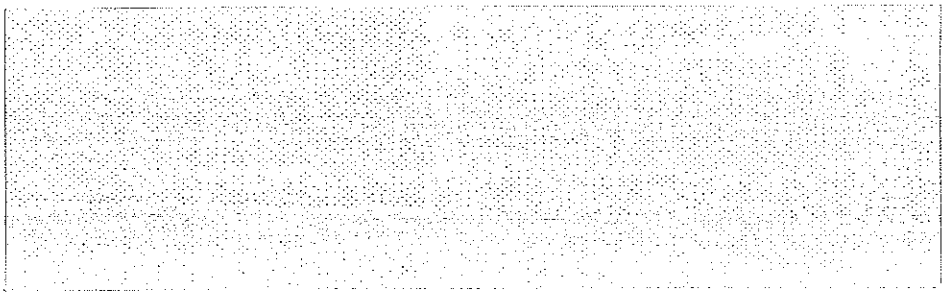
# EXPERIMENTAL CONCRETE AND BITUMINOUS SHOULDERS
Interim Report


## MATERIALS and TECHNOLOGY DIVISION





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Experimental concrete and bituminous shoulders interim report

# EXPERIMENTAL CONCRETE AND BITUMINOUS SHOULDERS
Interim Report

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A Category 2 project conducted in cooperation
with the U. S. Department of Transportation
Federal Highway Administration

Research Laboratory Section
Materials and Technology Division
Research Project 72 F-126
Research Report No. R-1271
Work Plan No. 13


Lansing, March 1985

# INTRODUCTION

This interim report covers the findings to date on the condition of Michigan's experimental concrete and bituminous shoulders. This is a Category 2 project conducted in cooperation with the U. S. Department of Transportation, Federal Highway Administration. The project was initiated to determine the relative cost[1] and performance of the portland cement concrete and improved bituminous stabilized shoulders on 20 projects.

## General Information

Twenty projects were to be used for evaluation of the condition and performance of shoulders; eleven were to be improved bituminous stabilized (IBS) shoulders, and nine were to be portland cement concrete (PCC) shoulders (Table 1). Because of changes at the time of construction or narrow shoulder width, projects 3, 9, and 12 were deleted from the evaluation and project 13 was reduced in length to a section that would permit a safe evaluation of its shoulder. The locations of the 20 projects are shown in Figure 1. Cross-sectional drawings showing shoulder design details are presented in Appendix A.

The projects range in length from 1.4 to 3.8 miles for the IBS shoulders and 0.5 to 8.9 miles for the PCC shoulders. The improved bituminous stabilized shoulders were constructed between April 1972 and the end of 1977 and the portland cement concrete shoulders were constructed between April 1972 and the end of 1978.

The performance of the shoulders was determined by condition surveys, noting the amount of cracking and other observable deterioration. The condition survey was conducted over a 10-mile test area (composite sample) for both the concrete and bituminous shoulders. The length of the test section for each project was determined by taking a percentage of the length of the project with respect to the total length of each shoulder type and multiplying that percentage (Table 2, Column 4) by the length of the test area (composite sample). The test section shoulder miles (SM) for the bituminous projects range from 0.6 to 1.7 miles and for the concrete projects the SM range from 0.2 to 3.9 miles (Table 2).

One of the bituminous shoulder projects (4) was used to carry traffic while traffic lanes were being replaced. The test sample length for project 4 was used to set up a separate test area (composite sample) and the project was surveyed for informational purposes only, as none of the other shoulder projects were used to carry traffic.

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[1]The relative costs of portland cement concrete and improved bituminous stabilized shoulders have been reported previously in MDOT Research Reports R-943 (1974) and R-1035 (1976).

TABLE 1
PROJECTS SELECTED FOR IMPROVED SHOULDER DESIGN

| Test Project No. | Project | Job No. | Location | Project Length, miles | Letting Date | Shoulder Material | Approximate Quantity, sq yd | Cost, sq yd |
|---|---|---|---|---|---|---|---|---|
| 1 | I-03035 | 00024A | I 196, 144th Ave to southeast of Ottawa County Line | 2.7 | 4-19-72 | Bituminous | 52,000 | $3.30 |
| 2 | I-82022 | 04280A | I 94, east of Haggerty to east of Ozra Rd | 2.0 | 5-17-72 | Bituminous | 51,000 | 4.60 |
| 3[1] | I-03035 | 00023A | I 196, north of 142nd St to southwest of 144th Ave | 4.2 | 7-19-72 | Bituminous | 68,000 | 3.10 |
| 4[2] | I-82191 | 02800A | I 75, Huron Rd to Gibralter Rd | 1.5 | 10-18-72 | Bituminous | 24,000 | 4.40 |
| 5 | I-82021 | 05126A | I 94 west of Borgman Rd easterly to west of Morton Rd and I 275 from C&O RR westerly and northerly to south of Huron River Dr, Wayne County | 1.7 | 1-17-73 | Bituminous | 52,000 | 3.90 |
| 6 | I-82021 | 05125A | I 94, west of Rawsonville Rd to west of Borgman Rd | 2.5 | 3-28-73 | Bituminous | 66,000 | 3.90 |
| 7 | I-82021 | 05127A | I 94, west of Morton Rd to east of Haggerty Rd | 1.4 | 5-16-73 | Bituminous | 38,000 | 4.00 |
| 8 | I-82293 | 04742A | I 275, M 153 to Plymouth Rd | 3.4 | 2-20-74 | Bituminous | 70,000 | 5.10 |
| 9[1] | I-82291[4] | 09904A | I 275, C&O RR north to I 275, I 94 interchange | 2.1 | 3-17-76 | Bituminous | 58,000 | 4.80 |
| 10 | I-82292[4] | 06537A | I 275, Hannan Rd north to PCRR | 3.2 | 4-21-76 | Bituminous | 60,000 | 4.90 |
| 11 | I-82292[4] | 06733A | I 275, PCRR to M 153, US 12 interchange | 3.8 | 5-19-76 | Bituminous | 71,000 | 4.90 |
| 12[1] | I-25031 | 04213A | I 75, Maple Rd to north of Arlene Dr, Flint | 3.3 | 12-20-72 | Concrete | 13,000 | 6.50 |
| 13 | I-25032 | 04215A | I 75, Grand Trunk Western RR to Pasadena Ave | 0.5 | 12-20-72 | Concrete | 23,000 | 8.50 |
| 14 | I-25032 | 04691A 04990A | I 75, south of M 57 to north of M 54 and M 83 | 5.9 | 12-20-72 | Concrete | 61,000 | 5.90 |
| 15 | I-25032 | 04991A | I 75, Pasadena to south of M 57 | 8.9 | 12-20-72 | Concrete | 95,000 | 5.90 |
| 16[3] | I-82123 | 04229A | I 96, M 39 east to St. Mary Ave | 0.6 | 4-18-73 | Concrete | 38,000 | 6.40 |
| 17 | I-82122 | 04533A | I 96, east of US 24 to east of Outer Dr | 1.0 | 10-17-73 | Concrete | 23,000 | 6.00 |
| 18[3] | I-82122 | 04534A | I 96, east of Outer Dr to Evergreen Ave | 1.0 | 10-17-73 | Concrete | 46,000 | 5.90 |
| 19[3] | I-82123 | 01270A | I 96, St. Mary Ave east | 1.4 | 10-24-73 | Concrete | 65,000 | 7.30 |
| 20 | I-82122 | 06547A | I 96, west of Newberg Rd east to east of Warren Ct, Livonia | 3.5 | 10-20-76 | Concrete | 77,000 | 5.50 |

[1] Project deleted from condition survey as the experimental shoulders were not placed or shoulders are too narrow to allow the condition survey to be conducted safely.

[2] Project used as temporary traffic lane in 1981.

[3] Project has local and express freeway lanes.

[4] Let as "Freeway Shoulders."

