Report No. CDOH-DTP-R-84-5

# EVALUATION OF CONCRETE PAVEMENT RESTORATION PROCEDURES AND TECHNIQUES

K.L.WOOD
Colorado Department of Highways
4201 East Arkansas Avenue
Denver, Colorado 80222

INITIAL REPORT
MARCH 1984

Prepared in cooperation with the
U.S. Department of Transportation
Federal Highway Administration

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views of the Colorado Department of Highways or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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16. Abstract

Restoration procedures and techniques have been designed to prolong the life of concrete pavements which have small areas of deterioration, good ride quality, and very limited problems at joints and cracks. These procedures include (1) Full and partial depth patching, (2) Understanding, (3) Diamond Grinding, (4) Restoration of load transfer at the joints, and (5) Resealing joints and cracks.

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## INTRODUCTION

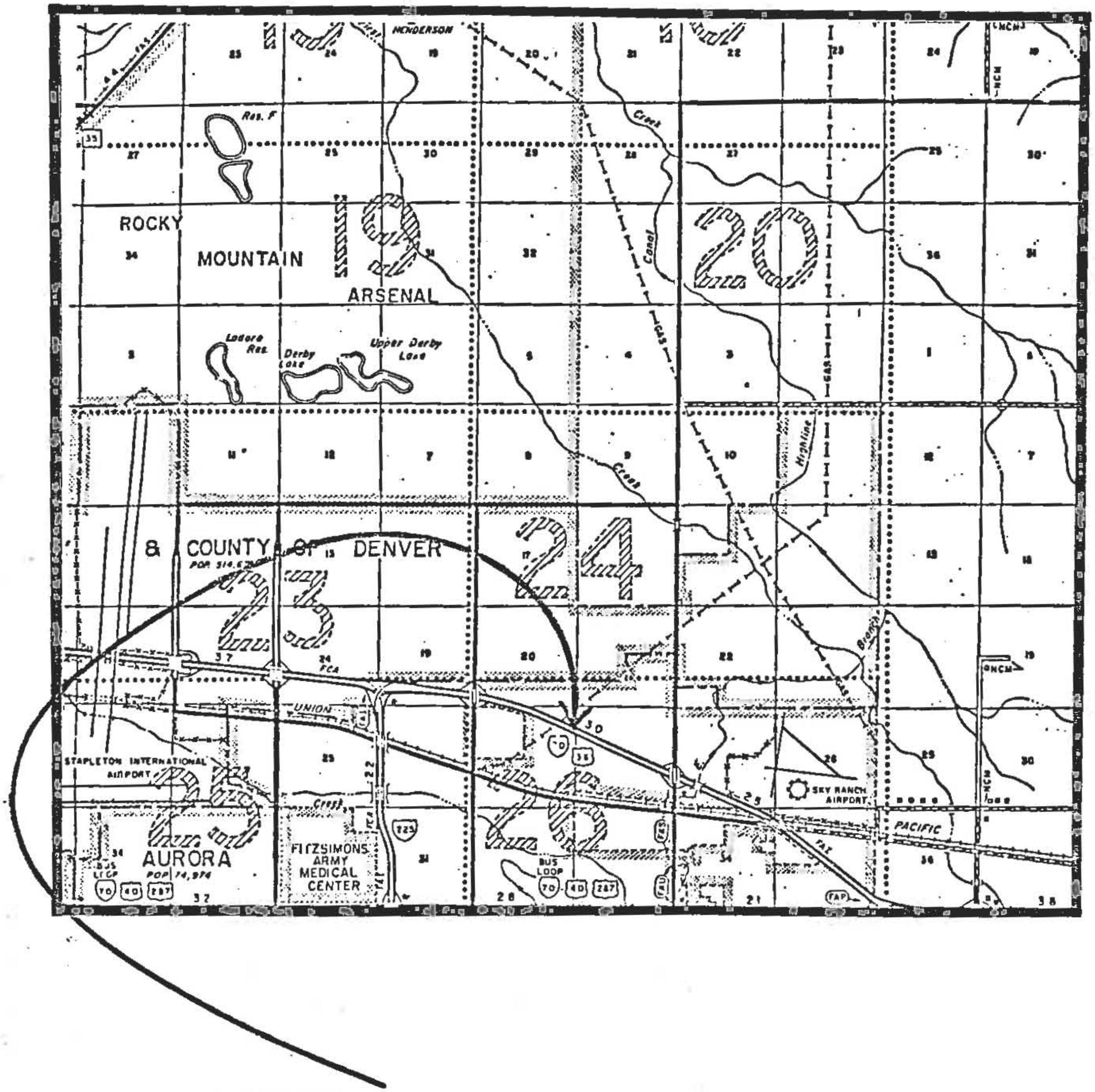
Long-term rehabilitation of Colorado Interstate concrete pavements was recently investigated by a six member panel. They reported their work in January, 1983, in a report entitled, "Rehabilitation of Concrete Pavement." Three significant statements were made at the beginning of their report: (1) Thirty-nine percent of Colorado's Interstate concrete pavements were considered to be in good condition and should perform satisfactorily for five or more years. (2) Another 39 percent were in fair condition and will need some attention within the next one to five years. (3) The remaining 22 percent were in poor condition and will need immediate attention. It is this high combined percentage of fair and poor condition pavements that Concrete Pavement Restoration (CPR) applies.

With the need to showcase the latest state-of-the art CPR a seminar and demonstration project was organized. The project was funded by the Federal Highway Administration (FHWA). It was a cooperative effort between the Colordo Department of Highways (CDOH), the American Concrete Paving Association (ACPA) and FHWA that resulted in the seminar and demonstration. Planned for the day after the AASHTO meeting (October 5, 1983), the project was designed to provide valuable information for approximately 200 state and federal highway officials and engineers along with industry representatives from throughout the country that were in attendance.

The demonstration began with a series of formal presentations at the Holiday Inn at I-70 and Chamber Road. The attendees were then bused to an active field construction project where they observed the state-of-the art CPR methods and procedures. This included full and partial concrete patching, undersealing, routing and crack sealing, joint restoration, installation of load transfer devices and diamond grinding. The demonstration site was located on the 19 year old eastbound lane on I-70 between Chambers Road and Tower Road in northeast Denver (see Figure I). Approximately 3,000 linear feet of concrete pavement was selected for demonstrating restoration with specific sites selected for each repair method.

# FIGURE #1

## PROJECT LOCATION
## CPR DEMO SITE




## CONCRETE PAVEMENT RESTORATION
## DEMONSTRATION PROJECT SITE
## I–70 E.B. LANE

## SEMINAR

Prior to and after the 2 hour tour of the active CPR project, a seminar was given for the attendees. Starting at 8:30 a.m. in the Holiday Inn (1/2 mile from project), presentations were given by representatives from Georgia, Colorado, and the FHWA.

The morning sessions was presided over by Harold J. Halm, Executive Director of the ACPA. The discussions centered around benefits of CPR. It was generally agreed on that by performing these repair and preventive maintenance techniques, the life of a concrete pavement can be prolonged for many years, which is the CPR objective. At 10:00 a.m. buses were made available to transport the attendees to the near by project for a "walk through." The tours lasted 2 hours.

The afternoon session began at 1:00 p.m. Douglas Bernard, Chief, Demonstration Projects, FHWA, Washington, D.C., presided over the afternoon seminar. The afternoon session was devoted to discussing the activities observed at the project demonstration site. Following a question and answer session the seminar was adjourned at 4:30 p.m. The agenda for the seminar is in Appendix A.

## <u>NON-DESTRUCTIVE TESTING</u> (N.D.T.)

Prior to the construction of the Demonstration Project, a condition survey was made on the concrete pavement. Using an 18,000 pound rear axle load on a maintenance truck and a Benkleman Beam deflections were measured on the concrete slabs. Deflections were taken during the first week of August (1983) when temperatures were in the 80's and 90's during the day. To avoid these high temperatures, and the resulting locking at the joints, measurements were made during the early morning hours between 4:00 a.m. and 7:30 a.m. Air temperatures were in the low 80's and 70's.

Using the Department's Rainhart Profilograph, roughness measurements were made in the wheel paths of the heavily traveled truck lanes. Also, the Department's AASHTO skid trailer was used to measure skid numbers on this section of concrete pavement. Rut depths were measured in the heaviest traffic lane in both wheel paths. Measurements were made on every other slab throughout the project.

The last part of the Pavement Condition survey consisted of mapping the existing cracks and measuring the faulting. The results of the condition survey are shown in Appendix B.

The Condition Survey is <u>the</u> guide for determining the rehabilitation alternatives. For example, a review of the crack maps indicate very few of the PCCP slabs are broken and that there is no joint spalling. This plus the roughness measurements made by the prolifograph indicate the slabs are stable and the ride quality is good. Also, the deflections measured indicate the PCCP slabs are relatively stable. Using only the above information, alternatives such as reconstruction and thick overlays of asphalt or PCCP would not be recommended at this point in time. What is needed are restoration procedures and techniques to prolong the life of a PCCP that is in relatively good condition as shown by the very important Condition Survey.

Based on the Condition Survey, the Department decided to remove the few cracked and broken slabs full depth and replace them with new PCCP. (The few joints that were spalled would be repaired by partial depth removal and replacement.) The loss of load transfer and the small voids would be repaired by installation of load transfer devices and undersealing the slabs. The rutting and faulting would be eliminated by diamond grinding and at the same time provide a smoother skid resistant surface. Finally, the poor condition of the joints would be changed by removing the old material, reshaping joints, and placing new sealants (cracks would be treated to keep severity low by routing and sealing).

## PROJECT CONSTRUCTION AND 30 DAY EVALUATION

The portion of I-70 chosen for the C.P.R. Demonstration is a 19 year old concrete pavement. It is in good condition with only small areas of deterioration and loss of ride quality due to cracking and poor joints. Faulting and rutting average about 1/4". Only 2% of the area could be considered for full depth replacement at the Demonstration. Five slabs had to be selected to Demonstrate partial depth repair because spalling did not exist.

The ADT and ADTT in 1964 was 2,350 and 990, respectively. Presently it is 5,640 (ADT) and 2,375 (ADTT). The year 2,000 estimate is 16,000 and 3,627 (8127 ADTT if the older method of including pick-up trucks were to be used). Therefore, this portion of I-70 was an ideal candidate for the complete CPR treatment of: 1) Full and partial depth concrete slab repair, 2) Undersealing, 3) Grinding, 4) Restoration of Load Transfer, and 5) Joint and crack sealing.

