Report No. CDOT-DTD-R-96-10

# Long-Term Performance of
## Accelerated Rigid Pavements, Project CXMP 13-0006-07

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Final Report
October, 1996

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

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# REPORT DOCUMENTATION PAGE

FORM APPROVED
OMB NO. 0704-0188



| 1. AGENCY USE ONLY (Leave Blank) | 2. REPORT DATE | 3. REPORT TYPE AND DATES COVERED |
|---|---|---|
| | October 1996 | Final Report |

**4. TITLE AND SUBTITLE**
Long-Term Performance of Fast Track Pavement, Colorado Project CXMP 13-0006-07

**5. FUNDING NUMBERS**
20.02

**6. AUTHORS(S)**
Ahmad Ardani

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(S)**
Colorado Department of Transportation
4201 E. Arkansas Ave.
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**8. PERFORMING ORGANIZATION REPORT NUMBER**
CDOT-DTD-R-96-10

**9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(S)**
Colorado Department of Transportation
4201 E. Arkansas Ave.
Denver, Colorado 80222

**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**

**11. SUPPLEMENTARY NOTES**
Prepared in Cooperation with the U.S. Department of Transportation, Federal Highway Administration

**12a. DISTRIBUTION/AVAILABILITY STATEMENT**
No Restrictions: This report is available to the public through the National Technical Information Service. Springfield, VA 22161

**12b. DISTRIBUTION CODE**

**13. ABSTRACT** (Maximum 200 words)

This report describes the post-construction evaluation of the fast track pavement in Sterling Colorado.. The field evaluation consisted of visual inspection, fault measurement, profile measurement and distress survey. A set of falling weight deflectometer (FWD) measurements was also acquired to assess the structural responses and to evaluate load transfer efficiency between the slabs.

The results of this study demonstrated that fast track concrete can be as durable as the conventional concrete pavement. After seven years of being in service the pavement has shown no sign of fatigue, only some minor distresses unrelated to fast track techniques.

Implementation: The use of fast track techniques, where suitable, is recommended.

**14. SUBJECT TERMS**
Accelerated Rigid Pavememt
Long-Term Performance
Fast Track

**15. NUMBER OF PAGES**
26

**16. PRICE CODE**

| 17. SECURTITY CLASSIFICATION OF REPORT | 18. SECURITY CLASSIFICATION OF THIS PAGE | 19. SECURITY CLASSIFICATION OF ABSTRACT | 20. LIMITATION OF ABSTRACT |
|---|---|---|---|
| Unclassified | Unclassified | Unclassified | |

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**Long-Term performance of Accelerated Rigid Pavements, Project CXMP 13-0006-07**

**Final Report**

**October, 1996**

## I. Background

The concept of accelerated rigid paving techniques (fast track) have been developed primarily, to minimize the impact of street closure, both in new construction as well as in rehabilitation projects.

The first phase of this study dealt with using fast track paving techniques and examining the effectiveness of a maturity meter in monitoring the strength gain of concrete pavement. The results of the first phase showed that fast track paving can reduce time needed to complete a project and minimize traffic delays. Furthermore, it was proven that the maturity meter can be used effectively for monitoring strength gain in concrete pavement.

The accelerated rigid paving technique was used on a project located on US 6 in Sterling Colorado, approximately 130 miles northeast of Denver. This six-lanes facility was experiencing an Average Daily Traffic (ADT), of 9600 vehicles with 6.4 percent of that volume consisting of heavy vehicles. This project consisted of paving 13,400 sq. yds. of an 8-inch plain jointed non-doweled, high early strength concrete covering six intersections. The concrete mix design called for 610-pound of Type III cement with added 20 percent Class F fly ash. Appendix A shows the details of the concrete mix design. For more information on the first phase of this study refer to **Report No. CDOH-DTD-R-89.**

Over the past few years much attention has been given to the use of accelerated paving (fast track) techniques in PCC pavements. According to a publication by American Concrete Pavement Association (ACPA), "Fast Track Concrete Pavements", fast track concrete pavement provides an alternative that can help meet the public's demand for solutions to congestion, traffic interruption and delays (2).

Although we are aware of their use by various paving industries and transportation agencies, there are questions regarding the long-term performance and durability of fast track jobs which need to be addressed. The intent of the second phase of this study is to observe and document the performance of the fast-track project in the field under actual traffic conditions.

## II. Literature Review

A Transportation Research Information Service (TRIS) search on the subject of "Long-Term Performance of Fast Track Concrete Paving", revealed very little regarding long-term results. Perhaps this is because fast track is still a relatively new technology dating back to the late 1980's.

## III. Objective

The primary objective of this study was to evaluate the long-term performance (post construction) of a fast track job constructed during the summer of 1989 in Sterling, Colorado.

## IV. Construction Summary

The project involved the rehabilitation of two one-way streets in the town of Sterling, located in north-eastern Colorado (1). The rehabilitation consisted of removal of an approximately 50-year old concrete pavement, base stabilization with lime, and paving two one-half mile long street sections.

The construction consisted of paving 13,400 sq. yds. With an 8-inch plain jointed non-doweled, high early strength portland cement concrete (PCC) without curb and gutter. Four test sections within the project were established for testing. The entire paving project utilized 610-pound Type III cement with added 20 percent Class F fly ash. Curing compound was used on the entire project. In addition, insulating blankets were used on one of the test sections (1). Appendix A shows the details of the concrete mix design developed for this project.

## V. Field Evaluation

Two rounds of inspection were conducted for this 6-year old fast track project; one during the month of September, 1991; and one in September of 1995. There was very little difference between the two inspections. Perhaps because the pavement is still relatively new (constructed in September, 1989). The field evaluation consisted of visual inspection, fault measurement, profile measurement and distress survey. A set of falling weight deflectometer (FWD) measurements was also acquired in early October, 1996 to assess the structural responses and to evaluate load transfer efficiency between the slabs. The following is the summary of the results:

### A. Visual Investigation

In general, the pavement surface appeared to be in good condition with minimal distresses. Overall, less than one percent of the slabs showed minor to moderate distresses. These distresses were primarily in the forms of small corner breaks, moderate sealant deterioration, minor spalling, moderate faulting and minor hairline cracks.

Hairline cracks adjacent and approximately parallel to transverse joints were detected at three isolated locations as shown in Photographs 1 through 3. This type of distresses are primarily attributed to over-working or over-finishing the concrete paste and are referred to as shrinkage cracking. Shrinkage cracks are shallow, fine cracks extending approximately 6 millimeters (1/4 of an inch) through the upper surface of the concrete (3). Discoloration of the immediate area, surrounding the cracks yield the presence of calcium hydroxide residue.

Photograph 4 shows some diagonal cracks which are believed to be caused by the irregular spacing of the joints at the transition between the manhole and the adjacent slabs.

Minor corner breaks were noted at few isolated locations (Photograph 5 and 6). These types of failures are primarily attributed to the lack of support or poor load transfer (non-doweled concrete slabs). It is CDOT's standard practice to not use load transfer devices for facilities with speed limits of less than 45 mph.