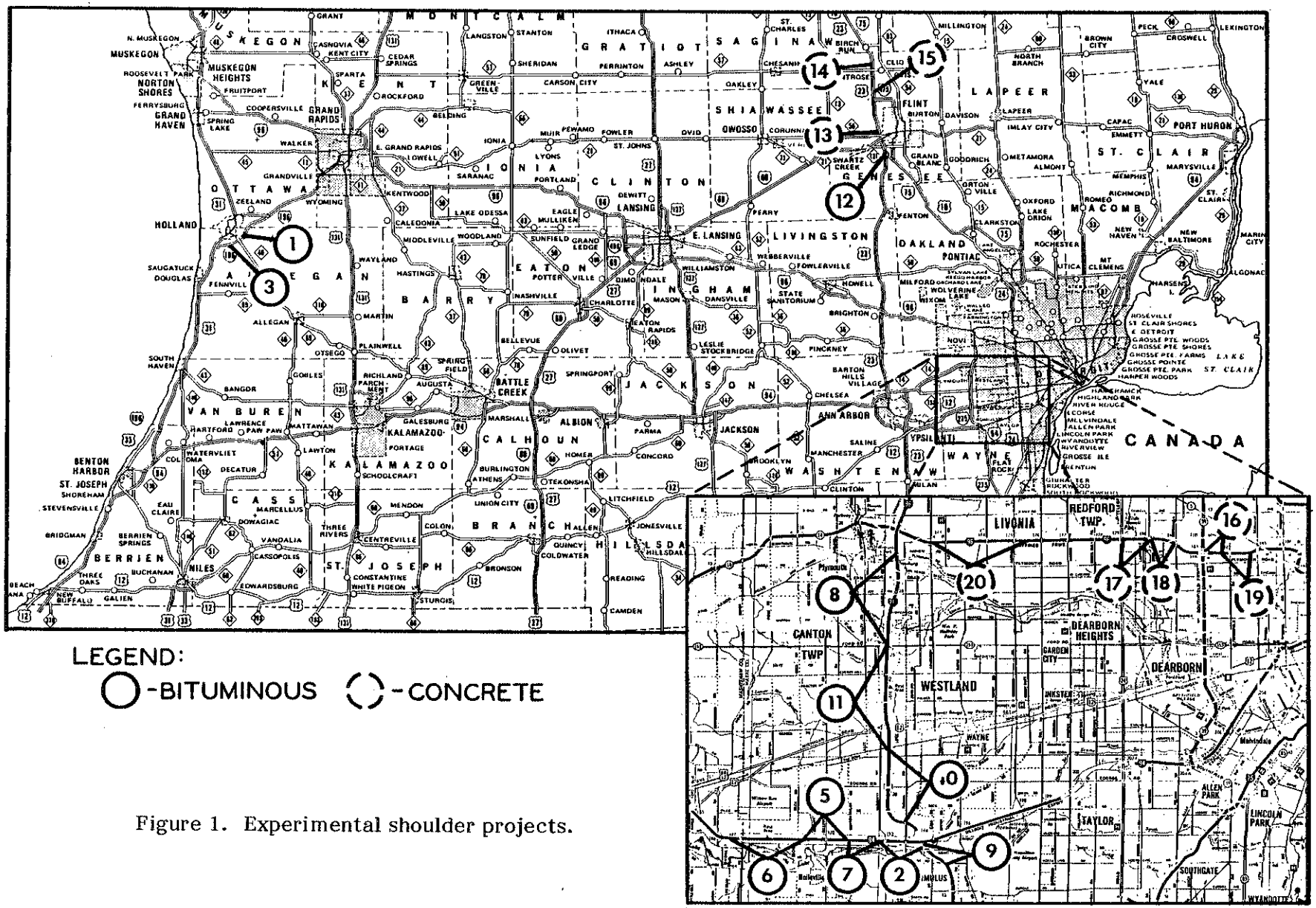



Figure 1. Experimental shoulder projects.

## TABLE 2
## EXPERIMENTAL PROJECTS SELECTED FOR IMPROVED SHOULDER DESIGN

| | Test Project No. | Year Completed | Length | | Traffic Data 1979 ADT | | Sand Subbase Thickness, in. | Aggregate Base Thickness, in. | Drainage Type [2] | Thick (Tapered) in. | Width, ft | | Bituminous Base Thickness, in. | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Miles | Percent[1] | Low | High | | | | | Inside | Outside | | |
| Bituminous Shoulders | 1 | 1974 | 2.7 | 12 | 9,600 | 9,600 | 10 | 3 | D | 8 | 5 | 9 | 5 | Composite sampling |
| | 2 | 1975 | 2.0 | 9 | 35,400 | 89,100 | 10 | 4 | D | 9-6-1/4 | 9 | 11 | 6 | from four groups of |
| | 3[3] | 1975 | 4.2 | - | 4,200 | 9,600 | 10 | 4 | D | 8-6-1/4 | 5 | 9 | - | projects: |
| | 4[5] | 1974 | 1.5 | 7 | 35,800 | 49,800 | 10 | 4 | D | 10-6-1/4 | - | 11 | 4 | (1, 3), (2; 4), |
| | 5 | 1975 | 1.7 | 8 | 18,100 | 35,400 | 10 | 4 | D | 9-6-1/4 | 9 | 11 | 5 | (5, 6, 7) and |
| | 6 | 1975 | 2.5 | 11 | 18,100 | 35,400 | 10 | 4 | D | 6-1/4 | 9 | 11 | 5 | (8, 9, 10, 11) |
| | 7 | 1975 | 1.4 | 6 | 18,100 | 35,400 | 10 | 4 | D | 9-6-1/4 | 9 | 11 | 5 | |
| | 8 | 1975 | 3.4 | 15 | 65,800 | 71,600 | 10 | 4 | D | 10-6-1/4 | 5 | 9 | 5 | |
| | 9[3] | 1976 | 2.1 | - | 52,600 | 65,800 | 10 | 4 | D | 10-6-1/4 | 5 | 9 | - | |
| | 10 | 1977 | 3.2 | 15 | 52,600 | 65,800 | 9 | 4 | D | 6 | 5 | 9 | 5 | |
| | 11 | 1977 | 3.8 | 17 | 52,600 | 65,800 | 10 | 4 | D | 9-6-1/4 | 5 | 9 | 5 | |
| Concrete Shoulders | 12[3] | 1973 | 3.3 | - | 21,000 | 25,700 | 10 | 3 | D | 3 | 2-3/4 | - | - | Composite sampling |
| | 13 | 1973 | 0.5 | 2 | 52,500 | 54,700 | 10 | 4 | D | 6 | 9 | - | - | from three groups of |
| | 14 | 1973 | 5.9 | 26 | 30,600 | 34,000 | 10 | 4 | D | 6 | 9 | - | - | projects: |
| | 15 | 1973 | 8.9 | 39 | 34,000 | 52,500 | 10 | 4 | D | 6 | 6-3/4 | - | - | (12, 13), (14, 15, 20) |
| | 16[4] | 1975 | 0.6 | 3 | 116,034 | 129,300 | 10 | 4 | C&G | 6 | 9-1/4 | 9-1/2 | - | and (16, 17, 18, 19) |
| | 17 | 1975 | 1.0 | 4 | 118,000 | 134,500 | 10 | 4 | C&G | 6 | 8 | 9-1/2 | - | |
| | 18[4] | 1975 | 1.0 | 4 | 118,000 | 134,500 | 10 | 4 | C&G | 6 | 8 | 9-1/2 | - | |
| | 19[4] | 1976 | 1.4 | 6 | 116,034 | 129,300 | 10 | 4 | C&G | 6 | 9-1/4 | 9-1/2 | - | |
| | 20 | 1978 | 3.5 | 16 | 24,800 | 64,600 | 9 | 4 | C&G | 6 | 6-1/2 | 9-1/2 | - | |

[1] (SM) = (Column 4) x (TSM) where SM = shoulder miles (SM) per test section
TSM = total shoulder miles of test area (composite sample).

[2] D = Ditch; C&G = Curb & Gutter.

[3] Project deleted from condition survey as the experimental shoulders were not placed when the project was constructed or the shoulders are too narrow to allow the condition survey to be conducted safely.

[4] Project has local and express freeway lanes.

[5] Project used as temporary traffic lane in 1981.

Three of the concrete shoulder projects (16, 18, and 19) consist of separated 'express' and 'local' freeway lanes and the test sample length used for the local roadways was the same as the test sample length of the express roadways. The total test sample lengths for the local roadways were used to set up a separate test area (composite sample) and the local roadways were surveyed for informational purposes only, as none of the bituminous shoulder projects had local and express lane roadways.

For safety purposes, only the shoulders adjacent to the stationing (generally the outside shoulder) were considered for the condition survey. The number of sample units per test section length and the interval between sample units was determined by methods described in Appendix B.

It was decided to split the number of sample units between the northbound and southbound or eastbound and westbound roadways. The samples were divided by using the odd numbered samples for the northbound (or eastbound) roadway and the even numbered samples for the southbound (or westbound) roadway.

The rating system for the initial condition survey classified the localized distress condition (major, average, or minor) at each of the sample units and deficiency points (DP) were assigned to the localized distress factors by severity (mild, moderate, or severe). The localized distress factors and the rating system used for the IBS and PCC shoulders is shown in Figure 2.

The rating system for the total deficiency points (TDP) for the test section is as follows:

| | |
|---|---|
| 0 - 30 | Excellent |
| 31 - 60 | Very good |
| 61 - 90 | Good |
| 91 - 120 | Fair |
| 121 - 150 | Poor |
| 151 - 180 | Very poor |
| 181 - 200 | Failed |

This being the initial condition survey, the relative performance of the bituminous vs. the concrete shoulders over time in service (Tables 3 and 4) and the deterioration of the shoulders vs. time (Fig. 3) were determined. In subsequent surveys the deterioration of the shoulders between surveys will be determined.

ROADWAY SHOULDER RATING FORM BITUMINOUS

TEST PROJ: _____ CONTROL SECT: _____ J.N.: _____ LOCATION: _____
STATIONING: _____ SAMPLE UNIT: _____ CONST. YEAR: _____
SHLDR. TYP.: _____ OUTSIDE: _____ CONST. YEAR: _____ SURVEY DATE: _____
TOTAL SURVEY LENGTH FOR TEST SECT.: _____ SURVEYED BY: _____

| A SHOULDER DISTRESS RATING SYSTEM | | | |
|---|---|---|---|
| SEVERITY LEVEL | MILD | MODERATE | SEVERE |
| DISTRESS CONDITION | | | |
| MAJOR | 1 | 5 | 7 |
| AVERAGE | 1 | 3 | 5 |
| MINOR | 1 | 2 | 3 |

REMARK'S:

| DISTRESS FACTOR BIT. | DP RATING | DP AWARD |
|---|---|---|
| RAVELING | 1 5 7 | |
| DROP OFF | 1 5 7 | |
| RUTTING | 1 3 5 | |
| SETTLEMENT | 1 3 5 | |
| DELINEATION | 1 3 5 | |
| BUMPS/SAGS | 1 3 5 | |
| ROUGHNESS | 1 2 3 | |
| POTHOLES | 1 2 3 | |
| CRACKING | 1 2 3 | |
| SEPARATION | 1 2 3 | |
| PATCHING | 1 2 3 | |

TDP=

ROADWAY SHOULDER RATING FORM CONCRETE

TEST PROJ: _____ CONTROL SECT: _____ J.N.: _____ LOCATION: _____
STATIONING: _____ SAMPLE UNIT: _____ CONST. YEAR: _____
SHLDR. TYP.: _____ OUTSIDE: _____ CONST. YEAR: _____ SURVEY DATE: _____
TOTAL SURVEY LENGTH FOR TEST SECT.: _____ SURVEYED BY: _____

| A SHOULDER DISTRESS RATING SYSTEM | | | |
|---|---|---|---|
| SEVERITY LEVEL | MILD | MODERATE | SEVERE |
| DISTRESS CONDITION | | | |
| MAJOR | 1 | 5 | 7 |
| AVERAGE | 1 | 3 | 5 |
| MINOR | 1 | 2 | 3 |

REMARK'S:

| DISTRESS FACTOR CONC. | DP RATING | DP AWARD |
|---|---|---|
| SURFACE DETERIORATION | 1 5 7 | |
| DROP OFF | 1 5 7 | |
| FAULTING | 1 3 5 | |
| SETTLEMENT | 1 3 5 | |
| DELINEATION | 1 3 5 | |
| SPALLING | 1 3 5 | |
| ROUGHNESS | 1 2 3 | |
| PUNCHOUT | 1 2 3 | |
| CRACKING | 1 2 3 | |
| SEPARATION | 1 2 3 | |
| PATCHING | 1 2 3 | |

TDP=

Figure 2. Rating forms showing distress factors for IBS and PCC shoulders.

