INVESTIGATION OF LOW STABILITY
BITUMINOUS BASE COURSE
US 131 MECOSTA COUNTY (FF 54014-17762A)
Final Report

MICHIGAN DEPARTMENT OF TRANSPORTATION

TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION

INVESTIGATION OF LOW STABILITY BITUMINOUS BASE COURSE US 131 MECOSTA COUNTY (FF 54014-17762A)

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SUMMARY

The thickness design for US 131 in Mecosta County (54014-17762A) called for a 4-in. bituminous base of 700-lb stability. At the start of paving, bituminous base stabilities averaged 505 lb. Field modification of the mix (addition of mineral filler) seemed to increase the stability; however, a significant portion of the base had already been placed using a mixture with lower stability values. Bituminous base and surfacing courses were placed during the 1983 construction season.

This investigation was initiated to assess the structural capacity of the pavement section as constructed, and to recommend any necessary corrective action. A preliminary evaluation was made on the basis of Marshall stability values and corresponding AASHTO layer coefficients which indicated little effect on the load carrying capacity (1). This preliminary evaluation also pointed out that stage construction was planned with an additional 130 lb/sq yd of wearing surface to be placed within five years.

Results of this study, based on deflection measurements as well as laboratory measured stiffness modulus values, indicate the pavement should last 13 or more years without further modification.

INTRODUCTION

This investigation was initiated as a result of low stability measurements of the base course mixture at the start of paving. The pavement section was designed for a base course mixture having a 700-lb stability; however, the first batches of material averaged only 505 lb even though the laboratory mix design resulted in a stability of 805 lb. The study was conducted for the purpose of determining whether an additional surfacing layer would be required, either at the time of construction or in the near future. A preliminary assessment of the structural adequacy indicated that additional surfacing would not be required for several years (1).

During the early part of base construction, field adjustments of the mixture were made to increase stability. Additional amounts of mineral filler were added to the mix resulting in an average stability of 700 lb for the base course.

RESEARCH PROGRAM

Core samples of the bituminous layers as well as Benkelman beam deflections were used as the basis for this investigation. Core samples were tested in the laboratory for Mashhall stability and flow, unit weight, resilient modulus, and tensile strength. Deflection basins measured by the Benkelman beam along with modulus values measured in the laboratory were used in a computerized analysis system to estimate the expected pavement life based on tensile strains in the bituminous layers (fatigue) and compressive strains in the subgrade (rutting) for the pavement section as constructed.

A review of laboratory mix design data was also conducted in an attempt to find possible causes of the low stabilities.

A laboratory mix design developed by the Bituminous Technical Services Unit prior to construction was reported as follows:

Material	Type	Source	Sp. Grav.
Asphalt Cement	AC-5	Amoco	1.023
Dense Graded Agg.	20C	Pit No. 54-60 Submitted 3/15/83	
Dense Graded Agg.	20C Modified	Pit No. 54-60 Submitted 4/18/83	

Marshall Mix Design (50 blow compactive effort)

Asphalt content, percent	4.5
Density, lb/cu ft	146.5
Stability, lb	805
Passing #8, percent	46.7
Passing #200, percent	3.4
Specific Gravity	2.348
Air Voids	6.6
V.M.A., percent	16.9
Flow, .01 in.	7
Voids filled with asphalt, percent	61.0

Aggregate Gradation

	Cumulative Percent Passing		
Sieve Size	20C	20C Mod	Blend
1 inch	100.0	100.0	100.0
3/4 inch	100.0	100.0	100.0
1/2 inch	85.9	92.5	87.2
3/8 inch	77.5	79.7	77.9
No. 4	59.6	57.0	59.1
No. 8	48.0	41.7	46.7
No. 30	34.0	23.6	31.9
No. 200	3.0	5.0	3.4
Crushed	24	44	28
Blend	80	20	100