### 1. Full and Partial Depth Repair

#### Full Depth Repair

Approximately 185 sq. yd. of full depth concrete pavement was removed and replaced. The method of removal was first to outline the removal area with a full depth sawcut. One of the transverse sawcuts would be on a slight angle so that the side at the center line was shorter than the longitudinal side at the asphalt shoulder forming a wedge. (All removals were 12 ft. wide, 9 full lane width, and in the driving lane). Next, the contractor drilled holes into the slab and inserted pins. With a cable attached to the pin and a rubber tire front end loader he slid and lifted the slabs out. The wedge shape of the slab allowed it to slide back before lifting without causing any damage to the adjacent concrete pavement. It is very easy to spall and damage the adjacent concrete. Caution must be exercised. Enough slabs were removed so that the concrete replacement pours would be completed by noon. This allowed traffic, which was detoured to the passing lane, to be back on the driving lane by 5:00 p.m., assuming the concrete would have enough strength. To assure this strength, the following design mix was used.

| | |
|---|---|
| Cement | 800 lbs. |
| Sand | 1040 lbs. |
| Size 67 Rock | 1740 lbs. |
| AIR Entraining Agent | 8.5 oz. |
| Plastocrete 161N | 32.0 oz. |
| Water | 275 lbs. |
| Calcium Chloride | 2% |
| Wt./cu. ft. | 140.7 lbs. |
| Slump | 2-3 in. |
| Total Air Content | 5-7 % |
| Water Cement Ratio | 0.344 |

The results of the test on field cyclinders made are as follows.

Strengths

| Specimen No. | Age | Compressive Strengths (PSI) |
|---|---|---|
| *1A | 6 Hrs | 400 |
| *1B | 24 Hrs | 2600 |
| 2A | 6 Hrs | 1200 |
| 2B | 7 Days | 4830 |
| 2C | 28 Days | 5750 |

*Delivered W/O Calcium Chloride

The first trucks of Ready Mixed Concrete delivered to the project were without the 2% Calcium Chloride. As a result the compressive strength breaks were quite low. However, traffic was allowed over the patched slabs with no adverse effects. All of the new concrete placed was inspected again 30 days after construction, and they are in very good condition. It appears that the 1,000 PSI compressive strengths, which was desired at the time traffic was allowed on the new slabs, is more than sufficient as a specification. Future deflections to be taken over the dowels placed in the joints will be checked to see if possibly some damage may have been caused at these load transfer dowels due to the low early strengths. So far deflections measured do not support the possibility of damage.

Partial Depth Repair

The joints on the project were not spalled. As a result, 5 slabs had to be selected to demonstrate 6 partial depth patches, one of which is shown in Photographs 5 and 6 in Appendix D. The spall repairs were performed with three basic systems.

1) Modified Portland Cement Concrete-Modified with:
   (a) High range water reducer
   (b) Styrene Butadiene Latex
   (c) Emulsified Epoxy
2) Magnesium Phosphate Cement-prepackaged
3) Methyl Methacrylate-a polymer prepackaged.
   The 30 day post inspection showed the partial depth patches performing as expected with one exception. The aggregate used with the prepackaged Polymer Concrete system (Methyl Methacrylate) resulted in a harsh surface. To correct this a skim coat of polymer concrete was placed over the surface. This has resulted in some spalling over the patch.

2. Undersealing

Approximately 2,660 sq. yds. of concrete pavement was undersealed on the Demonstration Project. The condition survey indicated the slabs were not entirely stable.

Using a Benkleman Beam and a truck with an 18,000 lb. rear axle weight, the deflections measured on the approach to the transverse joints averaged .040 inches. They averaged .050 inches on the leave side. The average differential deflection (approach vs. leave) was .016 inches (see Appendix B). As an experimental feature, two seperate hole patterns were used on the project for grout injection. Both gave the same results. These are shown in Appendix C.

The materials used to underseal were a mixture of class C fly ash, type I cement, and water. Ratios were 3 parts fly ash, 1 part cement, and 2 1/4 parts water. The mixture was pumped at about 50-75 PSI. The contractor who did the undersealing felt this pressure was ideal. High pressures can lead to broken slabs. And sometimes the breaks occur 6 months or more after the undersealing has been completed.

Another item monitored is the uplift of the slab. Since the objective of the undersealing is to fill voids under the concrete slabs and not displace the concrete slabs, a modified Benkleman Beam is used to signal cut-off of the pump. The allowable up lift of the slabs was established at .125 inches (1/8").

The undersealing significantly reduced slab deflections. Measurements recorded during this 30 day evaluation in the same locations averaged .016 inches, on the approach side and .009 inches on the leave side. The average difference was .008 inches.

3. Grinding

The condition survey indicated the concrete surface had both faulting (1/4") and rutting (1/4"). The Rainhart Profilograph measured 6.7 inches in the test section and the skid trailer resulted in an average number of 40.

After the slab replacement, spall repair, and undersealing were completed, the contractor removed 1/4" to 3/8" of the surface in the driving lane (a full lane width), by diamond grinding, thereby eliminating the faulting and rutting. The grinding machine (shown in photographs 9 and 10 in Appendix D), was an old Concut G-38, that had been rebuilt (using only the original frame and transmission). The contractor had removed the original 200 H.P. gasoline engine, among other things, and replaced it with a 375 H.P. diesel. This resulted in more than 250 H.P. at the cutting head.

The diamond grinding was a clean operation. A 5,000 gallon water tanker provided water to the grinder at the rate of 40 gal. per minute. The water and grindings were then vacuumed up and returned to the tanker where the water could be recycled every 100 minutes. This small demonstration project did not require the water to be recycled, but the capability was there, and it would allow them to operate on an eight hour shift with no water problems.

The 38" wide cutter made four passes in the driving lane with 2" of overlap per pass (after the first). The grinding was performed against the traffic. The contractor sited two reasons for this. First is safety. The operator can keep his eyes on the on coming traffic. Also, the large water tanker is placed between the grinder and traffic which serves as protection. Second, this allows the grinder to go up against the faulted joints as opposed to dropping off the joint. The result is a smoother surface after grinding. The first field evaluation 30 days after construction showed an increase in the skid number from 40 to 53. The roughness measured by the Rainhart Profilograph went from 6.7 inches to 3.1 inches in the test section.

4. Load Transfer Devices

The device selected for use on the Demonstration Project was the diamond device (as shown in photograph 11 in Appendix D). Thirty devices were installed in ten consecutive joints in the heavily traveled truck lane. Two were placed in the right wheel path and one in the left wheel path. The first one in the right wheel path is spaced 18 inches from the edge of pavement. The second is 18 inches inside the first. In the left wheel path the device is 18 inches from the longitudinal centerline joint.

Six inch core holes were drilled and centered over the transverse joints for the load transfer devices to be placed. The diamond shaped devices were fabricated from stainless steel, which protects them from corrosion. Inside the diamond or bellows is a factory installed flexible polyurethane foam for compression caused by normal horizontal slab movement. Also, foam rubber applied in the field is wrapped around the outside of the diamond to create a void for the necessary contraction. This is the same as the Double V or Barenburg device.

The core holes were groved with an air powered tool (photograph 12 in Appendix D) that put three groves in the holes. This provides more area to bond to and additional shear interlock (grout to slab). The grout used to secure the load transfer devices was a two component polymer concrete (Methyl Methacrylate System). A Methyl Methacrylate based primer was brushed on ahead of the placement of the load transfer device. This is a low viscosity primer designed to redissolve with the application of the Polymer Concrete and at the same time seal the core hole. The Deflections at the 10 joints prior to installation of the load transfer devices averaged .040 inches. The 30 day evaluation after installation resulted in average deflections of .009 inches, which is a significant improvement.

5. Joint and Crack Sealing

Joint Sealing

Four types of sealants were installed on the Demonstration Project. They were cold pour, hot pour, low modulus silicone, and preformed compression seals. To demonstrate the application procedures and to be able to evaluate all of the products used, the project was divided into 5 separate areas by slab and joint number (see attached test and evaluation sections layout sheet Appendix E).

Prior to installation of the sealants, the joints had to be prepared. The old sealant was removed and the sides of the old joints were refaced using a diamond blade saw. The joints in the concrete were cut 3/8 to 1/2 inches wide and 1 3/4 inches deep with one exception; the joints where the preformed compression seal was placed were all cut 1/2 inch wide. The asphalt shoulder joint was routed 3/4 inch wide and approximately 1/2 inch deep. After resawing the concrete, the joints were sandblasted to remove any residual sealer oil or other foriegn material which may prevent bonding of the new sealer. The last step was blowing out the joint with an air compressor to remove sand, dust, or any water remaining. The concrete/asphalt joint received only the air blast after routing.

On all of the concrete joints, except where the preformed compression seal was placed, a closed cell, compressible, polyethylene foam backer rod was placed in the joint. The backer rod prevents three sided adhesion and excessive use of sealants. It also helps provide the proper shape factor, since the parabolic curve formed by the backer rod at the bottom of the sealant results in less strain on the joint sealer. In the case of the silicone seals, it also provides support for the finishing tool. (See photograph 15 in Appendix D).

(a) Cold Poured Sealant

Only one cold poured seal was installed on the project. It was a High Float Emulsion (HFE-100 SC) with a rubber component applied at 100° by pouring from a bucket. This material was placed in joints 1 through 20. To date the emulsion seal has performed very poorly. There have been both cohesion and adhesion failures.

(b) Preformed Compression Neoprene Seal

This material was placed in joints 21 through 40. The contractor installed a 1 inch x 1 inch low stress seal with a complex web profile that may be a very effective seal if it remains in place. However, it may be too large a section for the short 20 feet spaced joints. A more desirable section would have been a 7/16 inch by 7/16 inch seal. It is also the most expensive of the joint seal materials. (See attached estimate cost).

Prior to installation, a lubricant was applied to the open joint to help slide the seal in place. After this lubricant dries it provides very little adhesion between the seal and concrete. Therefore, this seal relies solely on compression. The installation of the neoprene seal required two people. One would stretch the material approximately 5% while the other pushed a 4 wheel installation tool over the joint forcing the material in place. (See photograph 18 in Appendix D).

Thirty days after the installation, a 6" bulge occurred. This small bulge protrudes above the riding surface. It remains to be seen what the snow plows will do to it this winter and what happens during the hot summer.

(c) Low Modulus Silicone

Two different Silicones were installed in joints 41 through 80 (photograph 17 in Appendix D). The gray colored silicone (Dow-Corning) was placed in joints 41 through 60, and the black silicone (G.E.) was installed in joints 61 through 80. It should be noted that the black silicone required a primer. Both silicones were installed using air driven pumps. The silicone is placed into the joint and tooled so that the result is a concave curvature recessed 1/4 inch below the surface of the pavement. The curve at the bottom of the sealant provided by the backer rod and the concave curve on the finished top provided by the tooled surface result in the most desirable sealant shape for minimum strain. During the 30 day evaluation, some adhesion failures were noticed at joints 63, and 69 through 72. They are typically 3 inches long and 1/4 inch wide. It was the black colored silicone that debonded.