## TABLE 3
## AVERAGE TOTAL DEFICIENCY POINTS FOR COMPOSITE SAMPLE

| | Test Project No. | Total Deficiency Points Per Test Sample (TDP) | Shoulder Miles Per Test Sample (SM) | TDP/Mile | TDP x SM |
|---|---|---|---|---|---|
| Bituminous Shoulders | 1 | 72 | 1.2 | 60.0 | 86.4 |
| | 2 | 110 | 0.9 | 122.2 | 99.0 |
| | 5 | 128 | 0.8 | 160.0 | 102.4 |
| | 6 | 125 | 1.1 | 113.6 | 137.5 |
| | 7 | 110 | 0.6 | 183.3 | 66.0 |
| | 8 | 68 | 1.5 | 45.3 | 102.0 |
| | 10 | 132 | 1.5 | 88.0 | 198.0 |
| | 11 | 118 | 1.7 | 69.4 | 200.6 |
| | 4[1] | 26 | Total TDP x SM Bituminous Shoulder Normal Use (N.U.) ..... | | 991.9 |
| | $\overline{TDP} = \frac{1}{TSM}[\Sigma; (SM) \times (TDP)] = \frac{991.9}{10} = 99.19$ | | | | |
| Concrete Shoulders | 13 | 32 | 0.2 | 160.0 | 6.4 |
| | 14 | 38 | 2.6 | 14.6 | 98.8 |
| | 15 | 42 | 3.9 | 10.8 | 163.8 |
| | 16[2] | 41 | 0.3 | 136.7 | 12.3 |
| | 17 | 41 | 0.4 | 102.5 | 12.3 |
| | 18[2] | 50 | 0.4 | 125.0 | 20.0 |
| | 19[2] | 87 | 0.6 | 145.0 | 52.2 |
| | 20 | 55 | 1.6 | 34.4 | 88.0 |
| | 16[3] | 38 | Total TDP x SM Concrete Shoulder Mainline ..... | | 453.8 |
| | 18[3] | 30 | | | |
| | 19[3] | 73 | | | |
| | $\overline{TDP} = \frac{1}{TSM}[\Sigma; (SM) \times (TDP)] = \frac{453.8}{10} = 45.38$ | | | | |

[1] Used as temporary traffic lane in 1981
[2] Freeway
[3] Local

TSM = Total shoulder miles for composite sample = 10 miles.
TDP = Average total deficiency points for composite shoulder area inspected.
N = Total number of test sections of different lengths.

## TABLE 4
## AVERAGE SM x AGE FOR COMPOSITE SAMPLE AND RELATIVE PERFORMANCE

| | Test Project No. | Shoulder-Miles Per Test Sample (SM) | Condition Survey Year Minus Year Project Completed (Age) | SM x Age |
|---|---|---|---|---|
| Bituminous Shoulders | 1 | 1.2 | 10 | 12.0 |
| | 2 | 0.9 | 9 | 8.1 |
| | 5 | 0.8 | 9 | 7.2 |
| | 6 | 1.1 | 9 | 9.9 |
| | 7 | 0.6 | 9 | 5.4 |
| | 8 | 1.5 | 9 | 13.5 |
| | 10 | 1.5 | 7 | 10.5 |
| | 11 | 1.7 | 7 | 11.9 |
| | | | Total Bituminous N.U.[2] = | 78.5 |
| | $\overline{SM \times Age} = 78.5 \quad 8 = 9.81$ | | | |
| Concrete Shoulders | 13 | 0.2 | 11 | 2.2 |
| | 14 | 2.6 | 11 | 28.6 |
| | 15 | 3.9 | 11 | 42.9 |
| | 16[1] | 0.3 | 9 | 2.7 |
| | 17 | 0.4 | 9 | 3.6 |
| | 18[1] | 0.4 | 9 | 3.6 |
| | 19[1] | 0.6 | 8 | 4.8 |
| | 20 | 1.6 | 6 | 9.6 |
| | | | Total Concrete M.L.[3] = | 98.0 |
| | $\overline{SM \times Age} = 98.0 \quad 8 = 12.25$ | | | |

[1] Freeway
[2] Not used to carry traffic
[3] Mainline

Relative Performance = RP = $\frac{\overline{TDP}}{\overline{SM \times Age}}$

Relative Performance for Bituminous Shoulders

RP = $\frac{99.19 \text{ (Table 3)}}{9.81} = 10.1111$

Relative Performance for Concrete Shoulders

RP = $\frac{45.38 \text{ (Table 3)}}{12.25} = 3.7045$

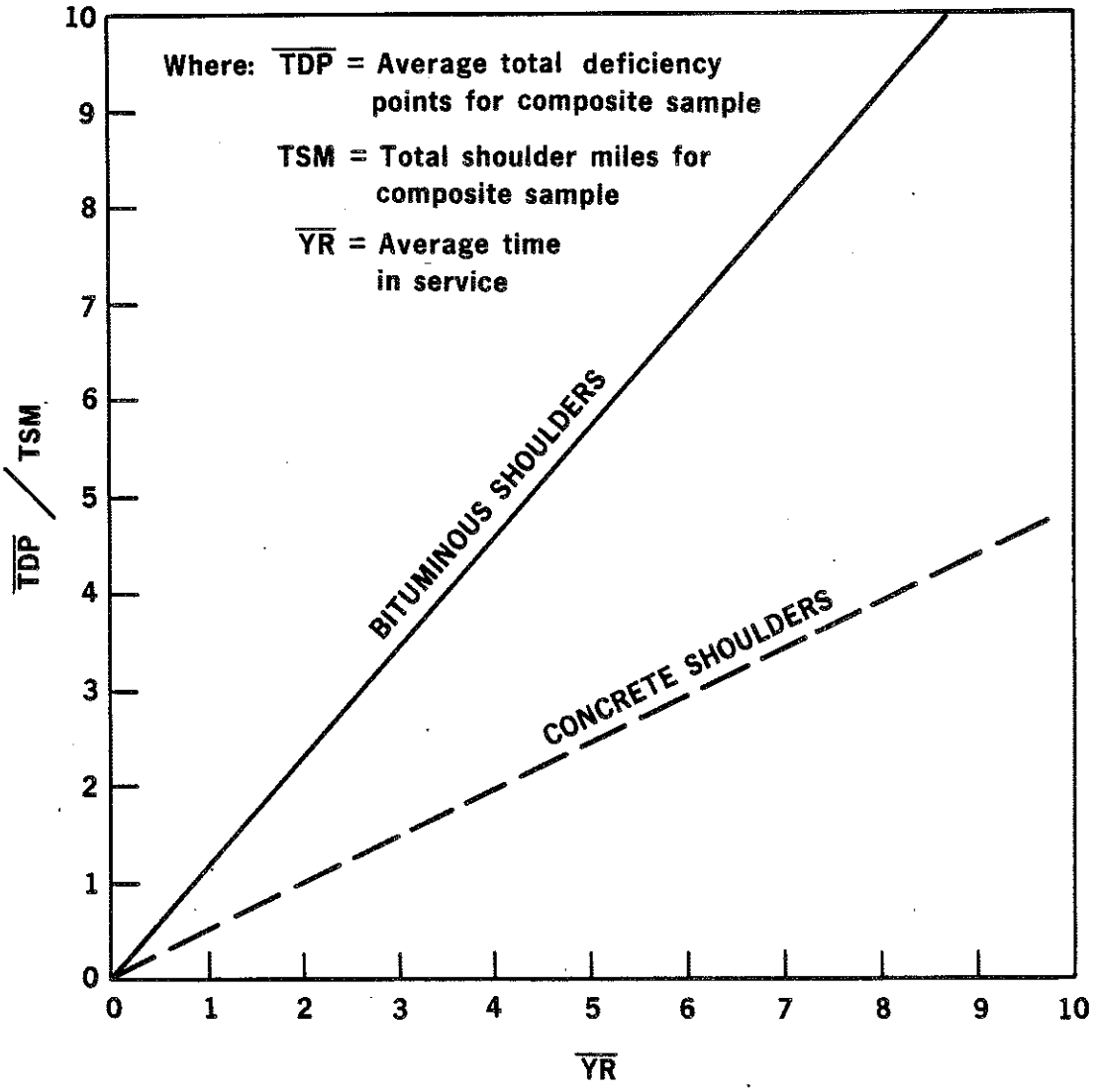



Figure 3. Deterioration of shoulders vs. average time in service.

## OBSERVATIONS

This initial condition survey was made six to eleven years after the test projects were completed.

The improved bituminous stabilized shoulders are in generally good condition. Figure 4 shows the typical condition of the bituminous shoulder in the fall of 1984. An evaluation of the condition survey by test project is given in Table 5. Specific comments for test projects 1, 3, 4, 9, 10, and 11, are as follows.

Project No. 1 - An extra sample was taken because a non-typical distress condition of moderate settlement was noted. The sample also had a moderate drop-off and moderate bump/sag distress conditions. The sample was taken for information only and was not used in the deficiency point rating for the test section.

Project No. 3 - The shoulders were changed at the time of construction to Michigan's standard paved shoulders, with 170 lb/sq yd of bituminous aggregate over Class AA shoulder material; therefore, the project was deleted from the survey.