Initial production of the base mixture resulted in stability values averaging 505 lb. Mineral filler added to the mixture during subsequent production increased the stability to an average of 700 lb. Sampling and stability testing to establish this change was conducted by the Bituminous Technical Services Unit of the Testing Laboratory and involved sampling of the material from truck loads as delivered from the plant; Marshall specimens were molded at the plant site and returned to the laboratory for testing. Marshall stability, flow, and density values are presented in Table 1 for the series of tests involving addition of mineral filler. Laboratory determined gradations were obtained for three of these mixtures and are shown in Table 2 along with the resultant job mix formula finally selected. Gradation specification limits, job mix formula and Range 1 tolerance limits (2) are shown in Figure 1 along with the recovered gradation of mix containing 2.6 percent additional mineral filler.

TABLE 1
INFLUENCE OF MINERAL FILLER
ON MARSHALL STABILITY VALUES

Lab. No. 83B-	Mineral Filler Added Percent	Unit Weight, pcf	Marshall Stability, lb	Flow, .01 in.
2290		148.8	530	5
2291	0	147.1	525	5
2292		145.9	460	5
Avg.		147.2	505	5
2293		148.9	750	5
2294	2.0	147.3	770	5
2295		148.0	625	6
Avg.		148.1	715	5
2296		148.0	615	5
2297	2.2	147.5	565	6
2298		147.7	740	5
Avg.		147.7	640	5
2299*		149.4	700	5
2300	2.2	149.1	1015	6
Avg.		149.3	858	6
2301		148.2	770	6
2302	2.4	148.5	510	6
Avg.		148.3	640	6
2303		149.0	680	6
2304*	2.5	149.2	705	6
Avg.		149.1	692	6
2305		148.8	630	6
2306*	2.6	148.5	735	6
Avg.		148.6	682	6

*Gradation analysis performed on these Mixtures.

Core samples, deflection, and rut depth measurements were obtained on the roadway at five test sections (Fig. 2). Layer thicknesses and type of subgrade material were also determined during the field evaluation phase and are summarized in Table 3. Core samples were tested in the laboratory for density, tensile stength, and resilient modulus at several temperatures. Average values are shown in Table 4 for each of the five test sections; tensile strength and stiffness modulus measured by the indirect tensile test, at 20 F, along with resilient modulus values measured at 20, 40 and 55 F are summarized in Table 4 for the bituminous base material. Similar values were measured for the surfacing layer and are given in Table 5.

Benkelman beam deflection basins measured for the five sections are shown in Figure 3. Deflection data for each of the sections are presented