(d) Hot Poured Elastimeric Sealants

Several types of hot poured seals were used. Basically, they were placed in two areas on the project. One area is located between joints 81 and 100, and the other is west of the project. The slabs in this area are numbered 1W (west) to 39W. These materials were placed at approximately 350° F, requiring special heating equipment. (Photograph 16 in Appendix D). It has been reported that these high temperatures can sometimes burn the top of the foam backer. Even so, the backer rod is still able to prevent three sided adhesion, prevent excessive use of the sealant, and provide the proper shape and depth. No problems were noted with any of the hot poured sealants during the 30 day evaluation. See attached sheet in Appendix E for the location of all the sealants used on the project. Besides all of the above mentioned areas, the contractor routed the longitudinal joints at the concrete and asphalt shoulders as well as some of the cracked asphalt. They were also sealed with a hot poured materials.

<u>Crack Sealing</u>

A small gas powered pivotal saw (as shown in photograph 19 in Appendix D) was used to route the cracks sealed on the project. The contractor demonstrated both carbide and diamond cutting saw blades. The diamond provided a superior cut because it did not spall (the carbide blades work best in the asphalt shoulder). The concrete cracks were routed about 3/8 inch wide and 1/4 inch deep. A modified hot poured rubber sealant was placed in the cracks. No backer rod was used in the bottom of the routed crack.

## COST ANALYSIS

One of the objectives of this study other than evaluating the post construction performance will be to make some determination of how long the CPR procedures and techniques "prolong" the life of the concrete pavement. Table 1 is a cost cycle analysis of CPR vs. a thick asphalt overlay (5 inches). It assumes that a 2 inch overlay will be required at 10 years and 20 years and that a 1 inch overlay will be placed at 30 and 35 years. If these and the other assumptions made are correct, then it can be seen that annual cost advantages are with the complete CPR system. Also, the assumption that 10 slabs per mile will need to be removed and replaced may be overestimated for most CPR projects.

Over the next three years, an annual evaluation of the project will be performed. The areas to be analyzed are shown in Figures 1 and 2, Appendix E. The evaluation will consist of several procedures.

First the full depth replacement slabs will be inspected for cracking and loss of transfer at the doweled joints. The Benkleman Beam will be used to check load transfer. Partial depth patching will be inspected for cracking and spalling.

Next, the undersealed area will be monitored. The return of faulting and at what point in time it recurs, if it does indeed recur, will be observed. This may be one of the most important restoration factors to consider in attempting to estimate the "prolonged life" of the pavement resulting from the CPR treatment.

Third, the rate of wear on the areas that received diamond grinding will be determined. Representatives from the concrete industry indicate that Colorado's concrete does not wear as quickly as concrete pavements in other states. Time will provide the answer especially in an environment that receives extensive studded tire wear.

The load transfer devices will be evaluated by measuring the load transfer ratio's. Again, the Benkleman Beam will be used for these measurements. Some of the holes in which the devices were placed in were groved. The performance of the devices placed in holes not grooved will be compared to the performance of the devices placed in the grooved holes.

Finally, all of the types and kinds of joint sealers will be evaluated. This will be accomplished by visual inspection of the sealers placed. In addition to the above, crack maps will be updated annually.

As previously noted, it is our intention to determine how long these activities prolong the service life of concrete pavements. Comparing the condition of the pavement before the project to the pavement condition after the CPR project may provide a data base to work with in obtaining the goals of the Demonstration Project held October 5, 1983.

Table 1
I-70 Concrete Pavement Rehabilitation Demonstration
C.P.R. VS. THICK ASPHALT OVERLAY

C.P.R.

| | |
|---|---|
| Hot Asphalt Pavement (ton) | $ 28 |
| Maintenance Cost (2 lane mile/yr.) | $ 1,000 |
| Full depth slab replacement-assume removing ten slabs/2 lane mile at $60/S.Y. | |
| Slab length = 20 ft. | |
| 10 (12 x 20) : 9 x $60 | $ 16,000 |
| Undersealing- | |
| $25/slab (.4 cu. ft./hole x 5 holes/slab x $12.50/cu. ft.) | |
| $5/hole drilled (5/slab) | |
| 5280/20 x (25 + 25) | $ 13,200 |
| Load Transfer Restoration at Joints | |
| $60 each installed placing 3/joint (2 in right wheel path and 1 in left wheel path every third joint). | |
| 5280/60 x 3 x 60 | $ 15,840 |
| Grinding- | |
| 1/4" @ $4.00/S.Y. | |
| (Outside 12' lane or truck lane only) | |
| (5280 x 12) : 9 x 11 | $ 28,160 |
| Joints and Cracking Sealing- | |
| Joints- | |
| Transverse-Hot Rubber @ 1.60 L.F | |
| (5280/20) x 24 x 1.60 | $ 10,560 |
| Longitudinal | |
| 5280 x 1.60 | $ 8,448 |
| Longitudinal at shoulders 1.60 L.F. | |
| 5280 x 2 x 1.60 | $ 16,898 |
| Cracks- @ 1.75 L.F. | |
| Assume 300 ft/mile | |
| 300 x 1.75 | $ 525 |
| TOTAL | $109,631 |

Assuming Hot Asphalt Pavement Overlay
at 10 years 2", 20 years 2", and 30 years 1"
at 35 years, 1"
and 28/ton and 110 lb/yd$^2$/in.

| | |
|---|---|
| For 2" overlay | $68,663 |
| For 1" overlay | $34,332 |

| | |
|---|---|
| CI=Initial Cost | \$109,631 |
| $R_1$=Resurface at 10 years (2" overlay) | \$ 68,663 |
| $R_2$=Resurface at 20 years (2" overlay) | \$ 68,663 |
| $R_3$=Resurface at 30 years (1" overlay) | \$ 34,332 |
| $R_4$=Resurface at 35 years (1" overlay) | \$ 34,332 |
| M.A.=Annual Maintenance cost | \$ 1,000 |

PW=109,631 + 68,663 (.6756) + 68,663 (.4564)
+ 34,332 (.3083) + 34,332 (.2534) + 1000
(19.7927) \$226,434

AC-Annual Cost
226,434 (.0505) <u>\$ 11,435</u>

<u>THICK APSPHALT OVERLAY (5")</u>

Thickness based on Asphalt Institute design method using .042" mean deflection and .011" differential deflection.

| | |
|---|---|
| Hot Asphalt Pavement (ton) | \$ 28 |
| Maintenance Cost (2 lane mile/yr.) | \$ 3,000 |

Hot Bituminus Pavement - 5" overlay
110 #/yd$^2$/in.
[(5280 x 38) : 9 x 440] : 2000 x 28 = \$137,327

Undersealing (required because average deflections after overlay are greater than allowed .014", and differential deflections at joints are greater than allowed .002").
\$20/slab (.4 cu. ft./hole x 4 holes x \$12.50/cu. ft.)
\$ 5/hole drilled (4/slab)
5280/20 x 40 = \$ 10,560

Hot Asphalt Pavement Overlay as per DOH Design Manual-
15 yrs. 2", 25 yrs. 2", 35 yrs. 1"

| | |
|---|---|
| For 2" overlay | \$68,663 |
| For 1" overlay | \$34,332 |

| | | | |
|---|---|---|---|
| C.I.=Initial cost | | | \$182,219 |
| $R_1$=Resurfacing | 15th yr. | (2") | \$ 68,663 |
| $R_2$= " | 25th | " " | \$ 68,663 |
| $R_3$= " | 35th | " (1") | \$ 34,332 |
| MA=Annual Maintenance Cost | | | \$ 3,000 |

PW= 137,327 + 68,663 (.5552) + 68,663
(.3751 + 34,322 (.2534) + 3000 (19.7927)= \$314,181

AC=Annual Cost Per Mile - 2 Lane
\$269,289 x .0505= <u>\$ 15,866</u>

# APPENDIX A

## Demonstration and Seminar

## Schedule

PORTLAND CEMENT
CONCRETE PAVEMENT RESTORATION (CPR)
Demonstration and Seminar

Denver, Colorado
October 5, 1983

7:30 - 8:20 Registration

## Morning Session

| | | |
|---|---|---|
| | Presiding | H. J. Halm<br>American Concrete Pavement Association |
| 8:30 a.m. | Welcome | (Representative)<br>Colorado Department of Highways |
| 8:45 a.m. | Georgia's Experience with CPR | (Representative)<br>Georgia Department of Transportation |
| 9:15 a.m. | Colorado's Organized Approach to CPR | (Representative)<br>Colorado Department of Highways |
| 9:45 a.m. | CPR Demonstration Features | John D'Angelo<br>Federal Highway Administration |
| 10:00 a.m. | Break | |
| 10:00 a.m. | Commence Bus Tour to Demonstration Site | |
| 12:00 p.m. | Lunch (Buffet) | |