Project No. 4 - The northbound shoulders are brand new concrete shoulders and were not surveyed; however, the southbound shoulders are still the original improved bituminous stabilized shoulders and they were surveyed. There is a 2-ft bituminous strip in the southbound shoulder next to the concrete pavement (Fig. 5). This was placed in 1982 to bring the shoulder edge back to the pavement edge elevation after the shoulder had been used to carry traffic during replacement of the two inside pavement lanes in 1981. In 1984, the outside lane was replaced but the shoulder was not touched. The 2-ft strip is not full-depth bituminous but the rest of the shoulder is still as placed in 1974.

Project No. 9 - The shoulders were changed at the time of construction to gravel to allow the project to open in December. The next spring the shoulders were stabilized in-place to a depth of 6 in. and bituminous was placed over the stabilized material; therefore, the project was deleted from the survey.

Project No. 10 - The northbound roadway has a 2-ft bituminous strip next to the pavement edge and at intervals of approximately 500 ft a 2-ft bituminous strip leading to the outside edge of the shoulder that were placed when edge drain was placed after the project was completed (Fig. 6). The 2-ft strip is not full-depth asphalt but the rest of the shoulder is the original IBS shoulder.

Project No. 11 - An extra sample was taken because a non-typical distress condition of severe cracking with loss of material at the back of the shoulder was noted. The sample also had moderate roughness and moderate raveling distress conditions. The sample was taken for informational purposes and not used in the deficiency point rating for the test section.

The average total deficiency point rating for the 10-mile test area (composite sample) for the bituminous shoulders was 99.19 (Table 3), which would correspond to a 'fair' classification.

The portland cement concrete shoulders are in generally good condition. Figure 7 shows the typical condition of the concrete shoulders in the fall of 1984. An evaluation of the condition survey by test project is shown in Table 6. Comments on non-typical conditions found in test projects 12, 13, 14, 15, 16, 17, 18, 19, and 20 are as follows.

## TABLE 5
## EVALUATION OF EXPERIMENTAL BITUMINOUS SHOULDERS

| Test Project No. | Length of Test Section, miles | Number of Sample Units in Test Section | Number of Sample Units Surveyed[1] | Distress Factors and Number of Surveyed Sample Units Showing Moderate (M) and/or Severe (S) Distress | | | | | | | | | | | Deficiency Point Rating for Test Section | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Ravel-ing | Drop-off | Rut-ting | Settle-ment | Delin-eation | Bumps Sags | Rough-ness | Pot-holes | Crack-ing | Sepa-ration | Patch-ing | | |
| 1 | 1.2 | 63 | 13 | | 2-M | | | 1-M | 1-M | | | 3-M 2-S | 2-M | 1-M | 72 | 2 |
| 2 | 0.9 | 48 | 12 | 12-M | | | | 12-M | | | | | 1-M | | 110 | |
| 3 | | | | | | | | | | | | | | | | 2 |
| 4 | 0.7 | 37 | 11 | | | | | | | | | 1-M | | | 26 | 3 |
| 5 | 0.8 | 42 | 12 | 12-M | | | | 12-M | | | | 3-M | | | 128 | |
| 6 | 1.1 | 58 | 13 | 13-M | | | | 13-M | | | | 2-M | | | 125 | |
| 7 | 0.6 | 31 | 11 | 11-M | | | | 11-M | | | | 1-M | | | 110 | |
| 8 | 1.5 | 79 | 13 | | | | | 6-M | | | | | | | 68 | |
| 9 | | | | | | | | | | | | | | | | 4 |
| 10 | 1.5 | 79 | 13 | 13-M | | | | 13-M | | | | 1-M | | | 132 | 4 |
| 11 | 1.7 | 90 | 14 | 12-M | 2-M | | | 3-M | | | | 2-M | | | 118 | 4 |

[1] As determined by using equation #1

[2] See Observation Section, page 9

[3] See Observation Section, page 9

[4] See Observation Section, page 9



## TABLE 6
## EVALUATION OF EXPERIMENTAL CONCRETE SHOULDERS

| Test Project No. | Length of Test Section, miles | Number of Sample Units in Test Section | Number of Sample Units Surveyed[3] | Distress Factors and Number of Surveyed Sample Units Showing Moderate (M) and/or Severe (S) Distress | | | | | | | | | | | Deficiency Point Rating for Test Section | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Surface Deteri-oration | Drop-off | Fault-ing | Settle-ment | Delin-eation | Spall-ing | Rough-ness | Punch-out | Crack-ing | Sepa-ration | Patch-ing | | |
| 12 | | | | | | | | | | | | | | | | |
| 13 | 0.2 | 16 | 8 | | | | | | 1-M | | | | | | 32 | 4 |
| 14 | 2.6 | 156 | 15 | | | | | | | | 1-S | 1-M | | | 38 | 4/5 |
| 15 | 3.9 | 317 | 15 | | | | | | | | | | | | 42 | 4 |
| 16[1] | 0.3 | 19 | 9 | 1-M | | | | | | | 2-M | 2-M | 1-M | | 41 | 4 |
| 17 | 0.4 | 35 | 11 | | | | | | 1-M | | | 2-M 1-S | | | 41 | 4 |
| 18[1] | 0.4 | 30 | 11 | | | | | | | | | 7-M 1-S | | | 50 | 4 |
| 19[1] | 0.6 | 39 | 12 | 2-M | | | | 6-M | 5-M | | | 8-M | | | 87 | 4 |
| 20 | 1.6 | 113 | 14 | 1-M | | | | | | | | 2-M | | | 55 | 4 |
| 16[2] | 0.3 | 19 | 9 | | | | | 2-M | | | | 2-M | | | 38 | 4 |
| 18[2] | 0.4 | 30 | 11 | | | | | | | | | 3-M | | | 30 | 4 |
| 19[2] | 0.6 | 39 | 12 | 5-M | | | 1-M | 5-M | 1-M | | 1-M | 1-M | | | 73 | 4 |

[1] Freeway

[2] Local

[3] As determined by using equation #1

[4] See Observation Section, page 13

[5] One sample unit was inadvertently skipped

Figure 4. Showing the typical condition of the experimental bituminous shoulders in the fall of 1984 (project 1).

Figure 5. Two-foot bituminous strip in shoulder next to the concrete pavement (project 4).

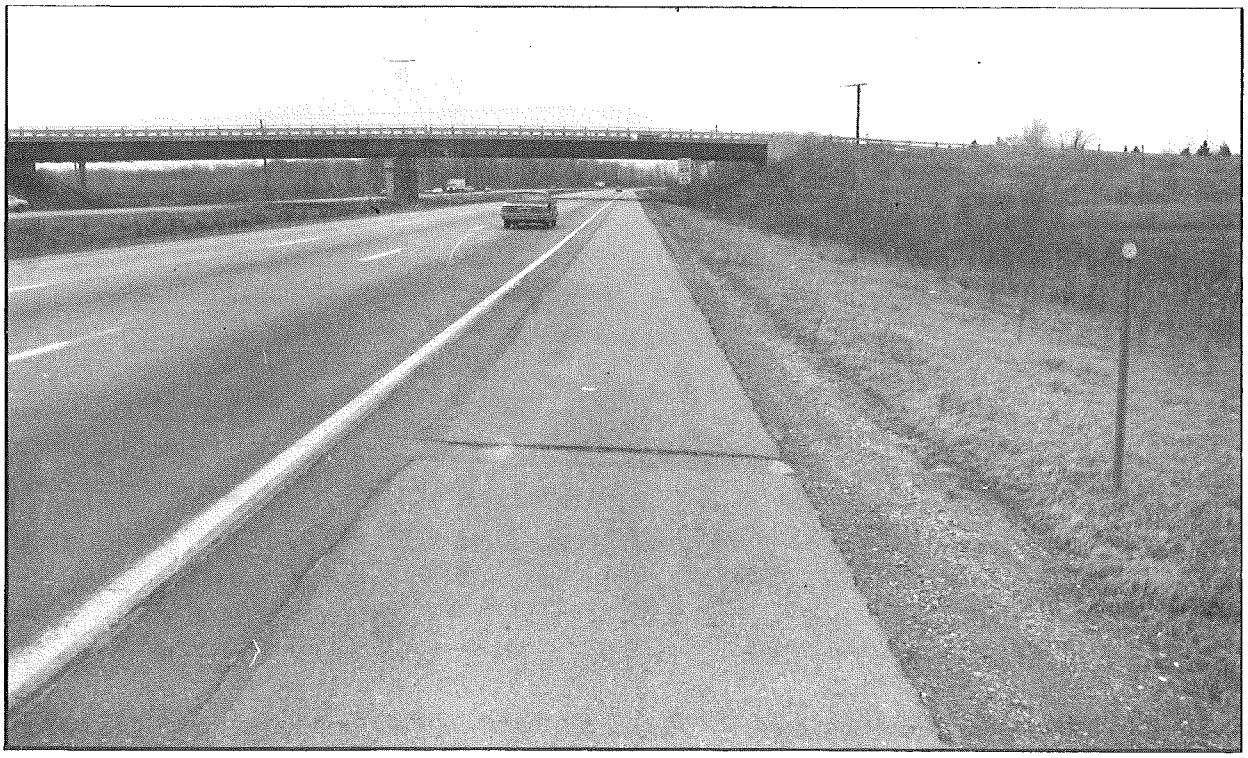


Figure 6. Two-foot bituminous strip next to pavement edge and two-foot bituminous strip leading to edge of shoulder for retrofit drainage system (Northbound roadway of project 10).

Figure 7. Showing the typical condition of the experimental concrete shoulders in the fall of 1984 (project 20).

Project No. 12 - The combined width of the valley gutter and concrete shoulder are not wide enough to allow the survey to be conducted safely; thus, the project was deleted from the survey.

Project Nos. 13, 14, and 15 - The shoulders are median shoulders that were placed with a third lane widening with bituminous overlay.