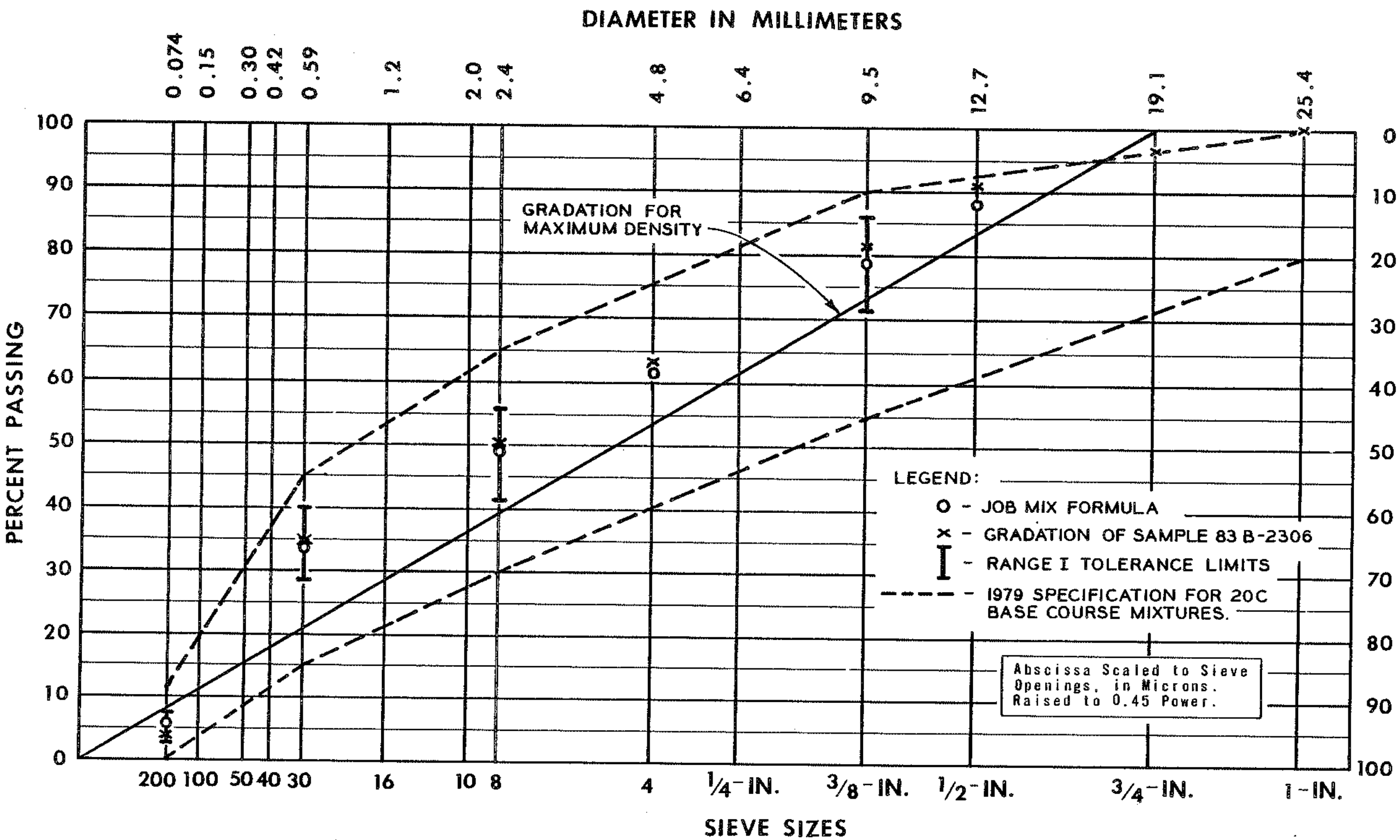

Figure 1. Gradation of 20C aggregate used in bituminous base course.