## Afternoon Session

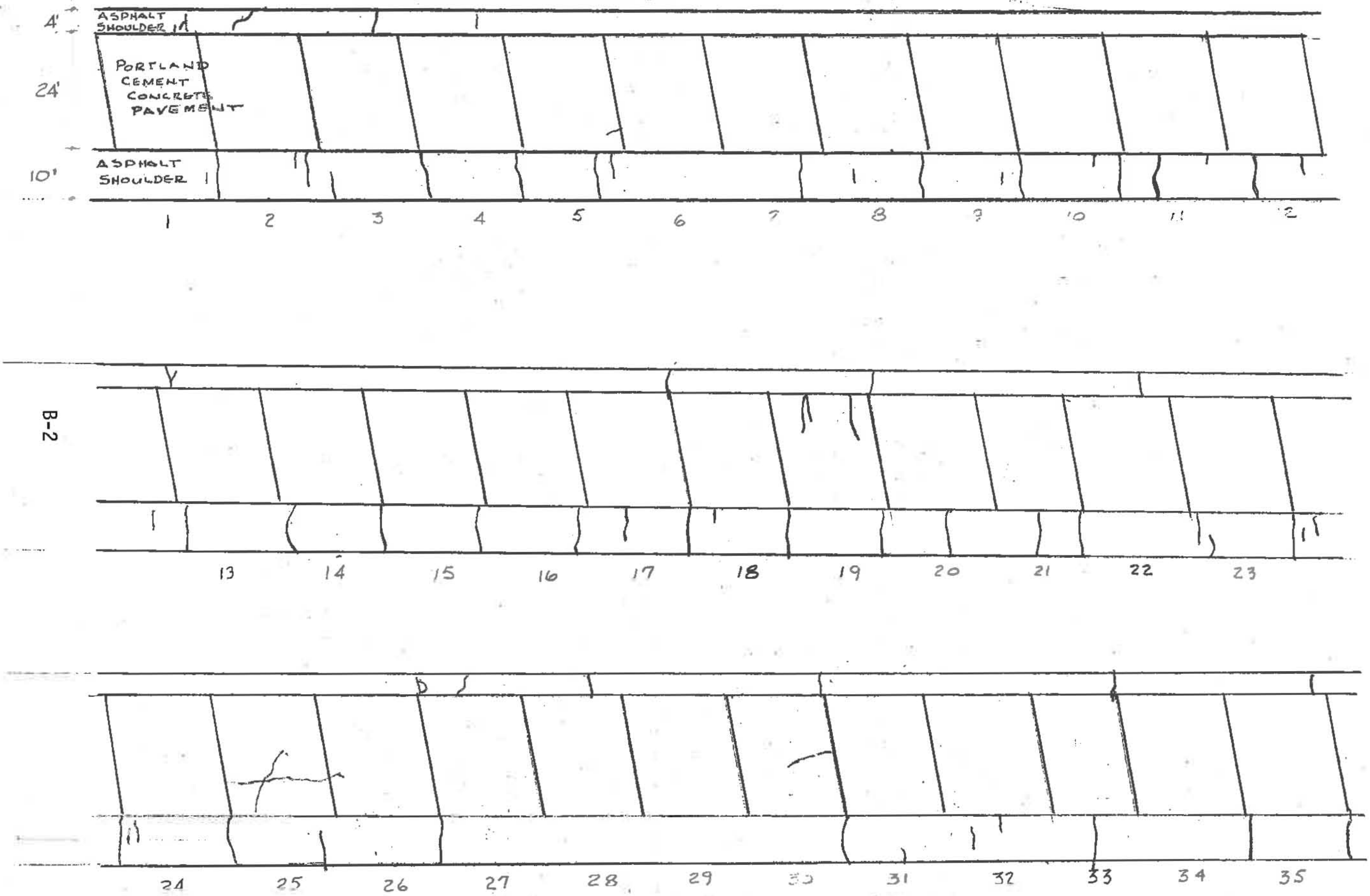
| | | |
|---|---|---|
| | Presiding | Douglas Bernard<br>Federal Highway Administration |
| 1:00 p.m. | Overview of Portland Cement Concrete Pavement Rehabilitation | William Yrjanson<br>American Concrete Pavement Association |
| 1:30 p.m. | Slab Replacement and Spall Repair | |
| 2:00 p.m. | Undersealing | |
| 2:20 p.m. | Break | |
| 2:30 p.m. | Load Transfer Restoration | |
| 3:00 p.m. | Diamond Grinding | |
| 3:30 p.m. | Joint Resealing | |
| 4:00 p.m. | Cost Benefits of CPR - A State Highway Agency Perspective | (Representative)<br>Georgia Department of Transportation |
| 4:30 p.m. | Questions and Answers | |

# APPENDIX B

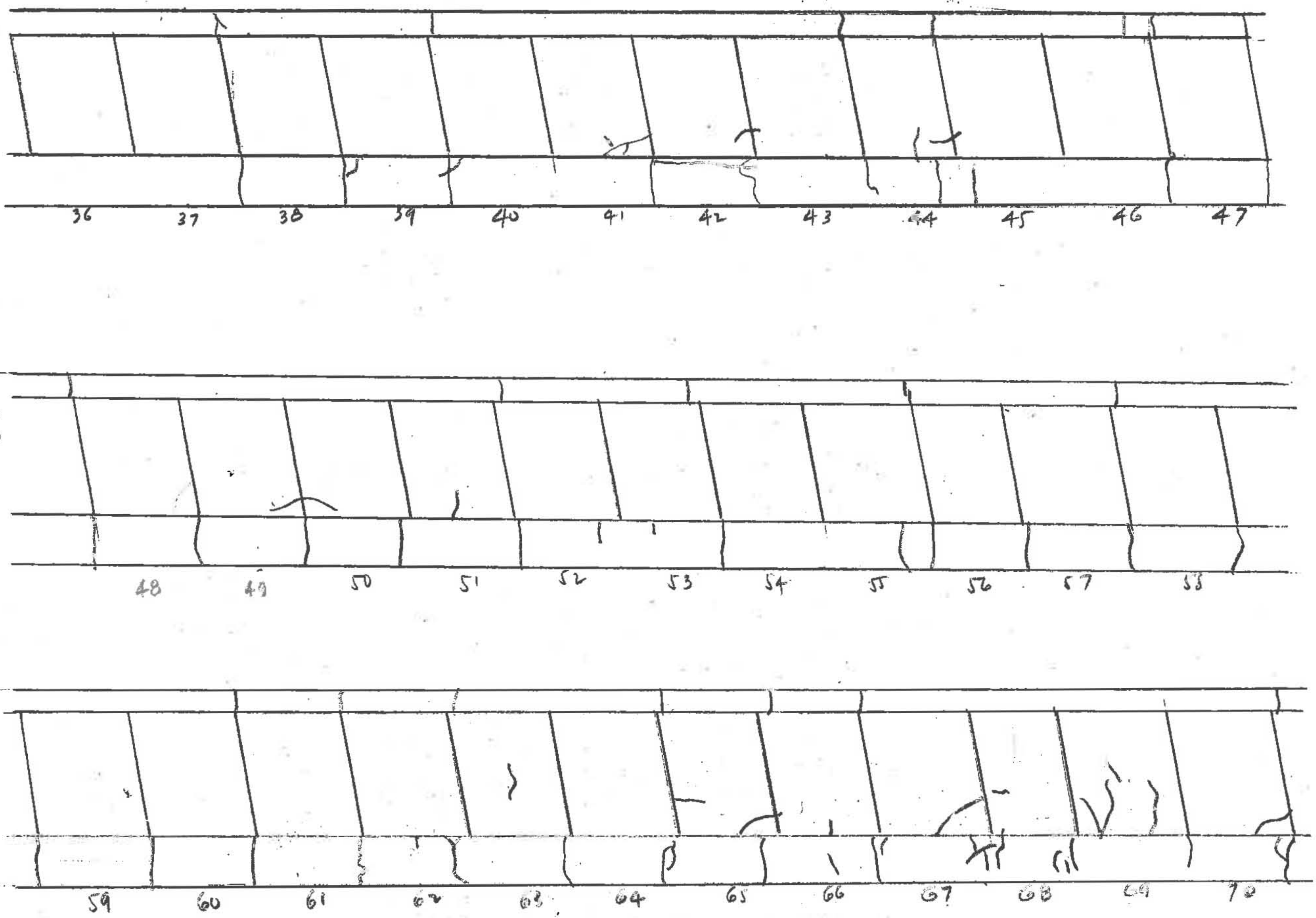
## Original

## Condition Survey

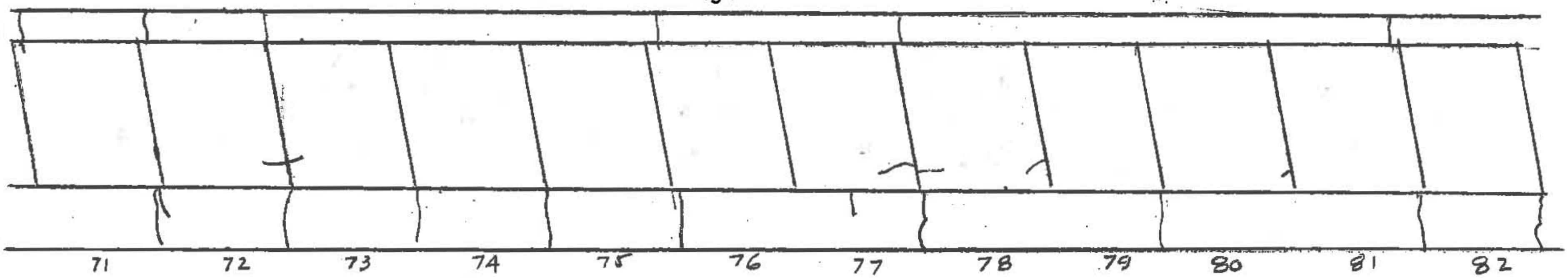
CONDITION SURVEY (Cracking Maps)
I-70, EBL (Chambers to Tower Rd.
August '83

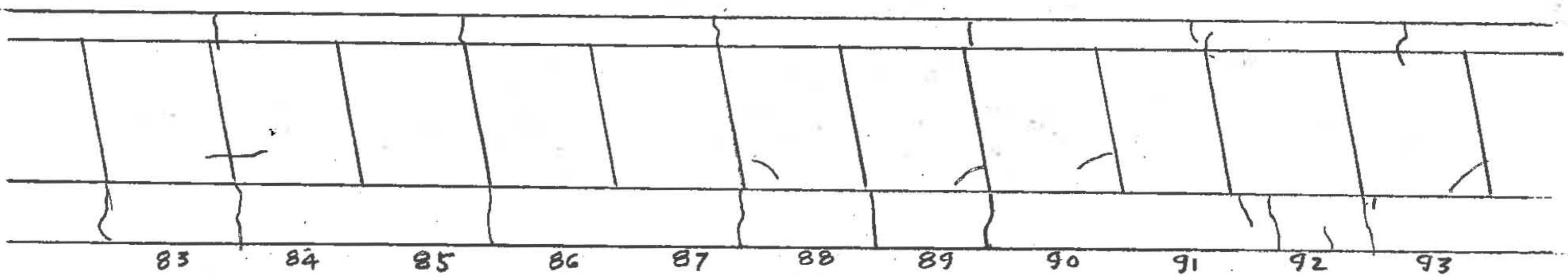


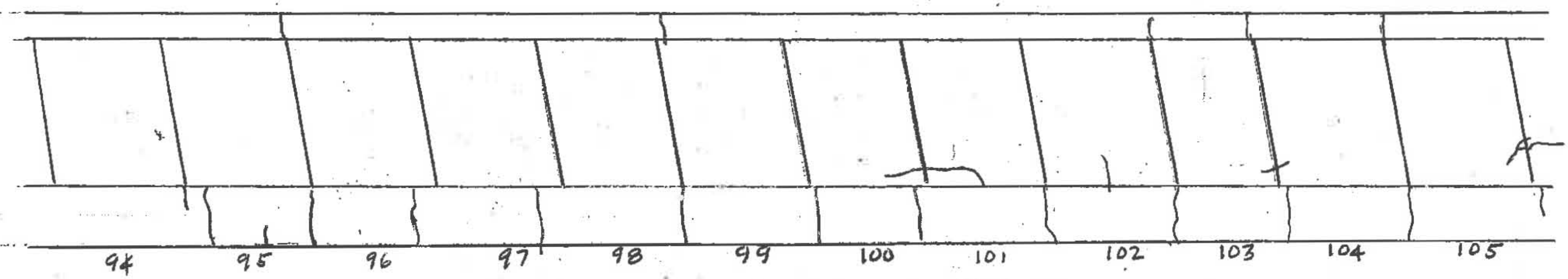
CONDITION SURVEY (Cracking Maps)
I-70, EBL (Chambers to Tower Rd.
August '83