Project Nos. 17 and 20 - These are in the Detroit area with curb and gutter between the pavement and shoulder.

Project Nos. 16, 18, and 19 - These projects are in the Detroit area with curb and gutter between pavement and shoulder and consist of both local and express freeway lanes. The surveyed shoulder for the express freeway lanes also serves as the median shoulder for the local lanes with either a concrete barrier or earth berm separating them. In the areas where there is a concrete barrier, there appears to be settlement or frost heave cracking in front of the barrier (Fig. 8). The amount of this sort of cracking for the express freeway lanes projects 16, 18, and 19 is 13, 15, and 19 percent, respectively.

The average total deficiency point rating for the 10-mile test area (composite sample) for the concrete shoulders is 45.38 (Table 6), which would correspond to a 'very good' classification.

## SUMMARY

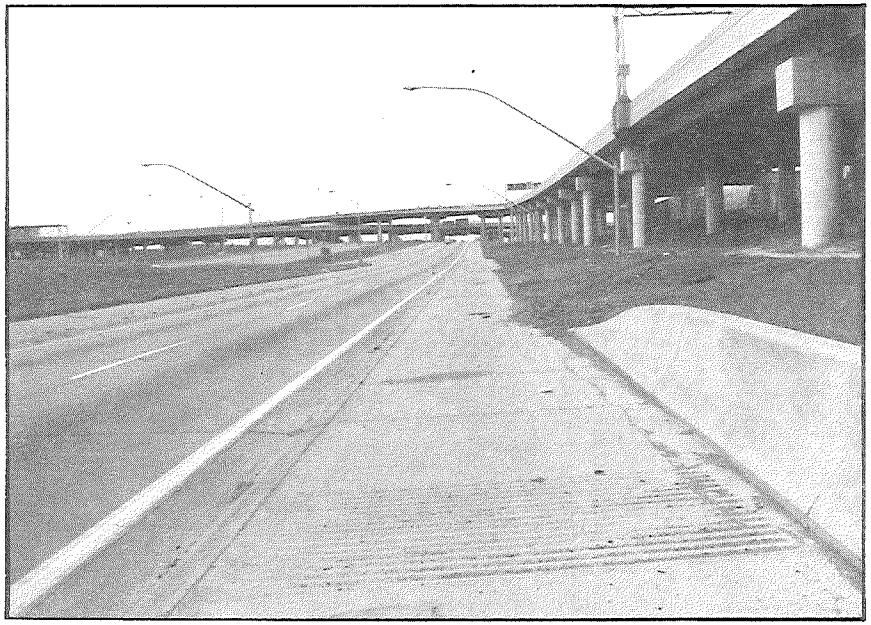
The condition survey of the experimental improved bituminous stabilized shoulders and portland cement concrete shoulders, after about six to eleven years of service has revealed the following:

1) The improved bituminous stabilized shoulders performed well and there were no major shoulder failures or repairs (where the shoulder was not used as a traffic lane).

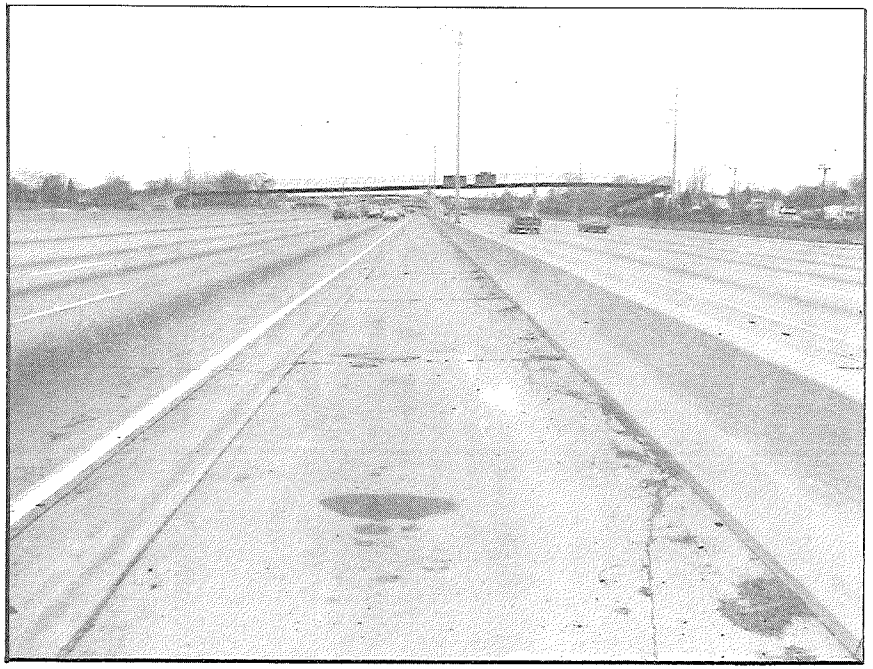
2) The portland cement concrete shoulders performed well and there were no major shoulder failures or repairs.

3) Where the concrete shoulder had concrete median barrier on it, there was more cracking than on shoulder sections without concrete barrier.

The bituminous shoulder used to carry traffic comprises a test area (composite sample) of 0.7 miles. The shoulders were surveyed for informational purposes and were not included in the deficiency point comparison between the IBS and PCC shoulders, as none of the other shoulder projects carried traffic.



Apparent settlement or frost heave cracking in front of barrier on project 16.



Apparent settlement or frost heave cracking in front of barrier on project 19.

Apparent settlement or frost heave cracking in front of barrier on project 18.

Figure 8. Cracking on projects utilizing concrete barriers.

The concrete shoulders for the 'local' lanes comprise a test area (composite sample) of 1.3 miles. Again, the shoulders were surveyed for informational purposes and were not included in the deficiency point comparison, as none of the bituminous projects had express/local lane combinations.

## CONCLUSIONS AND RECOMMENDATIONS

The portland cement concrete shoulders performed better than the improved bituminous stabilized shoulders, but also are more expensive to build. There was less surface deterioration, drop-off, and cracking in the concrete shoulders.

Where concrete shoulders are to have concrete barrier placed on them, better drainage should be considered, along with adherence to careful construction practices, to ensure that a uniform base is placed under the shoulder to stop cracking around the barrier.

Performance data will continue to be collected and maintained by the Research Laboratory, and additional information obtained will be presented in subsequent reports.

### Recommendations for Subsequent Surveys

1) The sample unit length should be in 100-ft increments by stationing for both bituminous and concrete shoulders.

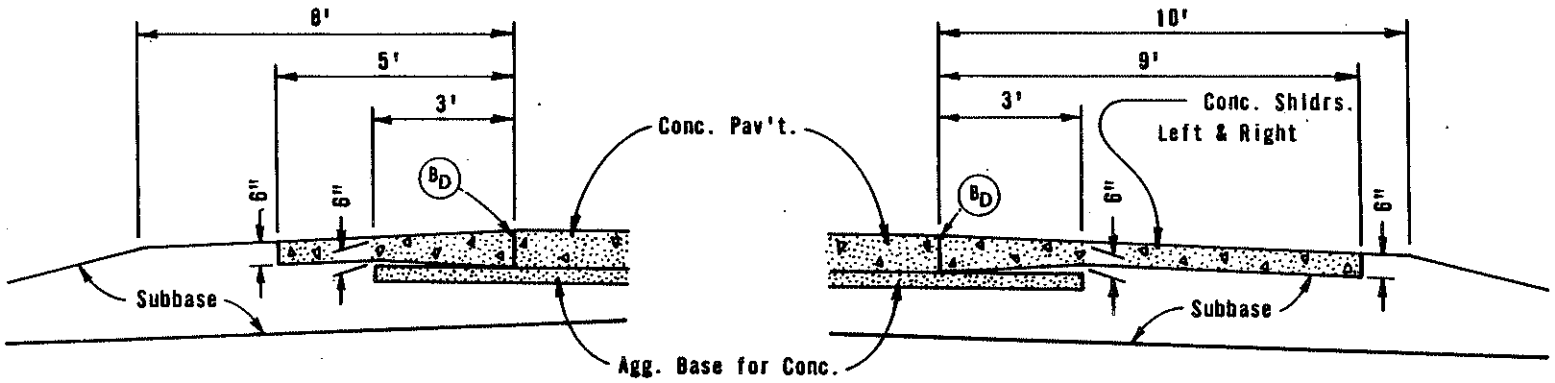
2) The condition surveys of the local lane shoulders should be continued for comparison with the express lane freeway shoulders on projects 16, 18, and 19 to see if the difference in total deficiency points for the test sections stays the same, increases, or decreases.

3) The condition survey should be continued on shoulders of project 4 to see if they continue to rate higher than the rest of the bituminous projects, despite the fact that they carried traffic during part or all of the 1981 construction season.