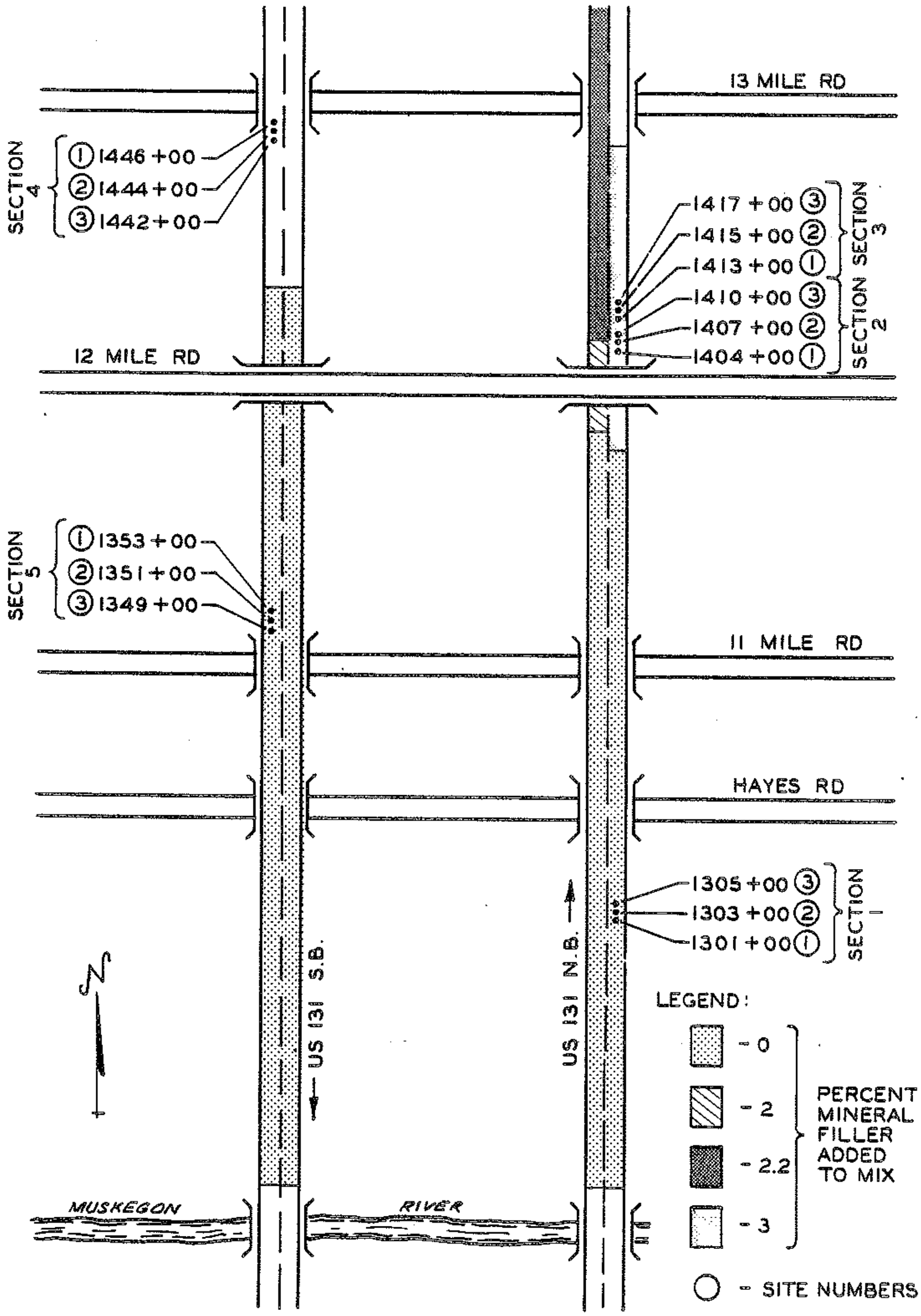

Figure 2. Location of core sampling, deflection and, rut depth measurement.

TABLE 2
AGGREGATE GRADATION OF BITUMINOUS BASE MIXTURES SAMPLED AT THE PLANT

Sieve Size	Cumulative Percent Passing Lab. No. 83B- 2299	2304	2306	Job Mix Formula
1	100	100	100	
3/4	96.2	96.7	96.5	
1/2	83.0	87.5	90.1	87.6
3/8	77.1	77.8	81.4	78.6
4	60.5	61.8	62.8	60.3
8	48.5	49.5	49.5	48.3
30	33.6	34.9	34.1	34.0
200	4.2	4.9	4.9	5.3
Min. Filler Added	2.2	2.5	2.6	3.0

TABLE 3
LAYER THICKNESS AND SUBGRADE MATERIAL

Layer	Section 1	2	3	4	5
Surface	1.6	1.3	1.5	—	—
Bit. Base	4.4	4.6	4.5	4.8	4.4
Agg. Base	3.8	5.5	5.0	5.9	4.6
Subbase	49.5	18.5 (43 sec.2c)	49.0	19.5 (40 sec.4-1)	18.3
Subgrade	Sandy Loam, and Sand	Sandy Loam, Silty Loam, Silty Sand	Clay Silt	Fine to Med. Sand	Fine Sand, Sandy Loam, Water at 46" Depth