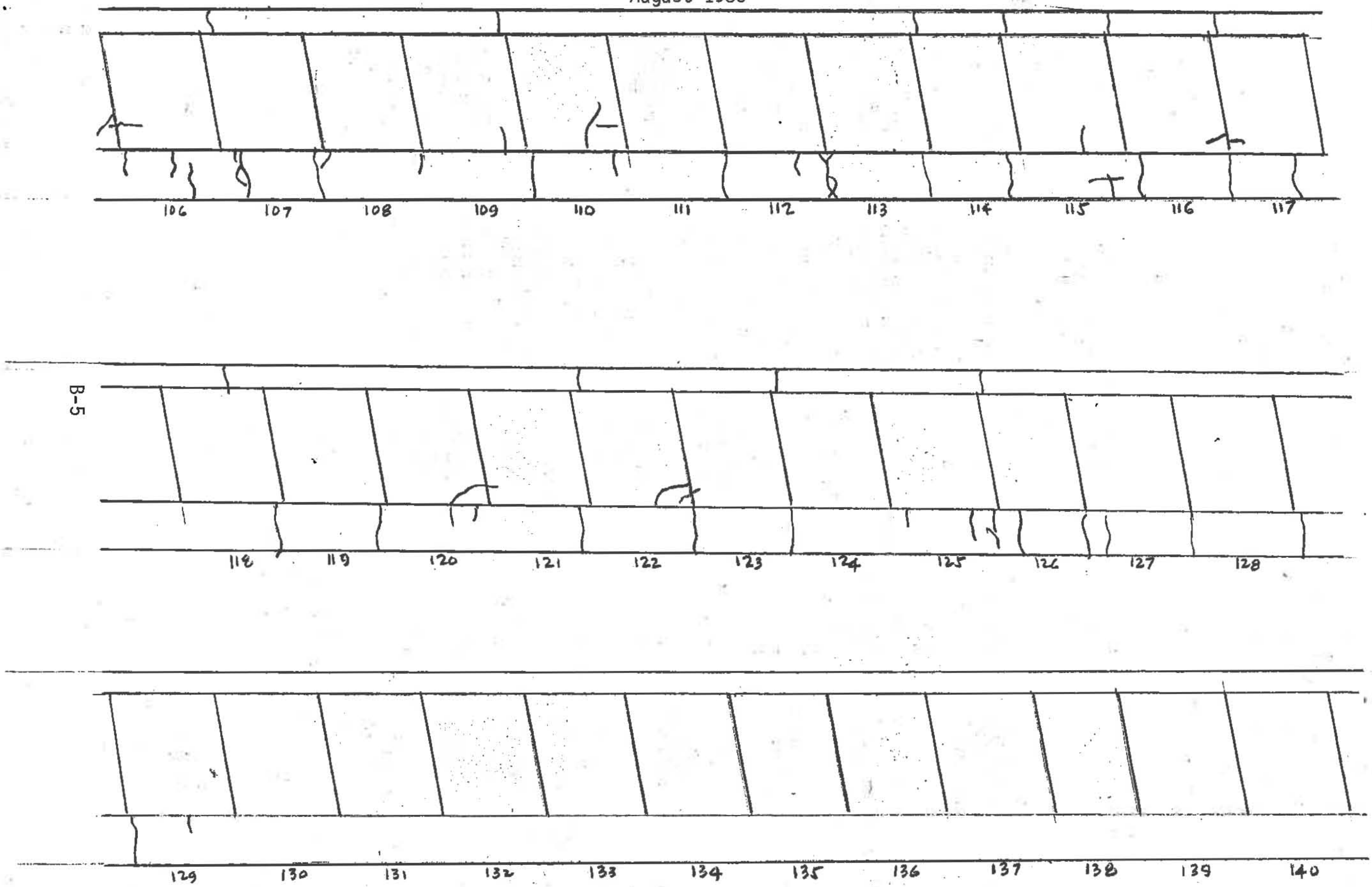
CONDITION SURVEY (Cracking Maps)
I-70, EBL (Chambers to Tower Rd.
August 1983



CONDITION SURVEY (Cracking Maps)
I-70, EBL (Chambers to Tower Rd.
August 1983



# CONDITION SURVEY
# ROUGHNESS
# RAINHART PROFILOGRAPH
# JULY 29,1983

E.B.L.
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Using a 0.2 inch filter measuring approximately 1000 ft., the result was 6.7 vertical inches of roughness in the test section.

# CONDITION SURVEY
# BENKLEMAN BEAM DEFLECTIONS
# BEFORE GROUTING

## EBL - I-70
## BETWEEN CHAMBERS AND TOWER ROAD
## AUGUST 1983

| SLAB/JOINT# | APPROACH INCHES | LEAVE INCHES | DIFFERENCE INCHES |
|---|---|---|---|
| 1 | .065 | .061 | .004 |
| 2 | .044 | .065 | .021 |
| 3 | .057 | .057 | .000 |
| 4 | .044 | .022 | .022 |
| 5 | .039 | .039 | .000 |
| 6 | .039 | .065 | .026 |
| 7 | .039 | .061 | .022 |
| 10 | .044 | .023 | .021 |
| 11 | .035 | .044 | .009 |
| 12 | .039 | .031 | .008 |
| 13 | .015 | .048 | .033 |
| 14 | .035 | .002 | .033 |
| 15 | .048 | .048 | .000 |
| 16 | .048 | .026 | .022 |

| SLAB/JOINT# | APPROACH INCHES | LEAVE INCHES | DIFFERENCE INCHES |
|---|---|---|---|
| 17 | .026 | .044 | .018 |
| 18 | .057 | .044 | .013 |
| 19 | .031 | .050 | .019 |
| 20 | .039 | .070 | .031 |
| 21 | .035 | .050 | .015 |
| 22 | .050 | .044 | .006 |
| 23 | .048 | .057 | .009 |
| 24 | .052 | .044 | .008 |
| 25 | .031 | .039 | .008 |
| 26 | .061 | .031 | .030 |
| 27 | .044 | .031 | .013 |
| 28 | .061 | .061 | .000 |
| 29 | .031 | .031 | .000 |
| 30 | .052 | .044 | .008 |
| 31 | .017 | .065 | .048 |
| 32 | .046 | .052 | .006 |
| 33 | .048 | .052 | .004 |
| 34 | .031 | .079 | .048 |
| 35 | .022 | .039 | .017 |
| 36 | .024 | .039 | .015 |
| 37 | .055 | .063 | .008 |
| 38 | .033 | .078 | .045 |
| 39 | .031 | .037 | .006 |
| 40 | .039 | .046 | .007 |

| SLAB/JOINT# | APPROACH | LEAVE | DIFFERENCE |
|---|---|---|---|
| | INCHES | INCHES | INCHES |
| 41 | .044 | .048 | .004 |
| 42 | .031 | .089 | .058 |
| 43 | .041 | .065 | .024 |
| 44 | .035 | .061 | .034 |
| 45 | .052 | .048 | .004 |
| 46 | .052 | .057 | .005 |
| 47 | .048 | .052 | .004 |
| 48 | .061 | .052 | .009 |
| 49 | .013 | .057 | .044 |
| 50 | .035 | .035 | .000 |
| 51 | .004 | .052 | .048 |
| 52 | .061 | .074 | .013 |
| 53 | .044 | .039 | .005 |
| 54 | .035 | .044 | .009 |
| 55 | .026 | .035 | .009 |
| 56 | .044 | .070 | .026 |

| | | | |
|---|---|---|---|
| PROJECT AVERAGES | .040 | .050 | .016 |

# CONDITION SURVEY
# RUT DEPTH (INCHES)
# JULY 29,1983

EBL

| SLAB/JOINT# | DRIVING LANE | |
|---|---|---|
| | R | L |
| 1 | 0.20 | 0.20 |
| 5 | 0.20 | 0.20 |
| 10 | 0.20 | 0.20 |
| 15 | 0.20 | 0.20 |
| 20 | 0.20 | 0.20 |
| 25 | 0.20 | 0.20 |
| 30 | 0.20 | 0.20 |
| 35 | 0.20 | 0.20 |
| 40 | 0.20 | 0.20 |
| 45 | 0.20 | 0.20 |
| 50 | 0.25 | 0.20 |
| 55 | 0.20 | 0.20 |
| 60 | 0.20 | 0.20 |
| 65 | 0.20 | 0.20 |
| 70 | 0.20 | 0.20 |
| 75 | 0.20 | 0.20 |
| 80 | 0.20 | 0.20 |
| 85 | 0.20 | 0.30 |
| 90 | 0.20 | 0.20 |
| 95 | 0.20 | 0.20 |
| 100 | 0.20 | 0.20 |
| 105 | 0.20 | 0.20 |
| 110 | 0.20 | 0.15 |
| 115 | 0.20 | 0.25 |

# CONDITION SURVEY
# SKID NUMBER

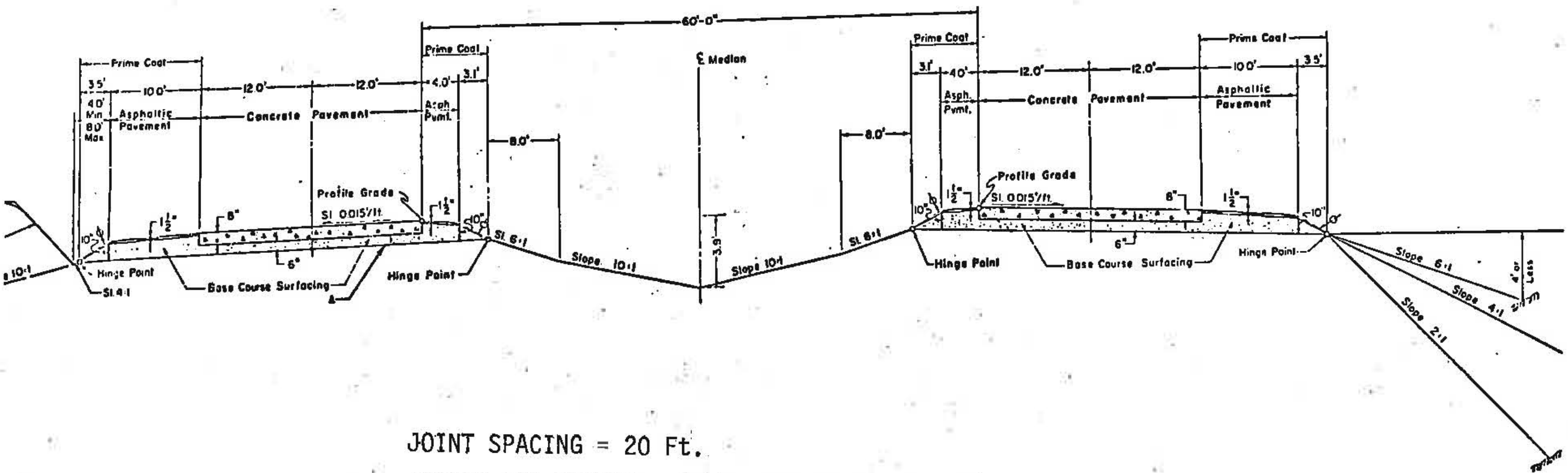
E.B.L.-TRUCK LANE
-----------------

SEPTEMBER 1983 40

# CONDITION SURVEY

## GENERAL NOTES

TYPICAL SECTION




JOINT SPACING = 20 Ft.