The principal failure mode observed at this location was sealant

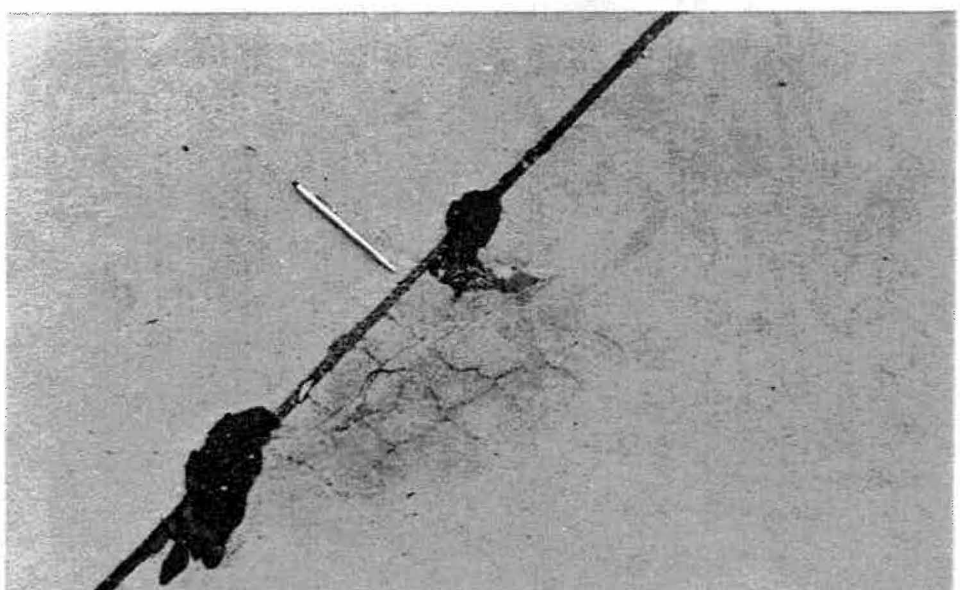


Photo 1&2: Localized Shrinkage Cracking.

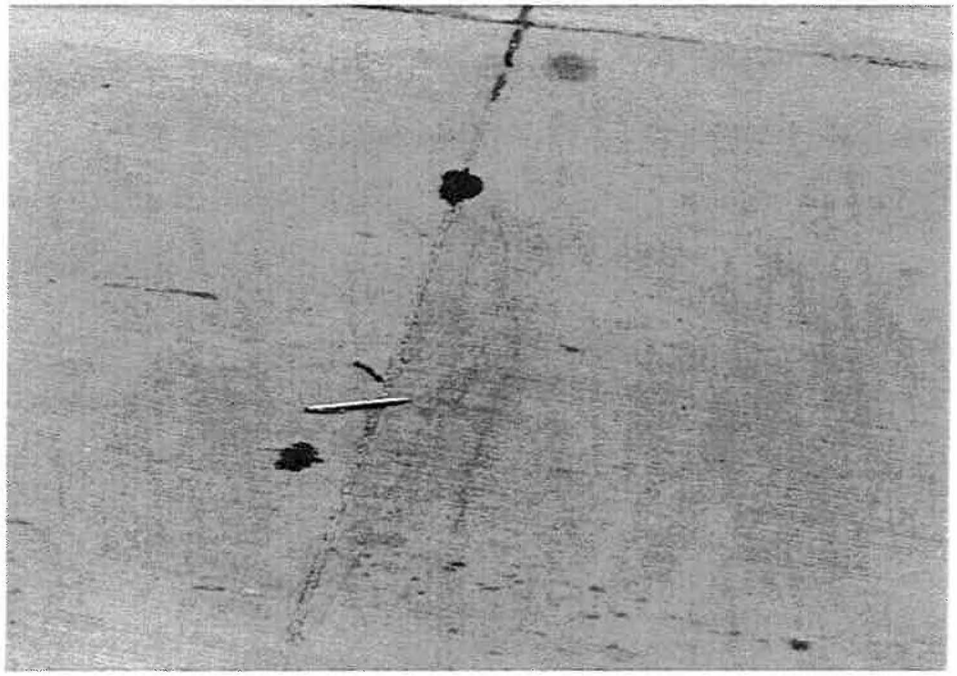


Photo 3: Shrinkage Cracking

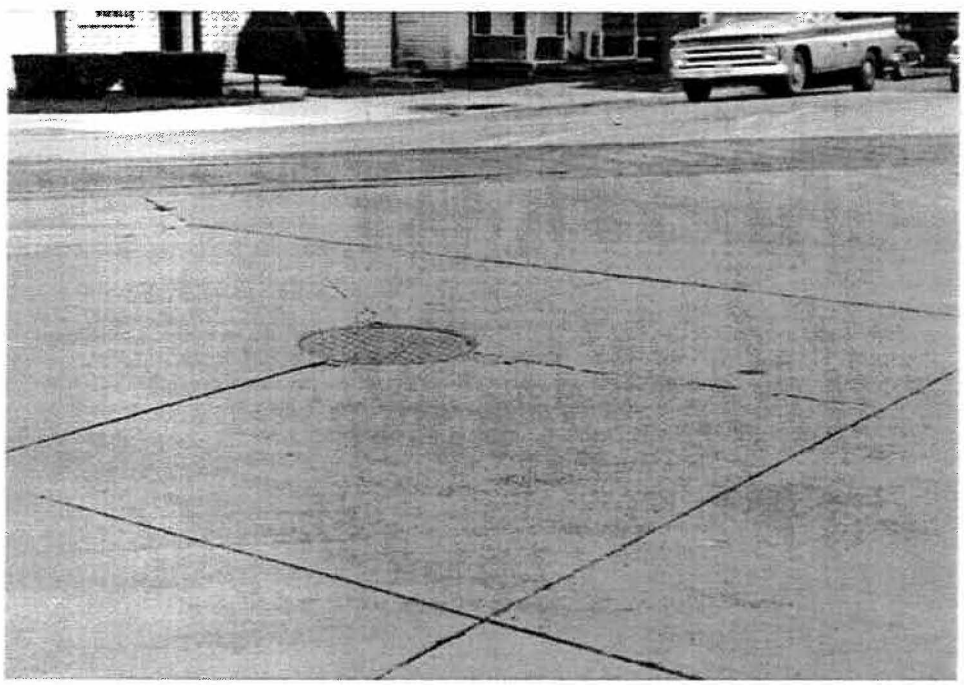


Photo 4: Formation of diagonal cracks due to presence of manhloe and/or irregular joint spacing.

related failures. The joints were overfilled with sealant material in many places (photograph 7). Cohesion, adhesion and extrusion failures were quite evident throughout the project as shown in Photograph 8.

Spall-related failures caused by the intrusion of incompressibles were also evident in few locations (Photograph 9).

## B. Faulting

Faulting is the difference between the elevation of the leave and the approach-slab and is measured one foot from the outside edge of the slab. A significant number of slabs exhibited faulting with varying degree of severity (table 1).