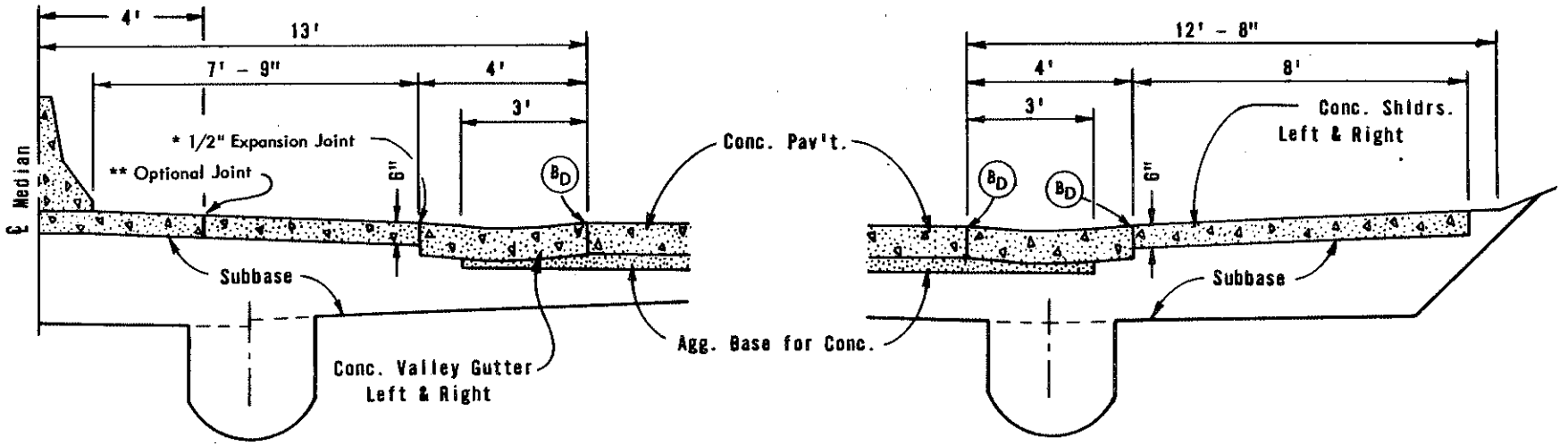
# APPENDIX A

## Design Details for Concrete and Bituminous Shoulders

# CONCRETE PAVED SHOULDERS




RURAL DUAL CONCRETE ROADWAY




URBAN DUAL CONCRETE ROADWAY
SECTION FOR CURB & GUTTER SIMILAR

* If contractor elects to pour shoulder monolithically with concrete valley gutter, expansion joint may be omitted where shown and placed at 4' either side of median ℄

** For wider medians, construct bulkhead or plane of weakness joints as shown. For median width shown or narrower, this joint is optional. No hook bolts or lane tie bars required.

Figure A1. Design details for concrete paved shoulders.

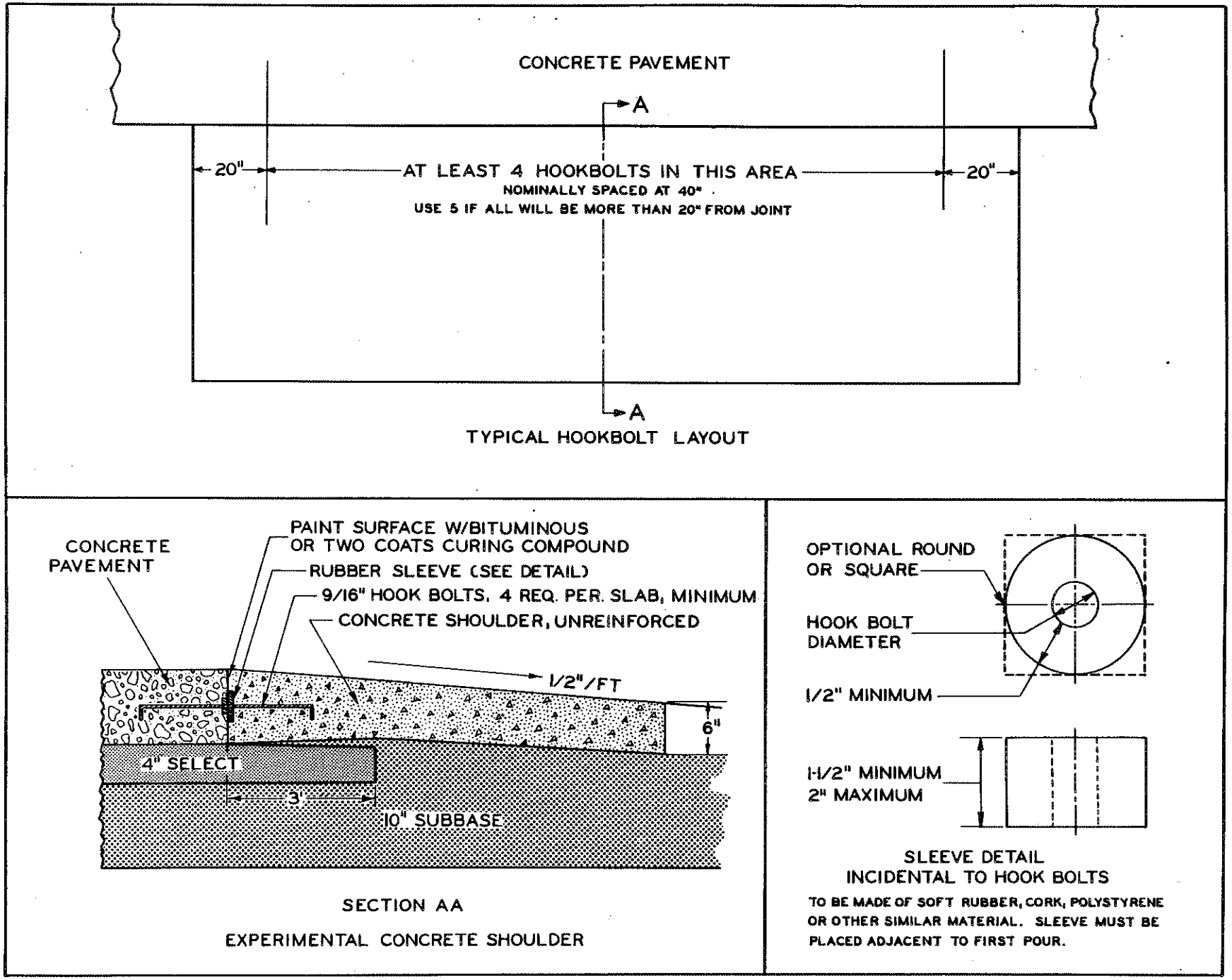
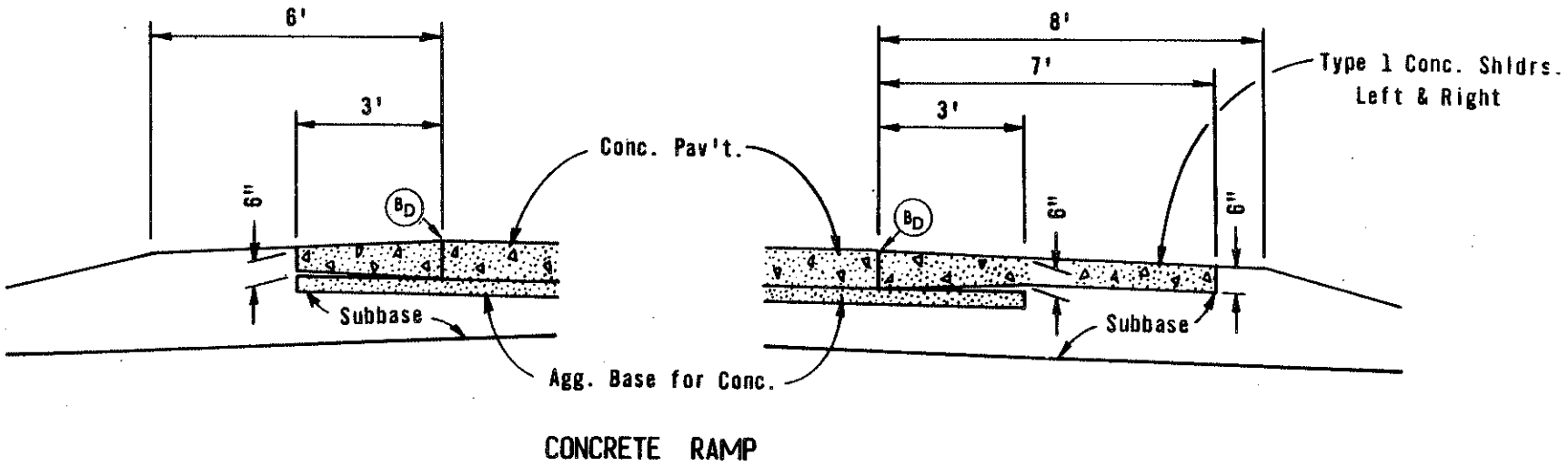
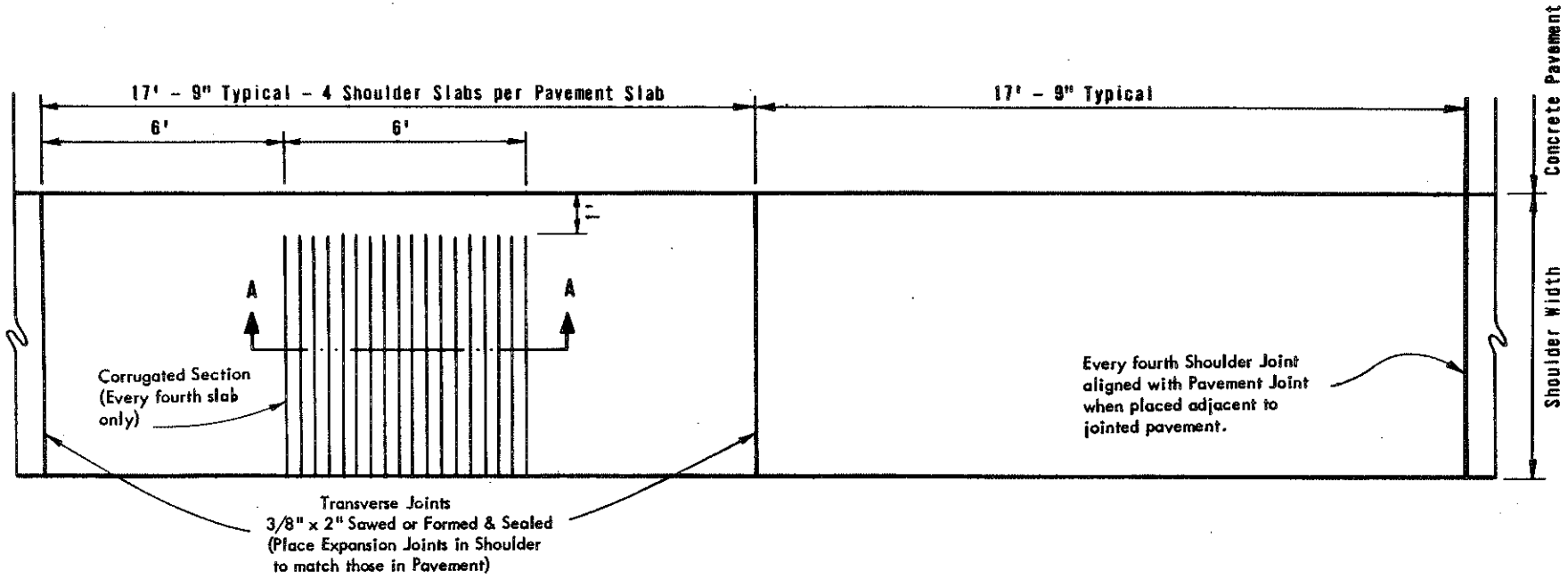



Figure A1 (con't). Design details for concrete paved shoulders.