JOINTS ARE SKEWED = 2 Ft. per 20 Ft. length.

STEEL REINFORCEMENT = 24 inch bars are placed in the longitudinal joint centerline. There was no load transfer device or steel placed in transverse joints.

# CONDITION SURVEY
## GENERAL NOTES
## CONTINUED

FAULTING - Faulting was measured by placing a straight edge on the approach side of a transverse joint and allowing it to overhang on the leave side. The average fault measured on the leave side was 1/4 inch.

JOINTS AND CRACKS - A visual inspection of the joints indicated their condition was poor. Recent maintenance of joints and the few cracks consisted of pouring an RC-800 in the joint or crack after cleaning with an air blast. Practically all of the joints and cracks had cohesion and adhesion failures of the sealant.

NOTE -

For purposes of a small demonstration project the Department elected to carefully survey and inspect every PCCP slab. On a full scale project approximately 10 to 15% of the slabs are surveyed.

APPENDIX C

30-Day

Condition Survey

(after completion of project)

# DEFLECTIONS
# AFTER GROUTING

## EBL - I-70
## BETWEEN CHAMBERS AND TOWER ROAD
## JANUARY 1984

| SLAB/JOINT# | APPROACH INCHES | LEAVE INCHES | DIFFERENCE INCHES |
|---|---|---|---|
| 1 | .024 | .017 | .007 |
| 2 | .017 | .013 | .004 |
| 3 | .007 | .013 | .006 |
| 4 | .024 | .011 | .013 |
| 5 | .022 | .013 | .009 |
| 6 | .024 | .020 | .004 |
| 7 | .013 | .017 | .004 |
| 8 | .024 | .017 | .007 |
| 9 | .020 | .013 | .007 |
| 10 | .020 | .017 | .003 |
| 11 | .011 | .011 | .000 |
| 12 | .020 | .011 | .009 |
| 13 | .015 | .009 | .006 |
| 14 | .002 | .009 | .007 |
| 15 | .026 | .013 | .013 |
| 16 | .013 | .009 | .004 |
| 17 | .007 | .011 | .004 |
| * 18 | .013 | .009 | .004 |

| SLAB/JOINT# | APPROACH INCHES | LEAVE INCHES | DIFFERENCE INCHES |
|---|---|---|---|
| * 19 | .017 | .009 | .008 |
| * 20 | .024 | .002 | .022 |
| 21 | .026 | .009 | .017 |
| 22 | .017 | .009 | .008 |
| 23 | .011 | .007 | .004 |
| 24 | .020 | .007 | .013 |
| 25 | .013 | .007 | .006 |
| 26 | .009 | .002 | .007 |
| 27 | .020 | .002 | .018 |
| 28 | .017 | .011 | .006 |
| 29 | .009 | .007 | .002 |
| 30 | .011 | .002 | .009 |
| 31 | .009 | .007 | .002 |
| 32 | .055 | .011 | .044 |
| 33 | .023 | .007 | .016 |
| 34 | .013 | .015 | .002 |
| 35 | .020 | .004 | .016 |
| 36 | .022 | .004 | .018 |
| 37 | .011 | .002 | .009 |
| 38 | .011 | .009 | .002 |
| 39 | .013 | .004 | .009 |
| 40 | .020 | .004 | .016 |
| 41 | .017 | .007 | .010 |
| 42 | .015 | .002 | .013 |

| SLAB/JOINT# | APPROACH INCHES | LEAVE INCHES | DIFFERENCE INCHES |
| --- | --- | --- | --- |
| 43 | .015 | .007 | .008 |
| 44 | .009 | .007 | .002 |
| 45 | .009 | .007 | .002 |
| 46 | .022 | .013 | .009 |
| 47 | .017 | .017 | .000 |
| 48 | .017 | .007 | .010 |
| 49 | .026 | .009 | .017 |
| 50 | .017 | .007 | .010 |
| 51 | .004 | .004 | .000 |
| 52 | .009 | .007 | .002 |
| 53 | .011 | .004 | .007 |
| 54 | .015 | .004 | .011 |
| 55 | .013 | .015 | .002 |
| 56 | .017 | .009 | .008 |

| | | | |
| --- | --- | --- | --- |
| PROJECT AVERAGES | .016 | .009 | .008 |

* NOT GROUTED

# SKID NUMBER
# AFTER GRINDING

E.B.L.-TRUCK LANE

JANUARY 1984 53

# ROUGHNESS AFTER GRINDING
# RAINHART PROFILOGRAPH
# NOVEMBER 14,1983

E.B.L.

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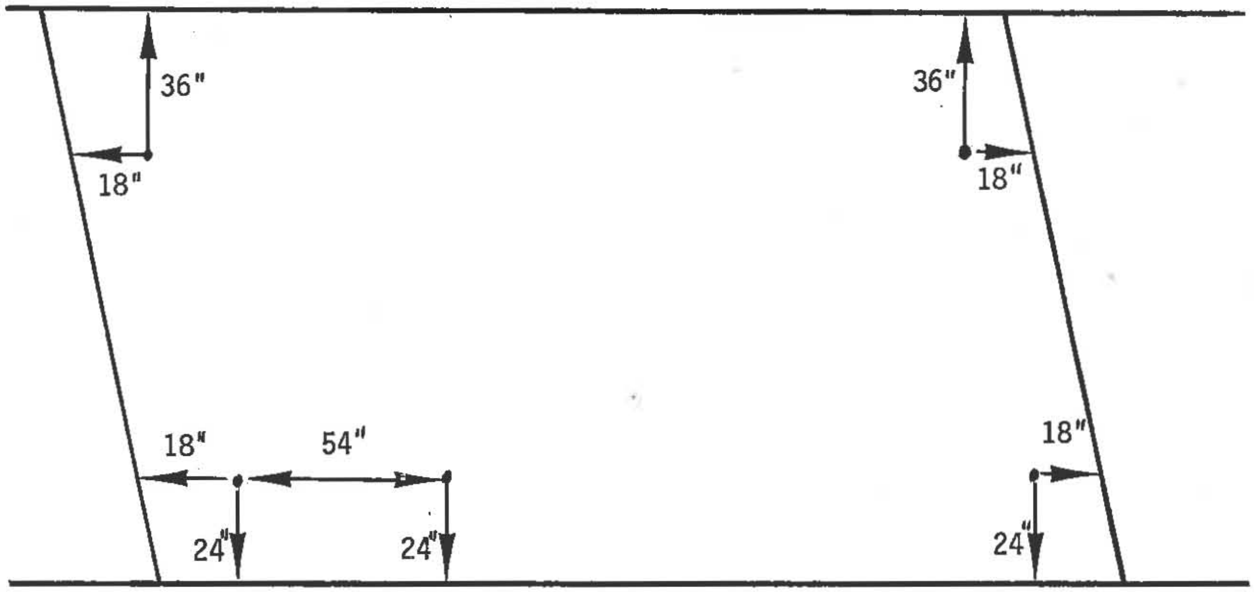
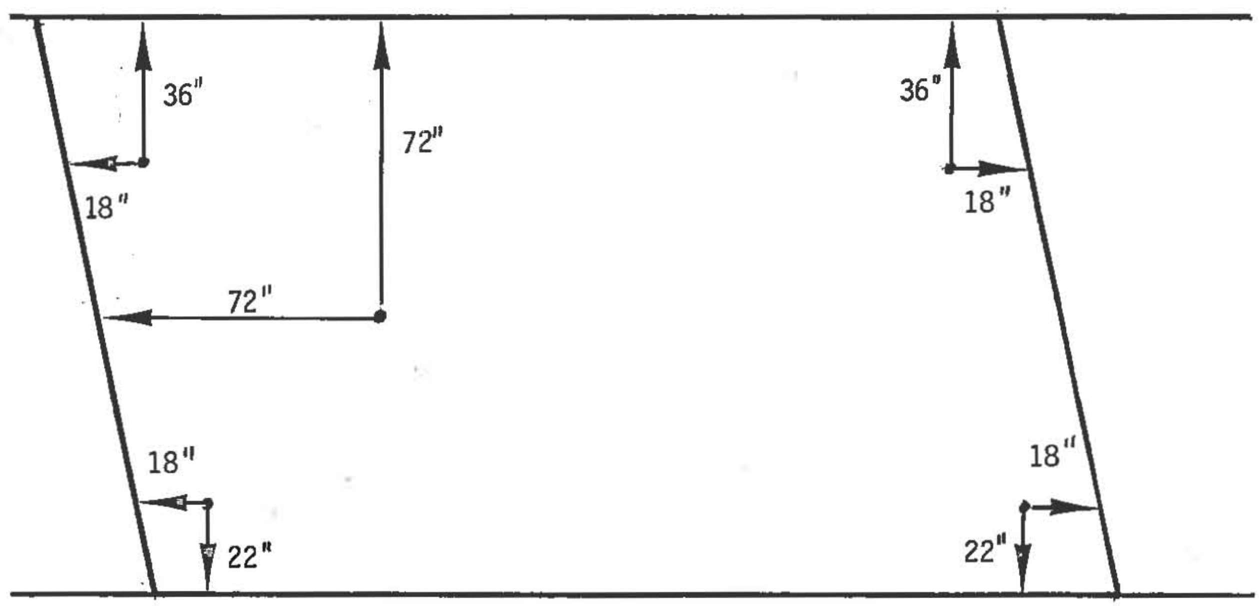
Using a 0.2 inch filter measuring approximately 1000 ft. the result was 3.1 vertical inches of roughness in the test section.