The SHRP Faultmeter, developed by Georgia Department of Transportation and assembled by Colorado DOT, was used to measure faulting at this site. This electronic digital faultmeter measures concrete joint faulting to the nearest 1 millimeter (Photograph 10).

The magnitude of faulting measured at this location ranged from a high of 6 millimeters (approximately 0.24 inches) to a low of 1 millimeter (0.04 inches). The overall average faulting measured was 3.0 millimeter (approximately 0.15 inches).

| FAULTING OCT. 19, 1995 | | | |
|---|---|---|---|
| Center of Left Edge of Slab | | | |
| Joint Num | Faultin (mm) | Joint Num | Faultin (mm) |
| 1 | 4.7 | 31 | 1.4 |
| 2 | 2.4 | 32 | 3.8 |
| 3 | 2 | 33 | 3.2 |
| 4 | 3.3 | 34 | 2.1 |
| 5 | 6.4 | 35 | 3.2 |
| 6 | 5.2 | 36 | 4.4 |
| 7 | 4.8 | 37 | 1.3 |
| 8 | 2.2 | 38 | 2 |
| 9 | 2.2 | 39 | 3.2 |
| 10 | 4.5 | 40 | 3.3 |
| 11 | 4.1 | 41 | 3.4 |
| 12 | 2.4 | 42 | 1.7 |
| 13 | 3.3 | 43 | 1.8 |
| 14 | 4.6 | 44 | 1.4 |
| 15 | 1.9 | 45 | 1 |
| 16 | 3.2 | 46 | 2.1 |
| 17 | 2.2 | 47 | 2.5 |
| 18 | 2.7 | 48 | 2.4 |
| 19 | 4.5 | 49 | 1.5 |
| 20 | 2.3 | 50 | 4.1 |
| 21 | 1.9 | 51 | 2.4 |
| 22 | 2.8 | 52 | 2.9 |
| 23 | 5.3 | 53 | 3.1 |
| 24 | 2.9 | 54 | 3.6 |
| 25 | 4.1 | 55 | 3.8 |
| 26 | 3.6 | 56 | 5.2 |
| 27 | 2.6 | 57 | 4.3 |
| 28 | 0.9 | 58 | 2.5 |
| 29 | 1.7 | 59 | 3.1 |
| 30 | 5.5 | 60 | 0.8 |

Average Fault = 3.02mm

Table 1

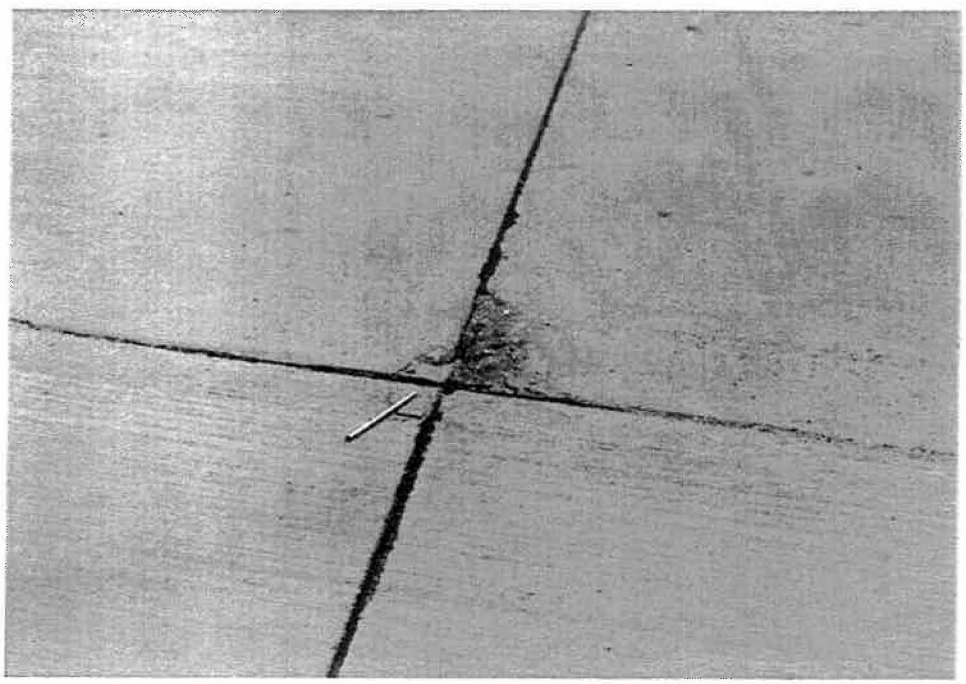


Photo 5&6: Minor corner breaks noted at two locations.

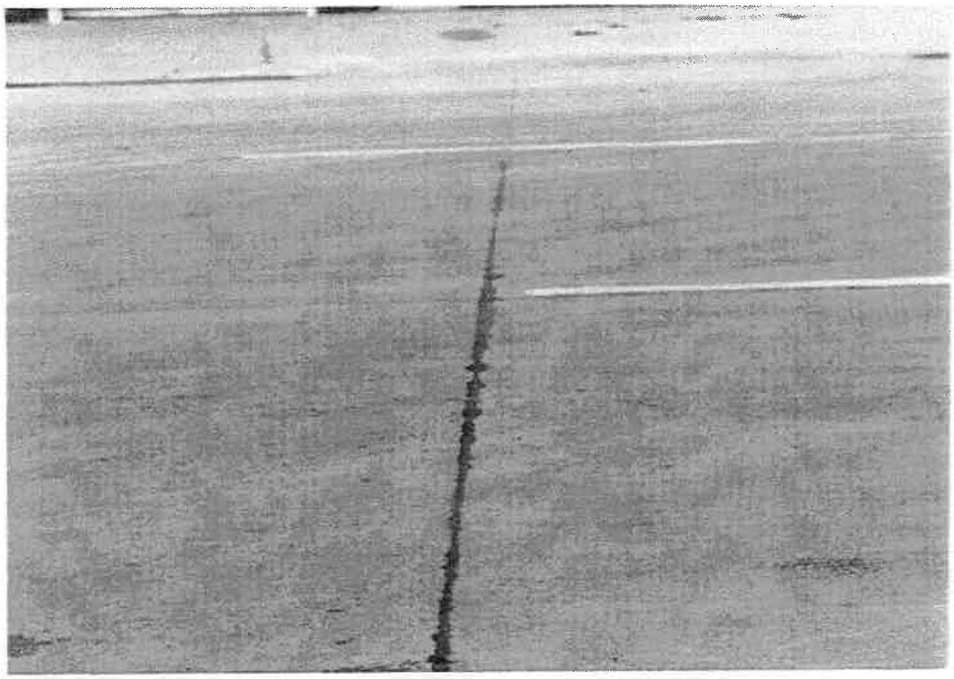


Photo 7: Example of an overfilled joint.