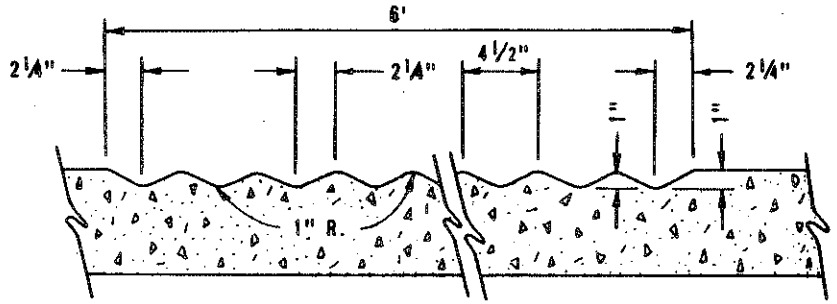

CONCRETE RAMP

Figure A1 (con't). Design details for concrete paved shoulders.




CONCRETE SHOULDER JOINT & CORRUGATED SECTION

NOTE: For medians, stop corrugation 6" from Median Barrier.




SECTION A - A

Figure A1 (con't). Design details for concrete paved shoulders.

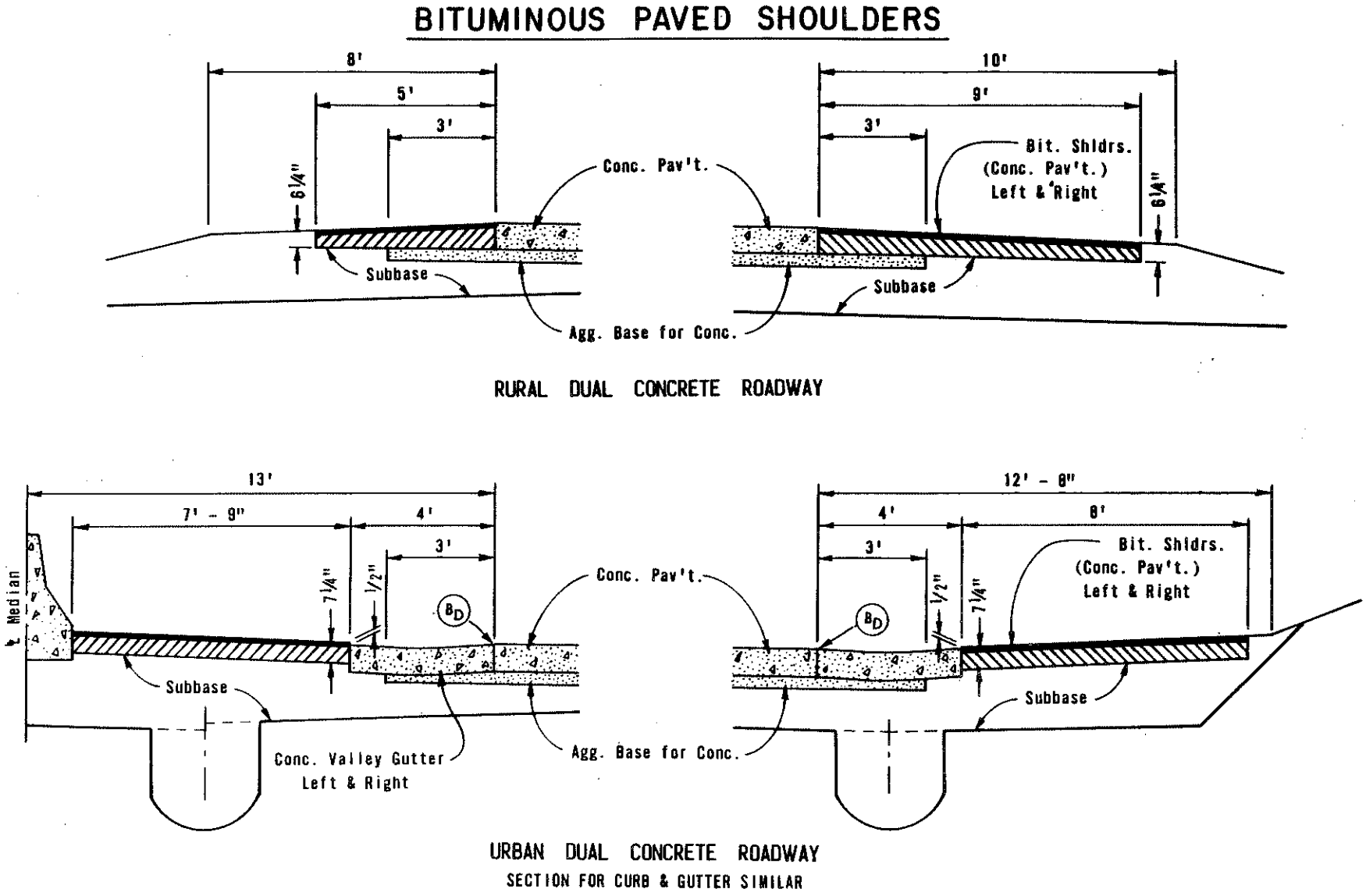



Figure A2. Design details for bituminous paved shoulders.

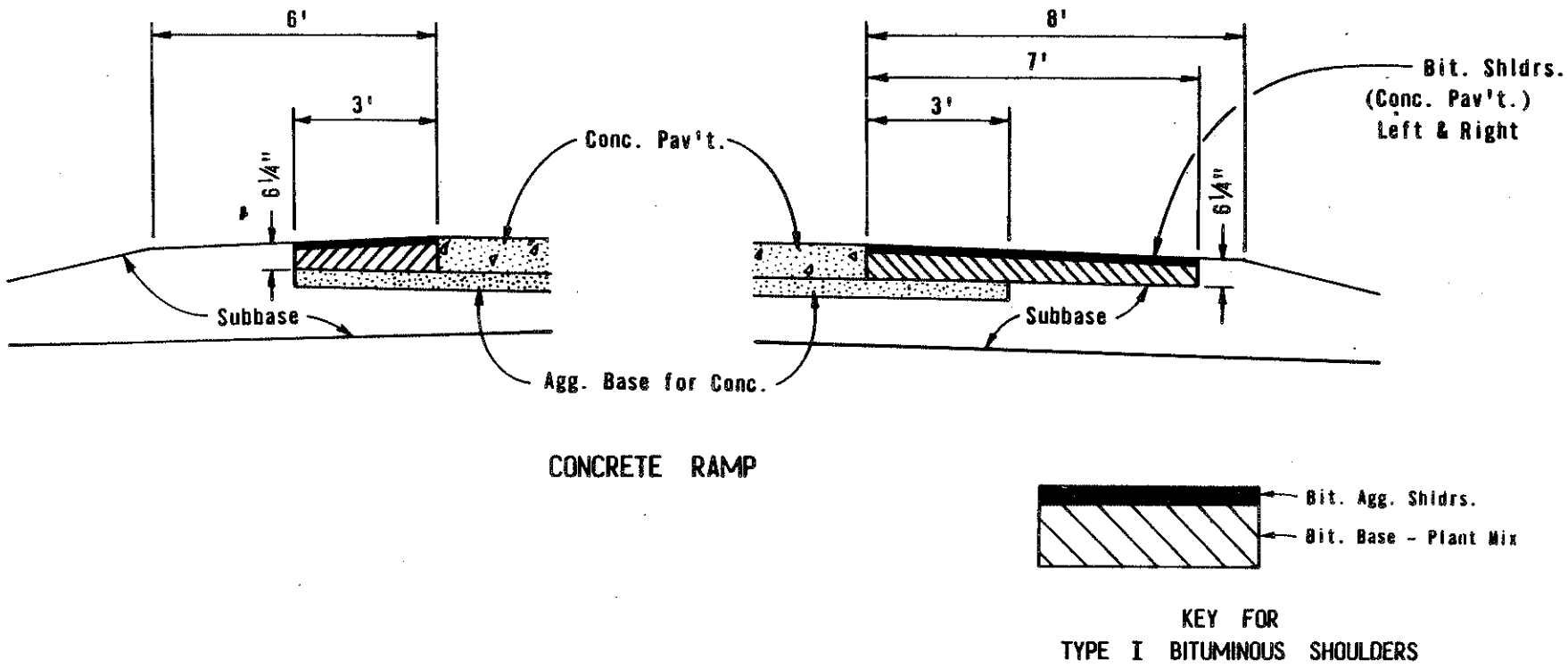



Figure A2 (con't). Design details for bituminous paved shoulders.