HOLE PATTERNS




Two hole patterns were used on the 56 continous slabs undersealed on this project. The intent was to measure the relative effectiveness of the two patterns by using the Benkleman Beam and/or Dynaflect. To date, there has not been any significant difference reported in deflections. Undersealing was performed in the truck lane only. The slabs are 12 ft. long and 20 ft. wide with skewed joints.

# APPENDIX D

## Pictorial Sequence

## of

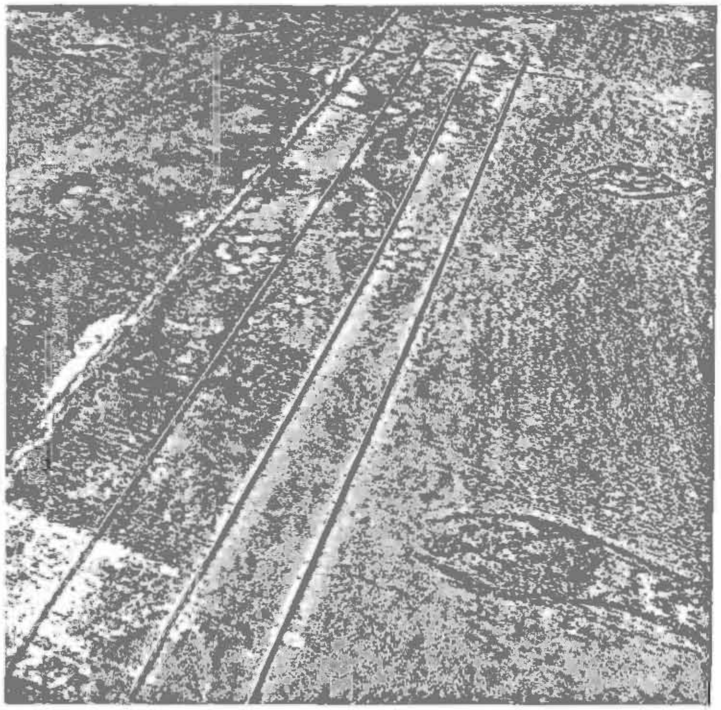
## Concrete Pavement Restoration

Non-destructive testing (NDT) equipment used on the preliminary engineering condition survey. Donahue Radar Void Detector which was one of several pieces of NDT equipment on display at the project site. This device is used to detect voids under the faulted slabs.

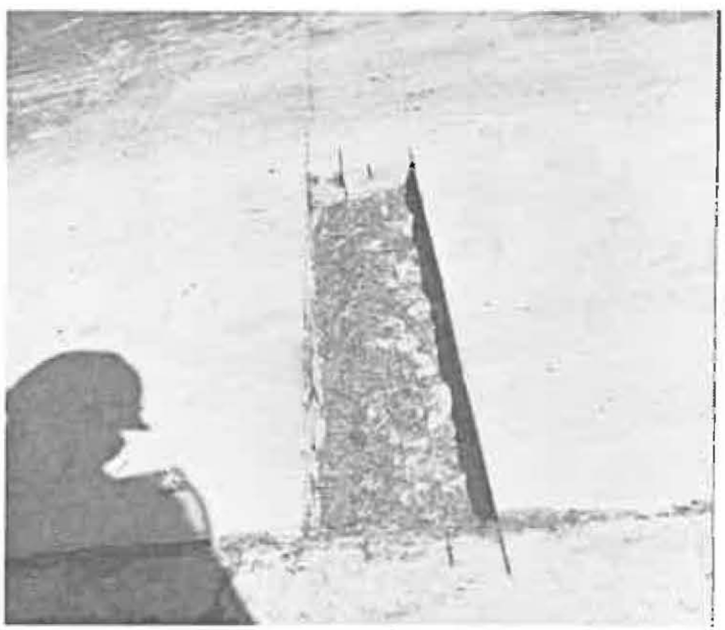
A group of attendees looking at the SAAB Friction Tester in display. This NDT is used for friction and roughness testing.

The Falling Weight Deflectometer was one of the most popular pieces of NDT on display.

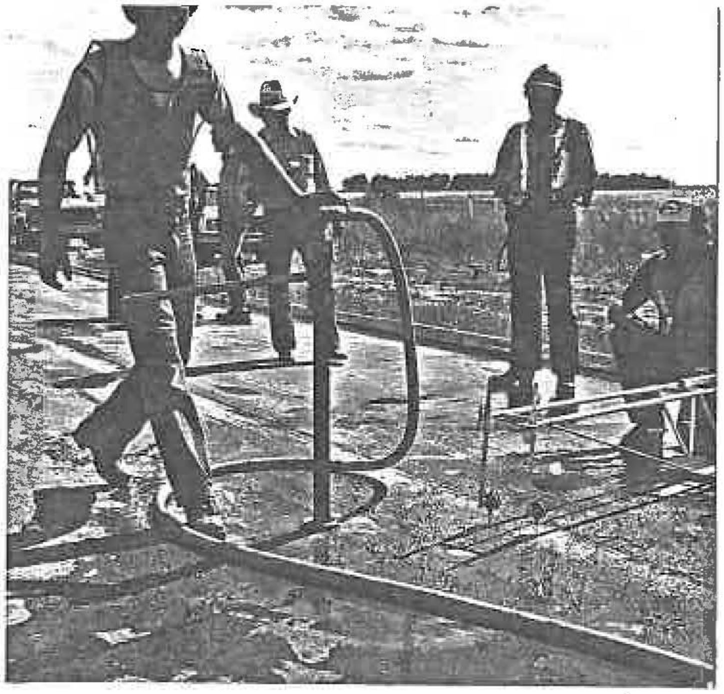
Removal and placing of old, broken concrete slabs is the first CPR procedure. Pictured is an 8 inch slab being lifted out of place. Prior to removal the slab was outlined with a full depth sawcut. Eight inch concrete will replace the old removed slab.



Spalled joints and cracks are also repaired during the period of time full depth removal and replacement is being performed. Since there was no spalling on the project, several slabs were selected to demonstrate partial depth repair. Here 3 sawcuts, 2 inches deep are made next to a joint for removal of a spalled area.



The material is removed with air hammers to the bottom of the spall. Attention was given to cleaning the spall before the modified Portland cement patching materials were placed.



Another CPR technique that was demonstrated was the slab undersealing. In a complete CPR system it would follow the full and partial depth slab repair. Pictured is the injection of the cement/fly ash mixture into the voids under the slab. A modified Benkleman Beam is being used to monitor the uplift of the slab.

A group of the attendees watching the undersealing operation being demonstrated.

After undersealing is completed, the concrete slab can be resurfaced by diamond grinding. Grinding was done on this project not only to provide a new surface but to remove the rutting and faulting.

Grinding was performed in the heavily traveled lane only (truck lane), while traffic was carried on the adjacent passing lane. The grinder cuts 38 inches wide, which requires four passes per lane.

The fourth CPR technique demonstrated was the restoration of the load transfer at the transverse joints. Pictured is the diamond load transfer device used on the project and the drilling operation.

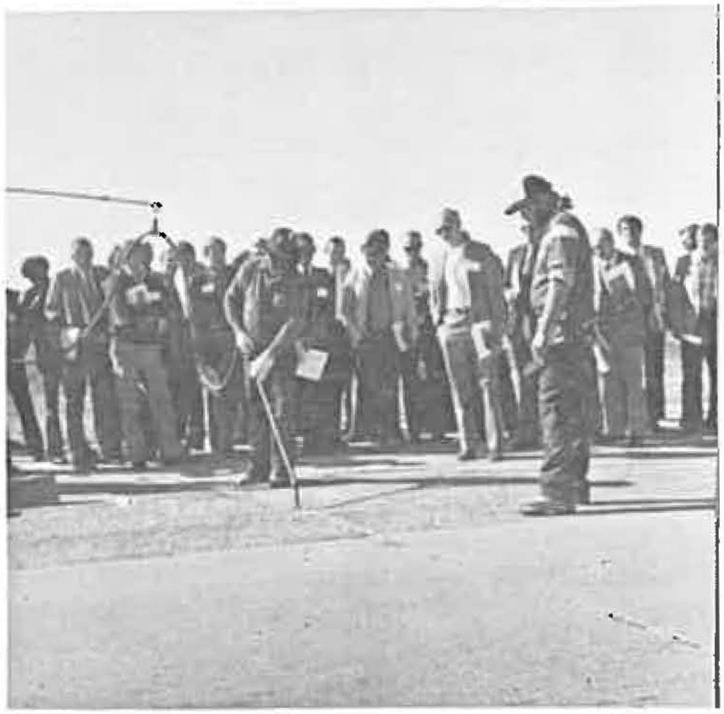
A special air driven tool was used to groove the inside of the core hole. This provides more area for bonding the grout to the concrete slabs and mechanical shear at the face of the grout/slab joint.

A group of attendees watching a demonstration on installing the load transfer devices.

The last CPR procedure that the contractors demonstrated was the resealing of joints and cracks. Here, a diamond saw is refacing a concrete transverse joint.

Next, after a thorough cleaning of the refaced joint, a backer rod was installed. The joints receiving the compression seal do not require a backer rod.

Hot poured material is placed in the concrete/asphalt shoulder joint for a group of attendees. Notice the squeegee which is used to spread the material and help fill the joint.



Procedures for applying silicone sealant are demonstrated.

A 1 inch by 1 inch piece of preformed neoprene compression seal is prepared for installation into the joint.

This machine is a short pivotal saw used to rout cracks.

The routed crack is inspected by a group of attendees just prior to cleaning and sealing. Sealing the cracks and joints is the last activity in the complete CPR system.