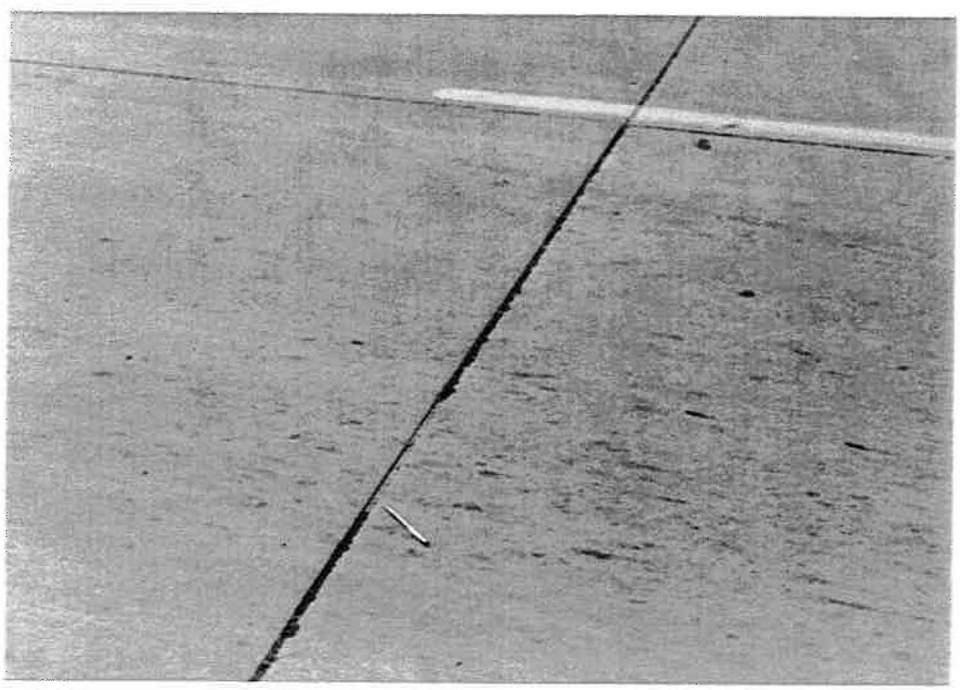


Photo 8: Badly deteriorated sealant materials.

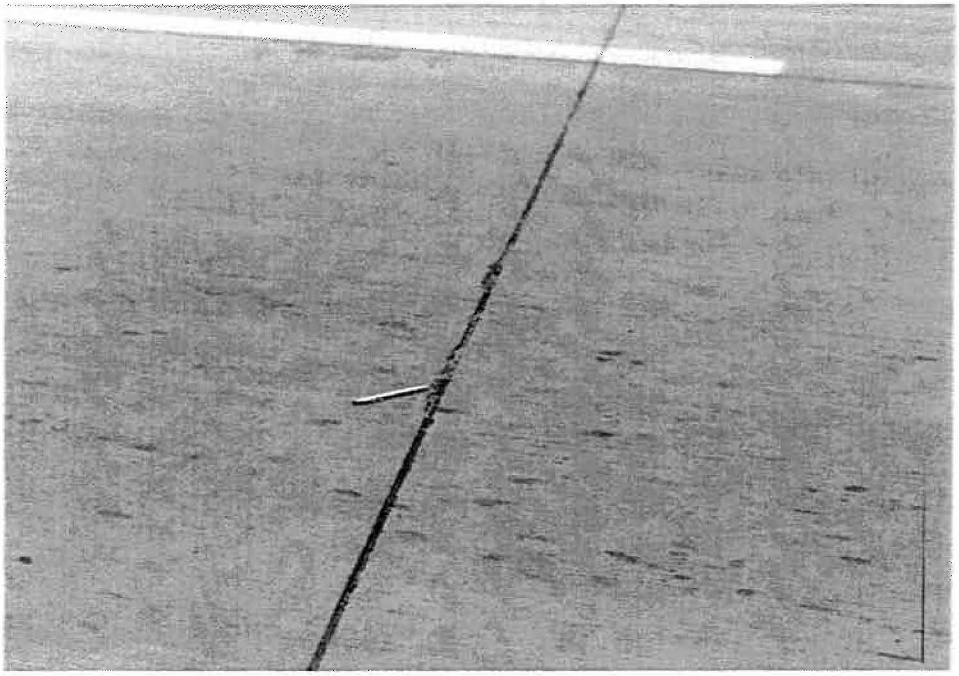


Photo 9: Minor joint spalling

## C. Deflections

To assess the structural response and the load transfer efficiency across the joints, deflection measurements were acquired using a falling weight deflectometer (FWD) at the leave-slab, approach-slab and at the mid-slab (Figure 1).

Maximum deflections (normalized to 9,000 lb) and load transfer efficiency rates between the slabs are shown in Figure 2 and 3. It appears that the slabs are structurally sound with an average deflection of 9.4 mils at mid-slabs. However, because the slabs were not equipped with load transfer devices ( no dowel bars), the average deflection at the approach and at the leave-slabs measured high (25.0 and 31.5 mils respectively) indicating poor rate of load transfer between the slabs.

It is a proven fact that dowel bars play a major role in reducing the critical stresses in the mainline slabs. As a portion of the load is transferred from the loaded slab to the adjacent slab, the magnitude of the stresses in the loaded slab are reduced by the amount of load transferred.

The rate of load transfer efficiency (LTE) is defined by the following equation:

$$LTE = dU/dL$$

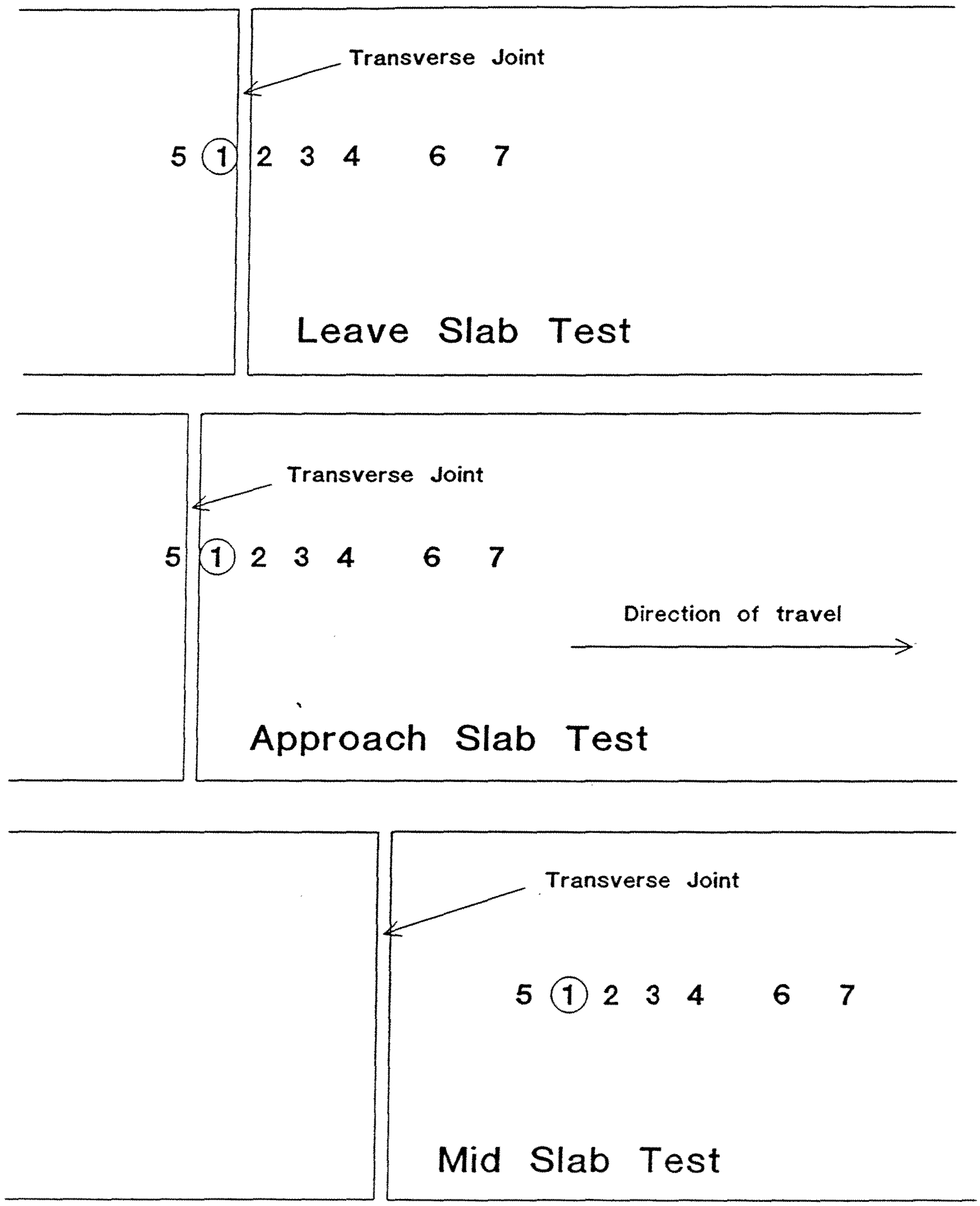
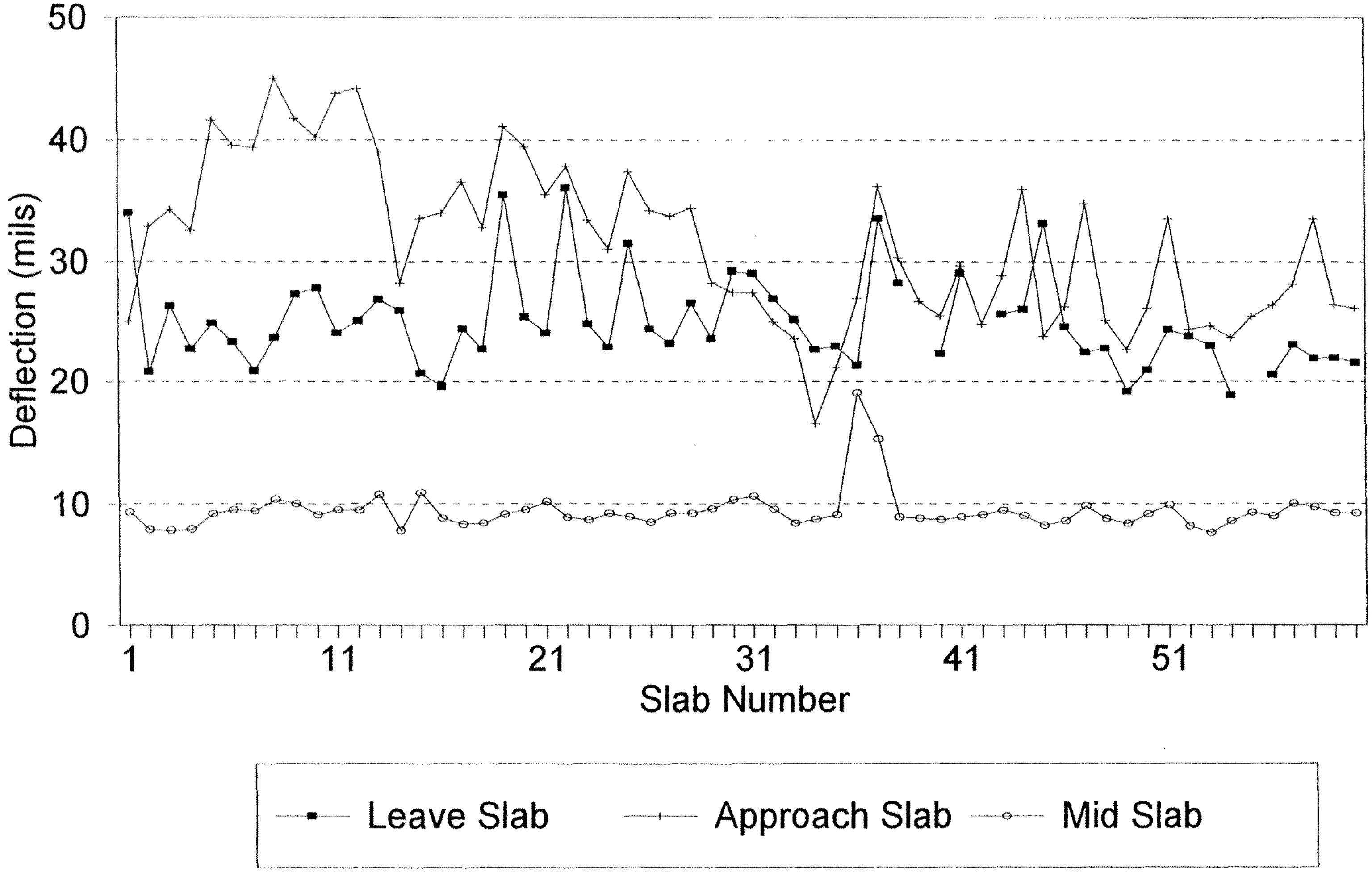

Transverse Joint
5 1 2 3 4 6 7
Leave Slab Test
Transverse Joint
5 1 2 3 4 6 7
Direction of travel
Approach Slab Test
Transverse Joint
5 1 2 3 4 6 7
Mid Slab Test

Figure 1

# FASTTRACK PAVING 10/20/95

Deflections (normalized to 9000 lb)




AVERAGES: LEAVE SLAB 25.0 APPROACH SLAB 31.5 MID SLAB 9.4

Figure 2

where

LTE = rate of load transfer in percent.

dU = unloaded slab deflection

dL = loaded slab deflection

As it can be seen on figure 3 the average rate of load transfer from the leave-slabs to the approach-slabs are approximately 52 percent. The average rate of load transfer from the approach-slabs to the leave slabs were only 20 percent. The poor rate of load transfer between the slabs are primarily attributed to the lack of dowel bars. For a complete review of the maximum deflections and load transfer efficiency rates refer to table 2.