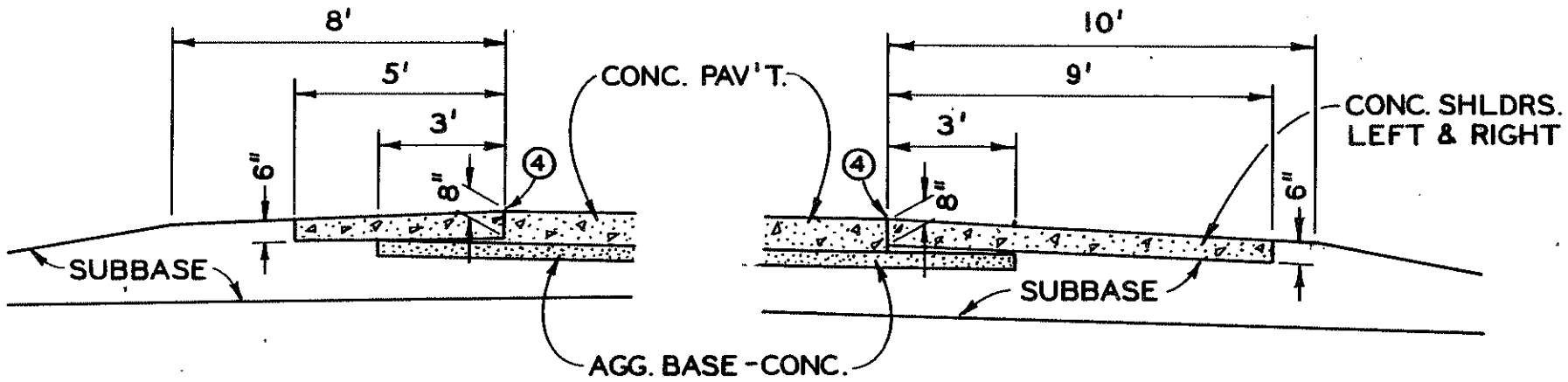



Figure A3. Revised detail for concrete paved shoulders.

## APPENDIX B

The number of sample units per test section length and the interval between sample units was determined by using the following equations:

$$N_{SU} = \frac{N_{TS}(\mu)^2}{(e)^2 \frac{N_{TS}-i}{4} + (\mu)^2} \quad (1)$$

$$i = \frac{N_{PL}}{M_{SU}} \quad (2)$$

where:

$N_{TS}$ = total number of sample units in the test section.

e = allowable error in the estimate of the section pavement condition index. As this was the initial survey it was assumed to be 5 to allow for 95 percent confidence in the survey.

$\mu$ = standard deviation of the pavement condition index between sample units in the test section. As this was the initial survey it was assumed to be 10.

$M_{SU}$ = $N_{SU}$ = minimum number of sample units for test section rounded to the nearest whole integer.

$N_{PL}$ = total number sample units in the project.

i = sample interval approximated to the smallest integer.

The number of sample units was determined for the IBS shoulders by dividing the length of the project or test sample length by the length of one sample unit which equals 100 ft. The number of sample units for the PCC shoulders was determined by dividing the project length or test sample length by the length of one sample unit which equaled the length of one pavement slab length or three or four shoulder slab lengths.

The total number of sample units ($N_{TS}$) in the test sample, the total number of sample units in the project ($N_{PL}$), minimum number of units to be sampled ($N_{SU}$ and $M_{SU}$), sample interval (i), random start number (s) for the first sample unit to be surveyed ('s' is selected at random between 1 and 'i' using random number tables), stationing for the POB and POE of the project, the beginning station for 's' and the length of one sample unit are shown in Table B1. The computations for '$N_{PL}$,' '$N_{TS}$,' '$N_{SU}$,' and 'i' and the determination of the sample units are shown in Figure B1.

TABLE B1
SAMPLING INFORMATION FOR SURVEY OF EXPERIMENTAL SHOULDERS

| Test Project No. | POB | POE | $N_{PL}$ | $N_{TS}$ | $N_{US}=M_{US}$ | i | s | Beginning Station for "s" | Length of One Sample Unit | Station Equation(s) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 240+41.89 | 385+00 | 142 | 63 | 13 | 10 | 1 | 242+00 | 100' | 352+35.13 BK = 352+26.14 AH |
| 2 | 1386+86.00 | 177+04 | 106 | 48 | 12 | 8 | 7 | 1393+00 | 100' | 143+97.03 BK = 115+59.59 AH |
| 3 | Deleted from survey because of changes at the time of construction | | | | | | | | | |
| 4[1] | NB 1312+00<br>SB 1312+00 | NB 190+00<br>SB1389+00 | 77 | 37 | 11 | 7 | 4 | 1315+00 | 100' | NB 1385+94.72 BK = 186+22.61 AH<br>(NB Shlds. new conc. surveyed SB) |
| 5 | 1218+52 | 1310+00 | 91 | 42 | 12 | 7 | 3 | 1221+00 | 100' | |
| 6 | 1086+00 | 1218+52 | 132 | 58 | 13 | 10 | 5 | 1090+00 | 100' | |
| 7 | 1310+00 | 1386+00 | 76 | 31 | 11 | 6 | 1 | 1310+00 | 100' | |
| 8 | 1507+37.72 | 1685+33 | 177 | 79 | 13 | 13 | 5 | 1512+00 | 100' | |
| 9 | Deleted from survey because of changes at the time of construction | | | | | | | | | |
| 10 | 1115+00 | 1287+50 | 171 | 79 | 13 | 13 | 4 | 1118+00 | 100' | 1124+46.75 BK = 1121+98.75 AH &<br>1180+09.06 BK = 1183+82.00 AH |
| 11 | 1287+50 | 1505+55.74 | 198 | 90 | 14 | 14 | 11 | 1298+00 | 100' | 1435+94.26 BK = 1435+63.59 AH &<br>1461+70.77 BK = 1481+42.57 AH |
| 12 | Deleted from survey because of narrow shoulders | | | | | | | | | |
| 13 | 961+00 | 990+00 | 44 | 16 | 8 | 5 | 4 | 962+91 | 65' | |
| 14 | 1480+00 | 1790+00 | 352 | 156 | 15 | 23 | 17 | 1494+13 | 88' | |
| 15 | 1009+12.23 | 1480+00 | 724 | 317 | 15 | 48 | 3 | 1010+42 | 65' | |
| 16[2] | 291+00 | 322+56.38 | 38 | 19 | 9 | 4 | 3 | 292+62.66 | 81'4" | |
| 17 | 101+99.41 | 155+00 | 86 | 35 | 11 | 7 | 6 | 105+04.41 | 61' | |
| 18[2] | 155+00 | 229+50 | 75 | 30 | 11 | 6 | 2 | 155+71.17 | 71'2" | 190+68.97 BK = 211+23.41 AH |
| 19[2] | 322+56.38 | 378+00 | 89 | 39 | 12 | 7 | 6 | 326+63.03 | 81'4" | 353+56.55 BK = 335+84.28 AH |
| 20 | 613+58 | 796+00 | 260 | 113 | 14 | 18 | 5 | 616+38 | 70' | |

[1]Project used as temporary traffic lane in 1981.

[2]Project has express and local lanes.

$$N_{TS} = \frac{1.1(5280)}{100} = 58.08$$

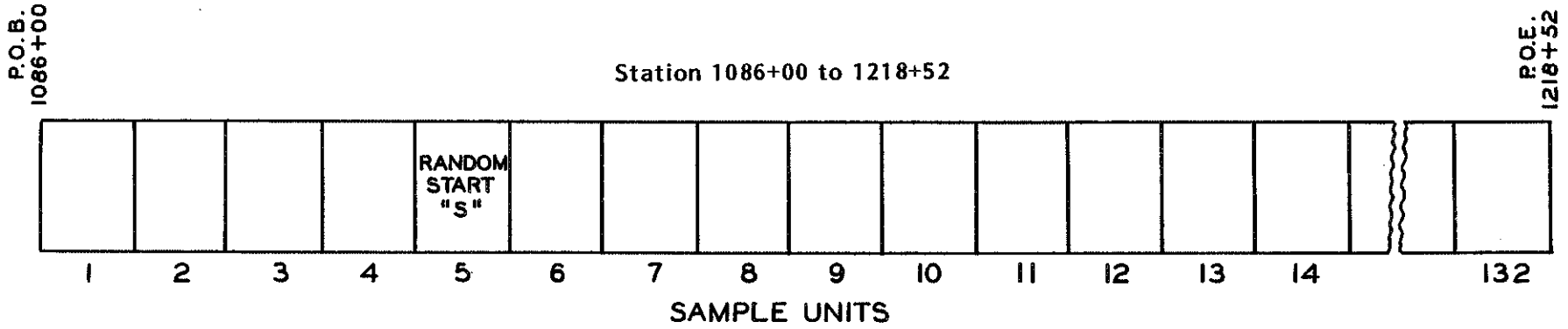
$$N_{PL} = \frac{2.5(5280)}{100} = 132$$

$$N_{SU} = \frac{N_{TS}(\mu)^2}{\frac{(e)^2}{4}(N_{TS}-1) + (\mu)^2}$$

$$N_{SU} = \frac{58(10)^2}{\frac{(5)^2}{4}(58-1) + (10)^2}$$

$$N_{SU} = 12.712$$

$$i = \frac{N_{PL}}{M_{SU}} = \frac{132}{13} = 10.15$$




Test Sample No. 1 = s = 5th sample unit
Test Sample No. 2 = s+i = 5+10 = 15th sample unit
Test Sample No. 3 = s+2i = 5+2(10) = 25th sample unit
Test Sample No. 4 = s+3i = 5+3(10) = 35th sample unit
Test Sample No. 5 = s+4i = 5+4(10) = 45th sample unit
Test Sample No. 6 = s+5i = 5+5(10) = 55th sample unit
Test Sample No. 7 = s+6i = 5+6(10) = 65th sample unit
Test Sample No. 8 = s+7i = 5+7(10) = 75th sample unit
Test Sample No. 9 = s+8i = 5+8(10) = 85th sample unit
Test Sample No. 10 = s+9i = 5+9(10) = 95th sample unit
Test Sample No. 11 = s+10i = 5+10(10) = 105th sample unit
Test Sample No. 12 = s+11i = 5+11(10) = 115th sample unit
Test Sample No. 13 = s+12i = 5+12(10) = 125th sample unit

Random start "s" for selection of sample units selected at random between 1 and "i" using random number tables.

Protect Length = 2.5 miles
Test Section = 1.1 miles

Figure B1. Example of computations for number of sample units in a test project.