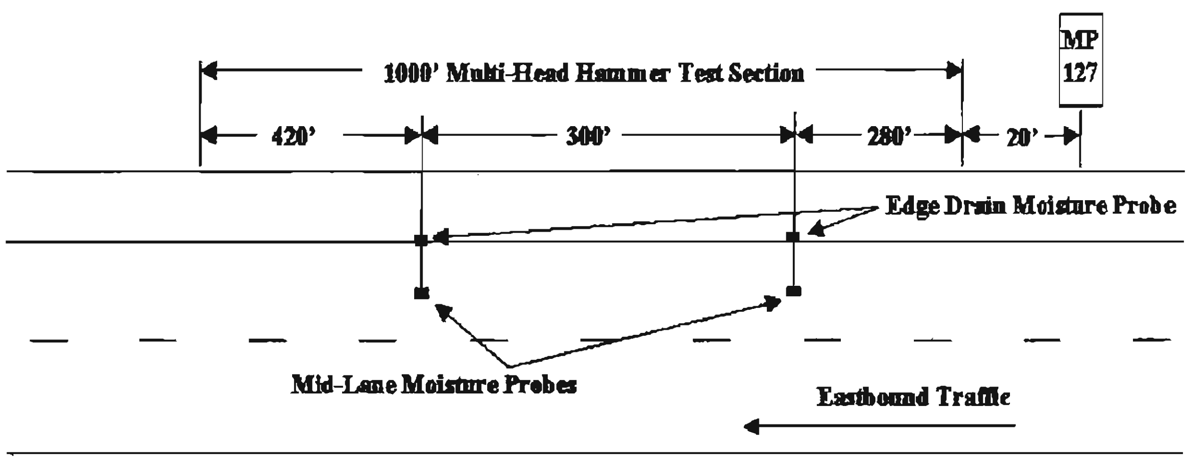


Figure 17. Locations of TDR soil moisture sensors.

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.