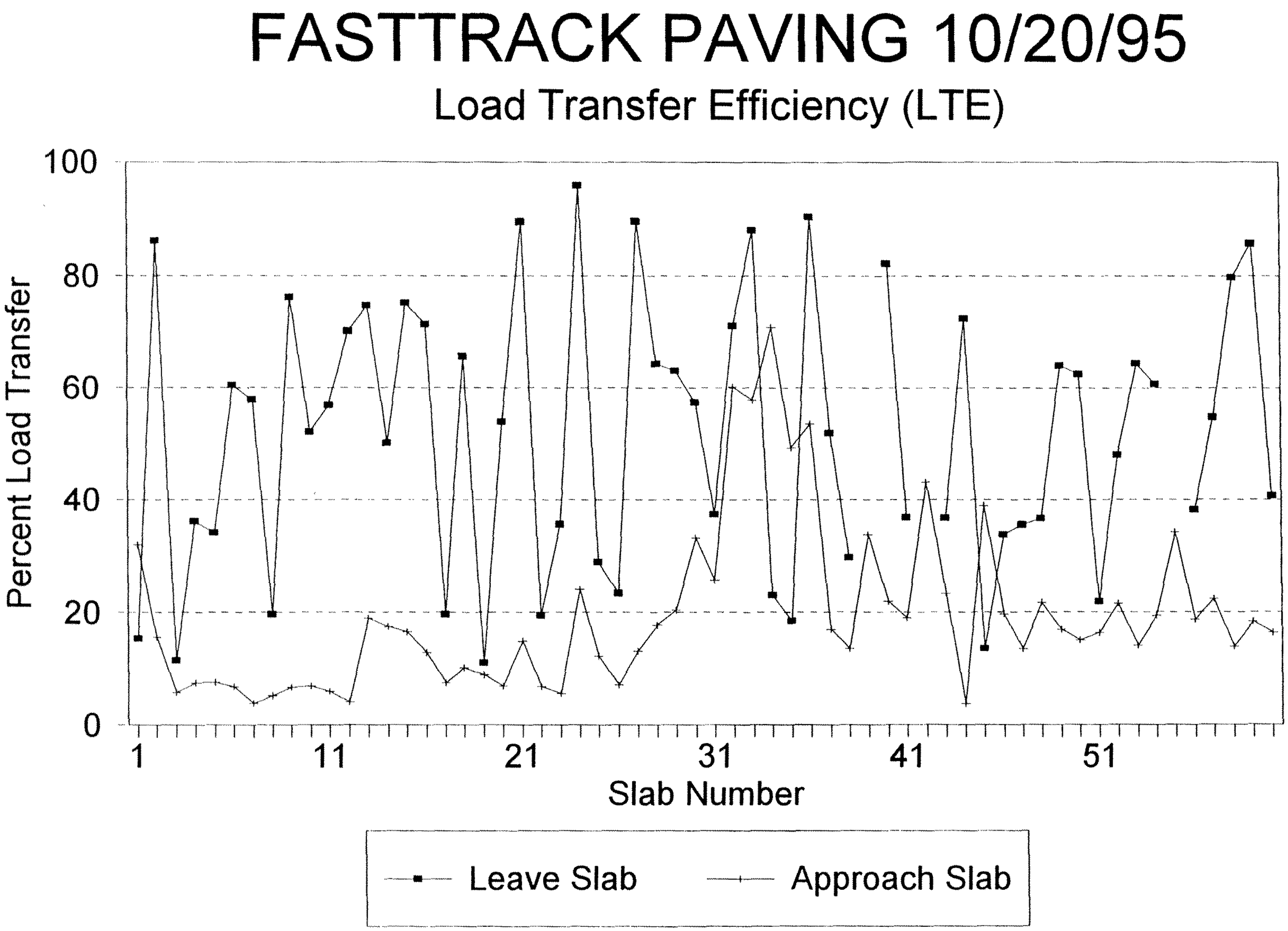
### D. Roughness

The right wheel path (RWP) and the left wheel path (LWP) roughness was measured using an Ames profilograph. Overall, the pavement appeared quite rough, with an average roughness of 27 inches per mile. However, due to a lower speed limit at this location (25 - 30 mph), the impact of roughness on the pavement performance will be minimal.

## VI. Summary And Conclusions

Based on the results of this project, the following is concluded:

- In general, the performance of fast track project in Sterling,




AVERAGE LTE: LEAVE SLAB 52% APPROACH SLAB 20%

Figure 3

| FAST TRACK | | | | | | | |
|---|---|---|---|---|---|---|---|
| FWD DEFLECTIONS (in mils normalized to 9000 lb load) | | | | | | | |
| | APPROACH SLAB | | | LEAVE SLAB | | | MID SLAB |
| | | | LTE | | | LTE | |
| SLAB | Sensor | Sensor | Sensor | Sensor | Sensor | Sensor | Sensor |
| | # 1 | #2 | #2/#1 | #1 | #5 | #5/#1 | #1 |
| 1 | 34.02 | 5.17 | 0.15 | 25.10 | 8.02 | 0.32 | 9.29 |
| 2 | 20.82 | 17.94 | 0.86 | 32.86 | 5.11 | 0.16 | 7.87 |
| 3 | 26.38 | 3.00 | 0.11 | 34.27 | 1.93 | 0.06 | 7.82 |
| 4 | 22.76 | 8.23 | 0.36 | 32.59 | 2.41 | 0.07 | 7.91 |
| 5 | 24.93 | 8.50 | 0.34 | 41.54 | 3.13 | 0.08 | 9.15 |
| 6 | 23.36 | 14.13 | 0.60 | 39.55 | 2.69 | 0.07 | 9.51 |
| 7 | 20.92 | 12.10 | 0.58 | 39.34 | 1.50 | 0.04 | 9.41 |
| 8 | 23.74 | 4.64 | 0.20 | 45.00 | 2.31 | 0.05 | 10.38 |
| 9 | 27.36 | 20.84 | 0.76 | 41.69 | 2.77 | 0.07 | 9.98 |
| 10 | 27.83 | 14.49 | 0.52 | 40.21 | 2.76 | 0.07 | 9.08 |
| 11 | 24.13 | 13.73 | 0.57 | 43.76 | 2.59 | 0.06 | 9.48 |
| 12 | 25.12 | 17.62 | 0.70 | 44.15 | 1.79 | 0.04 | 9.47 |
| 13 | 26.90 | 20.08 | 0.75 | 38.98 | 7.35 | 0.19 | 10.76 |
| 14 | 26.00 | 13.04 | 0.50 | 28.25 | 4.92 | 0.17 | 7.76 |
| 15 | 20.69 | 15.54 | 0.75 | 33.49 | 5.48 | 0.16 | 10.90 |
| 16 | 19.61 | 14.00 | 0.71 | 34.00 | 4.33 | 0.13 | 8.78 |
| 17 | 24.46 | 4.79 | 0.20 | 36.54 | 2.72 | 0.07 | 8.31 |
| 18 | 22.74 | 14.94 | 0.66 | 32.82 | 3.29 | 0.10 | 8.39 |
| 19 | 35.43 | 3.87 | 0.11 | 41.05 | 3.60 | 0.09 | 9.18 |
| 20 | 25.44 | 13.70 | 0.54 | 39.37 | 2.69 | 0.07 | 9.52 |
| 21 | 24.13 | 21.60 | 0.90 | 35.48 | 5.22 | 0.15 | 10.16 |
| 22 | 36.08 | 6.98 | 0.19 | 37.78 | 2.55 | 0.07 | 8.87 |
| 23 | 24.89 | 8.89 | 0.36 | 33.41 | 1.83 | 0.05 | 8.61 |
| 24 | 22.91 | 21.96 | 0.96 | 31.04 | 7.45 | 0.24 | 9.23 |
| 25 | 31.48 | 9.08 | 0.29 | 37.39 | 4.56 | 0.12 | 8.87 |
| 26 | 24.44 | 5.69 | 0.23 | 34.19 | 2.40 | 0.07 | 8.44 |
| 27 | 23.19 | 20.77 | 0.90 | 33.74 | 4.37 | 0.13 | 9.20 |
| 28 | 26.62 | 17.12 | 0.64 | 34.45 | 6.09 | 0.18 | 9.21 |
| 29 | 23.62 | 14.88 | 0.63 | 28.25 | 5.74 | 0.20 | 9.60 |
| 30 | 29.22 | 16.76 | 0.57 | 27.44 | 9.10 | 0.33 | 10.30 |
| 31 | 29.01 | 10.87 | 0.37 | 27.44 | 7.05 | 0.26 | 10.61 |
| 32 | 26.99 | 19.17 | 0.71 | 25.08 | 15.09 | 0.60 | 9.57 |
| 33 | 25.19 | 22.18 | 0.88 | 23.58 | 13.62 | 0.58 | 8.38 |
| 34 | 22.72 | 5.23 | 0.23 | 16.52 | 11.69 | 0.71 | 8.67 |
| 35 | 23.02 | 4.25 | 0.18 | 21.22 | 10.46 | 0.49 | 9.07 |
| 36 | 21.34 | 19.28 | 0.90 | 26.99 | 14.43 | 0.53 | 19.10 |
| 37 | 33.49 | 17.37 | 0.52 | 36.17 | 6.09 | 0.17 | 15.28 |
| 38 | 28.26 | 8.39 | 0.30 | 30.34 | 4.07 | 0.13 | 8.87 |
| 39 | | | | 26.75 | 9.03 | 0.34 | 8.79 |
| 40 | 22.34 | 18.33 | 0.82 | 25.53 | 5.58 | 0.22 | 8.62 |
| 41 | 29.01 | 10.68 | 0.37 | 29.67 | 5.62 | 0.19 | 8.89 |
| 42 | | | | 24.90 | 10.74 | 0.43 | 9.04 |
| 43 | 25.72 | 9.45 | 0.37 | 28.88 | 6.73 | 0.23 | 9.44 |
| 44 | 26.11 | 18.92 | 0.72 | 35.93 | 1.36 | 0.04 | 8.95 |
| 45 | 33.12 | 4.45 | 0.13 | 23.83 | 9.28 | 0.39 | 8.17 |
| 46 | 24.62 | 8.31 | 0.34 | 26.32 | 5.18 | 0.20 | 8.56 |
| 47 | 22.46 | 7.98 | 0.36 | 34.78 | 4.64 | 0.13 | 9.80 |
| 48 | 22.79 | 8.35 | 0.37 | 25.15 | 5.45 | 0.22 | 8.71 |
| 49 | 19.24 | 12.33 | 0.64 | 22.72 | 3.84 | 0.17 | 8.32 |
| 50 | 21.02 | 13.14 | 0.62 | 26.23 | 3.92 | 0.15 | 9.15 |
| 51 | 24.40 | 5.34 | 0.22 | 33.50 | 5.47 | 0.16 | 9.87 |
| 52 | 23.84 | 11.43 | 0.48 | 24.45 | 5.25 | 0.21 | 8.16 |
| 53 | 23.06 | 14.85 | 0.64 | 24.73 | 3.47 | 0.14 | 7.55 |
| 54 | 18.97 | 11.51 | 0.61 | 23.68 | 4.58 | 0.19 | 8.51 |
| 55 | | | | 25.46 | 8.72 | 0.34 | 9.24 |
| 56 | 20.59 | 7.89 | 0.38 | 26.48 | 4.95 | 0.19 | 8.97 |
| 57 | 23.14 | 12.64 | 0.55 | 28.15 | 6.29 | 0.22 | 10.05 |
| 58 | 21.99 | 17.52 | 0.80 | 33.50 | 4.62 | 0.14 | 9.68 |
| 59 | 21.99 | 18.83 | 0.86 | 26.48 | 4.84 | 0.18 | 9.22 |
| 60 | 21.61 | 8.78 | 0.41 | 26.16 | 4.27 | 0.16 | 9.19 |
| AVG | 25.00 | 12.48 | 0.52 | 31.47 | 5.45 | 0.20 | 9.36 |

Table 2

Colorado has been excellent. The results of this research study demonstrated that fast track concrete pavement can be as durable as the conventional concrete pavement. After seven years of being in service the pavement has shown no sign of fatigue, only some minor distresses unrelated to fast track techniques.

- During the evaluation of the fast track project in Sterling, some minor distresses were detected. These distresses which were primarily in the form of localized shrinkage cracking, sealant related failures and minor spalling are construction related and are not attributed to fast track techniques.

- Fast Track concrete construction requires minimal changes in the traditional mix design procedures and construction practices.

- The use of fast track techniques, where suitable, is recommended along with close attention being paid to project planning, mix design, quality of materials, and quality of construction.

## VII. References


1- Hutter, Werner, "Accelerated Rigid Paving Techniques, Colorado Project CXMP 13-0006-07, Special Project 201" Report No. CDOH-DTD-R-89-6, 1989.

2- American Concrete Pavement Association (ACPA), "Fast Track Pavements", Technical Bulletin, TB-004.0 IT, 1989.

3- U.S. DOT/Federal Highway Administration, "Higway Pavement Distress Identification Manual", 1979.

Appendix A

COMMERCIAL TESTING LABORATORIES

A DIVISION OF CTL/THOMPSON, INC.

March 23, 1989

Irving F. Jensen Company, Inc.
P.O. Box 1148
Castle Rock, Colorado 80104

Attention: Mr. Dave Clark

Subject: Job No. 4044
Trial Mix Study for
CDOH Class AX Paving Mix
Sterling City Street Project
Sterling, Colorado

Dear Sir:

This report presents results of our trial mix study and tests associated with our studies to establish proportions for a concrete paving mix for the Sterling City Street Project, Sterling, Colorado. One concrete mix was proportioned and tested to verify compliance with the requirements of a CDOH Class AX concrete paving mix.