# APPENDIX E

## Test and Evaluation

## Sections

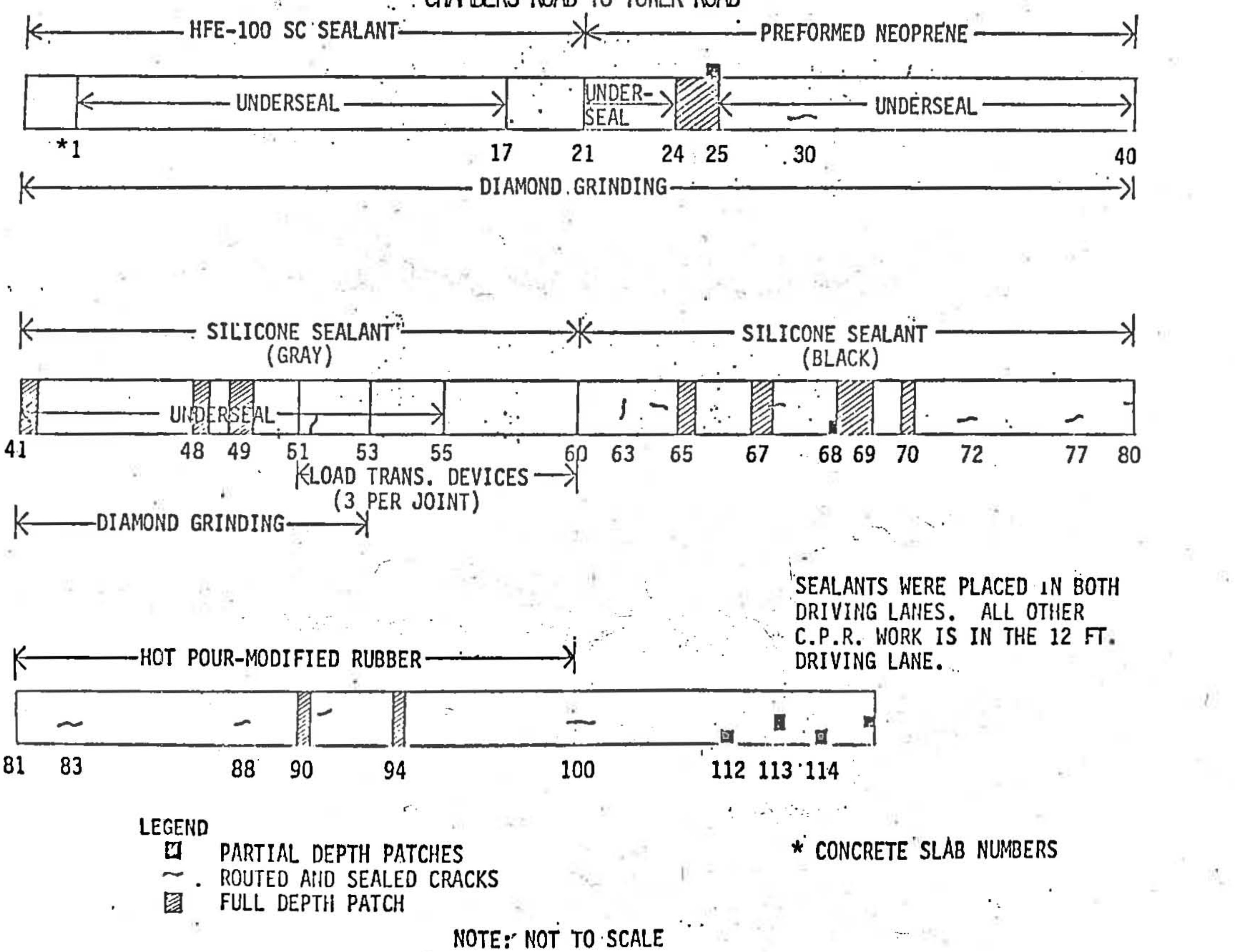
# Figure 2

C.P.R. TEST AND EVALUATION

SECTIONS

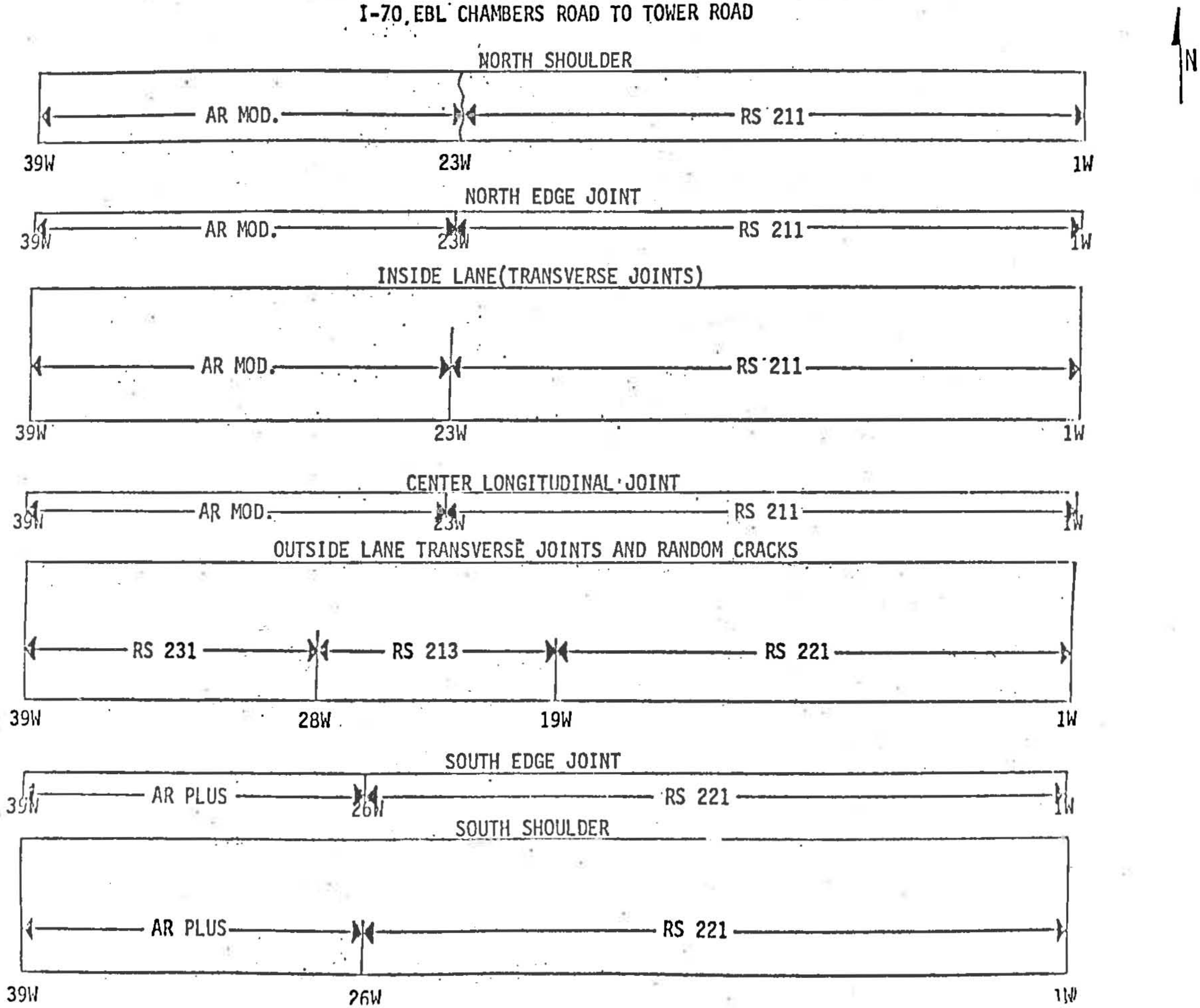
I-70 EBL

CHAMBERS ROAD TO TOWER ROAD



## Figure 3

C.P.R. TEST AND EVALUATION SECTIONS
I-70 EBL CHAMBERS ROAD TO TOWER ROAD



# SEALANTS PLACED ON DEMO PROJECT IN CONCRETE AND ASPHALT JOINTS AND CRACKS

| JOINT/SLAB NO. | TYPE AND NAME | LOCATION |
|---|---|---|
| 1 - 21 | HFC - 100SC | TRANSVERSE JOINTS (PCCP) |
| 22 - 40 | PREFORMED NEOPRENE(WABO) | TRANSVERSE JOINTS (PCCP) |
| 41 - 60 | SILICONE(DOW CORNING) | TRANSVERSE JOINTS (PCCP) |
| 61 - 80 | SILICONE(GEN. ELECTRIC) | TRANSVERSE JOINTS (PCCP) |
| 81 - 100 | PRODUCT 9005 ALLIED MATERIALS CORPORATION | TRANSVERSE JOINTS (PCCP) |
| 1W - 23W | RS 211 (CRAFCO) | NORTH SHLDR. (ASPHALT) |
| 24W - 39W | A.R. MODIFIED (CRAFCO) | NORTH SHLDR. (ASPHALT) |
| 1W - 23W | RS 211 (CRAFCO) | NORTH EDGE JOINT ASPHALT/PCCP |
| 24W - 39W | A.R. MODIFIED (CRAFCO) | NORTH EDGE JOINT ASPHALT/PCCP |
| 1W - 23W | RS 211 (CRAFCO) | CENTER LONGITUDINAL JOINT (PCCP) |
| 24W - 39W | A.R. MODIFIED (CRAFCO) | CENTER LONGITUDINAL JOINT (PCCP) |
| 1W - 19W | RS 221 (CRAFCO) | TRANSVERSE JOINTS & CRACKS (PCCP) |
| 20W - 28W | RS 213 (CRAFCO) | TRANSVERSE JOINTS & CRACKS (PCCP) |
| 29W - 39W | RS 231 (CRAFCO) | TRANSVERSE JOINTS & CRACKS (PCCP) |
| 1W - 26W | RS 221 (CRAFCO) | SOUTH EDGE JOINT ASPHALT/PCCP |
| 27W - 39W | A.R. PLUS (CRAFCO) | SOUTH EDGE JOINT ASPHALT/PCCP |
| 1W - 26W | RS 221 (CRAFCO) | SOUTH SHOULDER - ASPHALT |
| 27W - 39W | A.R. PLUS (CRAFCO) | SOUTH SHOULDER - ASPHALT |

TABLE A
SEALANT COSTS

| Material | | Date | Material Cost/lb. | *Installed Cost/ft. |
|---|---|---|---|---|
| Dow Corning Silicone #888 | | 10/5/83 | $2.81 | $1.27 |
| GE Silicone | | 10/5/83 | $2.81 | $1.27 |
| Preformed Neoprene | | 10/5/83 | 1.25/lin ft | $3.10 |
| Allied Joint Compound | | 10/5/83 | 0.40 | $0.52 |
| Crafco | RS 221 | 10/5/83 | 0.43 | $0.52 |
| | RS 211 | 10/6/83 | 0.42 | $0.52 |
| | RS 213 | 10/7/83 | 0.46 | $0.53 |
| | RS 231 | 10/7/83 | 0.73 | $0.57 |
| | AR Mod | 10/11/83 | 0.33 | $0.50 |
| | AR Plus | 10/11/83 | 0.41 | $0.52 |
| HFE 100 SC | | 10/17/83 | 0.13 | $0.47 |

* Includes joint preparation