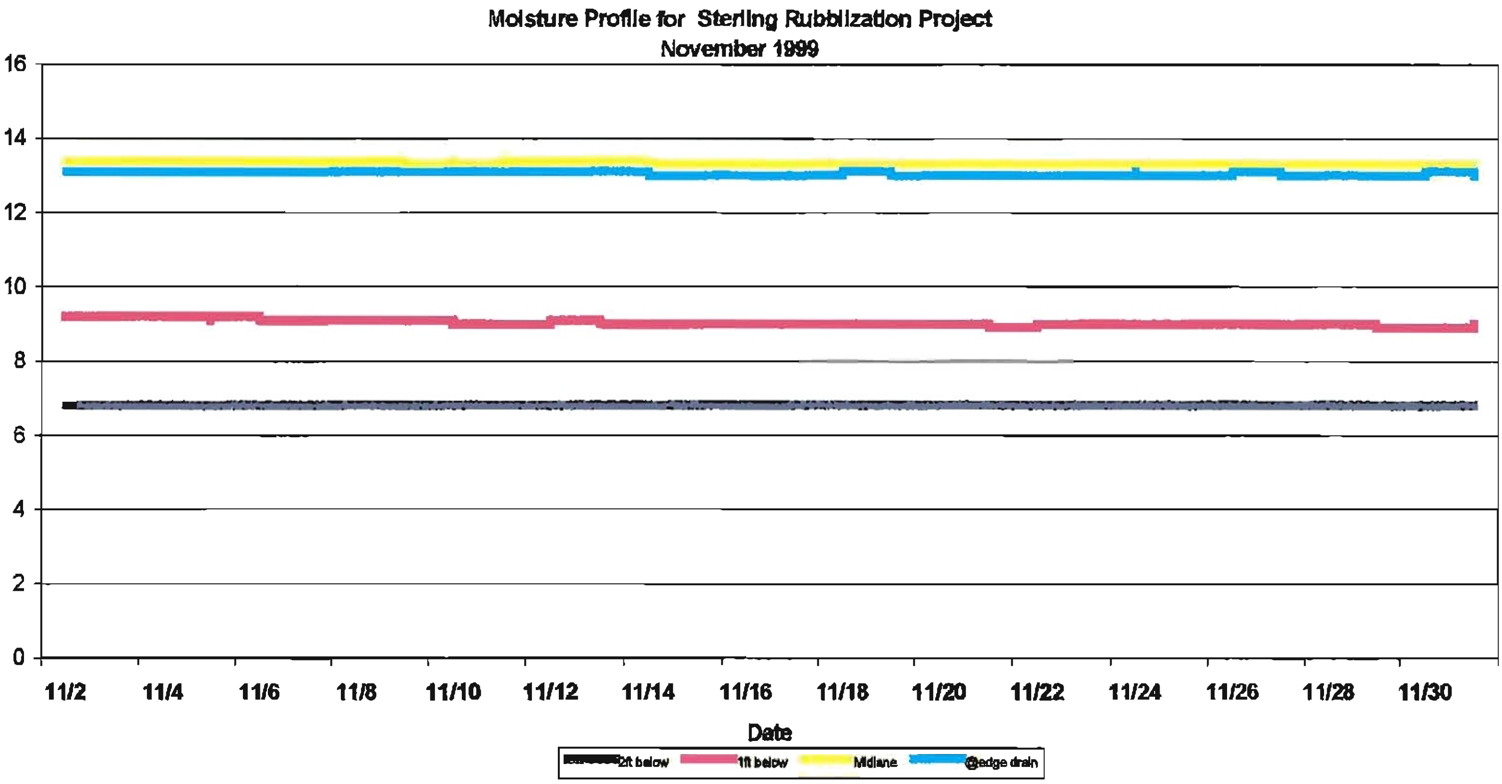


Figure 22. Moisture data recorded during November 1999.

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	0.8	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	1.9	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	0.3
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	0.6	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	1.0	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	0.9	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)

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

☑ New mix design with no change

☐ Staff Materials called and concurs with change or reapproval

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

Date:

Staff Materials Representative

Signed: [signature] 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

Form 43 Serial #: 17

Mix Design: Westest 15399 A
Date: 10/05/1999

From Project:
From Project S. A.:

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

☐ Mix Design Based On Ndes

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

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 Data at N (Design)

Property	Target Value	Tolerance
Stability:	42	Minimum
% Voids:	4.0	+/- 1.2
% VMA:	14.0	+/- 1.2

Date:

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

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

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) AMOUNT	(1) 017A ASPHALT PAVING CO. UNIT PRICE	(1) AMOUNT	(2) 159C KIEWIT WESTERN CO UNIT PRICE	(2) 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

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	AMOUNT	(1) 017A ASPHALT PAVING CO. UNIT PRICE	AMOUNT	(2) 159C KIEWIT WESTERN CO UNIT PRICE	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

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LETTING NO. . 98111901
LETTING DATE 11/19/98

CONTRACT ID : C11204
REGION : 4

COUNTIES : LOGAN

LETTING TIME : 10:00 AM

ITEM CODE	ITEM DESCRIPTION	QUANTITY	(0) -EST- ENGINEER'S ESTIMATE UNIT PRICE	AMOUNT	(1) 017A ASPHALT PAVING CO. UNIT PRICE	AMOUNT	(2) 159C KIEWIT WESTERN CO UNIT PRICE	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

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

CONTRACT ID : C11204
REGION : 4

COUNTIES : LOGAN

(3) 417A	(4) 163D	(5) 071A
PCL CIVIL CONSTRUCTORS, I	WESTERN-MOBILE NORTHERN,	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

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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	AMOUNT	(4) 163D WESTERN-MOBILE NORTHERN, UNIT PRICE	AMOUNT	(5) 071A COULSON EXCAVATING CO. IN UNIT PRICE	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

DATE : 11/19/98
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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	AMOUNT	(4) 163D WESTERN-MOBILE NORTHERN, UNIT PRICE	AMOUNT	(5) 071A COULSON EXCAVATING CO. IN UNIT PRICE	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
Computer Software Product
CDOT
Research
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.

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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.

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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.

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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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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.