**Concrete Mix Design Criteria:**

In accordance with your instructions and CDOH specifications, the following criteria and materials were used to proportion the mix:

| | |
|---|---|
| Cementitious Materials Content: | 610 lbs + 20% Nixon Class F Fly Ash |
| Total Air Content: | 4.0 - 8.0 percent |
| Slump: | 2-1/2 to 3-1/2 inches |

Materials:
- Cement - Ideal, Type III
- Fly Ash - Nixon, Class F
- Sand - McAtee
- Size No. 67 Aggregate - Connell Resourses
- Air-Entraining Admixture - Con Ad AEA, Eagle Admixtures
- Water-Reducing Admixture - Con Ad N (3.5 ozs/cwt), Eagle Admixtures

**Concrete Aggregates:**

Concrete aggregates were tested for properties needed to compute mix proportions and to verify compliance with CDOH and AASHTO specifications. Results of these tests are presented in Table No. 1. The aggregates tested meet the requirements of AASHTO and CDOH for the properties tested.

**Trial Mix Proportions and Physical Properties:**

One mix was proportioned in general accordance with ACI 211, "Recommended Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete". Proportions and physical properties are presented in Table No. 2. Mix proportions and compressive strength tests indicate mix Y-1680 meets CDOH criteria to qualify as a Class AX concrete mix.

In an attempt to determine when you could reasonably expect in-situ compressive strengths of 2500 psi, cylinders were placed ouside our lab in a thermostatically controlled curing box. We attempted to maintain the curing temperature at $45^{O}$F, however, unusually warm weather caused our curing box to have an actual average temperature of $59^{O}$F. We tested two cylinders cured in this box for 56 hours. The average compressive strength was 3580 psi. Using a linear interpretation of the rate of reaction of portland cement versus temperature, it is our opinion the concrete mixture tested would have attained a compressive strength of 2500 psi between 2-1/2 and 3 days when cured in an average temperature of 45 degree Fahrenheit.

If you have any questions regarding this report, or if we can be of further service, please call.

Very truly yours,

COMMERCIAL TESTING LABORATORIES

Richard J. Hammerberg, P.E.,
Project Engineer

Reviewed By:

Orville R. Werner II, P.E.,
Senior Engineer

RJH/ORW/drw

Enclosures

**TABLE NO. 1, Page 1 of 2**

## PHYSICAL PROPERTIES OF AGGREGATES

Client: Irving F. Jensen Company, Inc.
Aggregate Source: Fine Aggregate - McAtee
Coarse Aggregate - Connell Resources, Fort Collins, Co.

AASHTO T 27, Sieve Analysis of Fine and Coarse Aggregates

| Sieve Size | Connell Resources 3/4-Inch Sample % Pass | Size No. 67 AASHTO M 43 Specs. % Pass | McAtee Fines Sample % Pass | Blended Mat'l Material, 37% #67, 63% Fines Sample % Pass | Class AX CDOH Specs. % Pass |
|---|---|---|---|---|---|
| 1 inch | 100 | 100 | | 100 | 100 |
| 3/4 inch | 100 | 90-100 | | 100 | - |
| 1/2 inch | 72 | - | 100 | 90 | 65-90 |
| 3/8 inch | 32 | 20-55 | 99 | 74 | - |
| No. 4 | 2 | 0-10 | 93 | 59 | 45-70 |
| No. 8 | 0.5 | 0-5 | 81 | 51 | 35-55 |
| No. 16 | | | 63 | 40 | 20-45 |
| No. 30 | | | 39 | 24 | 5-25 |
| No. 50 | | | 15 | 9 | - |
| No. 100 | | | 4 | 2.5 | 0-5 |
| AASHTO T 11, Material Finer Than No. 200 Sieve by Washing, (%): | 0.3 | | 0.9 | 3.0% Max. | |
| Fineness Modulus: | | | 3.06 | 2.3 - 3.1 | |
| Sand Equivalency: | | | 97 | | 80 Min. |

AASHTO T 85/T 84, Specific Gravity and Absorption of Course and Fine Aggregate

| Sample Identification | Specific Gravity Bulk (SSD) | Absorption (percent) |
|---|---|---|
| McAtee Fines | 2.58 | 0.8 |
| Connell Resources, Size #67 | 2.64 | 0.7 |

ASTM C 40, Organic Impurities in Fine Aggregate for Concrete

| Sample I.D. | Plate No. | AASHTO M 6 Specifications |
|---|---|---|
| McAtee Fines | 1 | Plate 3 or Less (Standard) |

**TABLE NO. 1, Page 2 of 2**

## PHYSICAL PROPERTIES OF AGGREGATES (CONT'D)

Client: Irving F. Jensen Company, Inc.

AASHTO T 96, Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

| | |
|---|---|
| Sample I.D.: | Connell Resources, Size No. 67 |
| Grading Used: | B, 500 Revolutions, 11 Spheres |
| Percentage of Wear: | 33.7% |
| AASHTO M-80 Specifications: | 50.0% Maximum |

CTL Job No. 4044
Date: March 23, 1989

22 LIPAN STREET DENVER, COLORADO 80223 303 / 825-3207

TABLE NO. 2

Client: Irving F. Jensen Company, Inc.
Aggregates: Coarse Aggregate - Connell Resources, Fort Collins, Colorado
Fine Aggregate - McAtee
Cement: Ideal Type III
Fly Ash: Nixon, Class F

**CONCRETE MIX PROPORTIONS**

Identification No.: Y-1680 Date Made: February 20, 1989

**MIX PROPORTIONS** (Per 1.01 Cubic Yard of Concrete)

| | | |
|---|---|---|
| Cement | 610 | lbs |
| Fly Ash | 122 | lbs |
| Con Ad N (3.5 ozs/cwt) | 25.6 | ozs |
| Con Ad AEA | 14.8 | ozs |
| Sand | 1710 | lbs |
| Coarse Aggregate (Size #67) | 1020 | lbs |
| Water | 290 | lbs (34.8 gals) |

In the above proportions, aggregate weight is for aggregate in the saturated, surface dry condition. Corrections must be made for aggregates that vary from these moisture conditions.

**PHYSICAL PROPERTIES OF CONCRETE**

| | |
|---|---|
| Unit Wt. of Mixed Concrete, pcf: | 140.8 |
| Slump, in.: | 3 |
| Air Content, % (Pressure Method, ASTM C 231): | 6.0 |
| Water/Cementitious Materials Ratio, (lb/lb): | 0.396 |

**COMPRESSIVE STRENGTH OF TEST CYLINDERS, psi**

| | 2-Day | 3-Day | 4-Day | 7-Day | 28-Day |
|---|---|---|---|---|---|
| | 3870 | 4700 | 5160 | 5540 | 6530 |
| | 4120 | 4780 | 5200 | 5600 | 6320 |
| | | | | | 6490 |
| Average: | 3995 | 4740 | 5180 | 5570 | 6445 |

COMMERCIAL TESTING LABORATORIES

Richard J. Hammerberg, P.E.

COLORADO REGISTERED RICHARD J. HAMMERBERG 25430 PROFESSIONAL ENGINEER

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