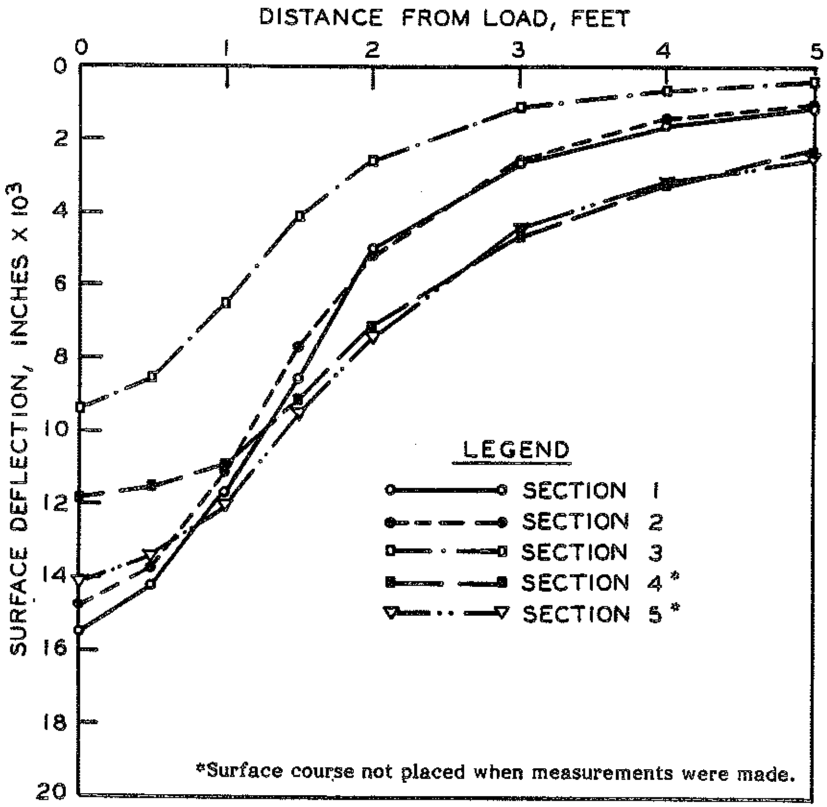

Figure 3. Benkelman beam deflection basins for the five test sections.

TABLE 4
SUMMARY OF STIFFNESS MEASUREMENTS
BASE COURSE MATERIAL

Test Temp., F	Loading Time, Sec.	Resilient Modulus, PSI x 10^{-6}				
		Section				
		1	2	3	4	5
20	0.02	3.37	3.05	3.26	2.97	2.71
	0.9	2.39	2.39	2.25	1.92	1.87
40	0.02	1.62	2.07	2.05	1.84	1.58
	0.9	0.77	1.04	1.00	0.79	0.71
55	0.02	0.87	1.22	1.02	0.84	0.89
	0.9	0.25	0.38	0.31	0.21	0.25
Indirect Tensile Strength,psi		297	335	365	347	314
Stiffness Modulus, E, (at 20 F), psi		0.21	0.21	0.35	0.22	0.35
Loading time to failure, sec.		25.8	28.4	26.1	31.4	23.6
Density, pcf		146.3	148.3	145.1	147.7	145.0

TABLE 5
SUMMARY OF STIFFNESS MEASUREMENTS
SURFACING MATERIAL

Test Temp., F	Loading Time, Sec.	Resilient Modulus, M_r, psi				
		Section				
		1	2	3	4*	5*
20	0.02	2.69×10^6	2.36×10^6	2.28×10^6	—	—
	0.9	1.72×10^6	1.45×10^6	1.49×10^6	—	—
40	0.02	1.42×10^6	1.28×10^6	1.23×10^6	—	—
	0.9	5.39×10^5	4.20×10^5	5.29×10^5	—	—
55	0.02	6.80×10^5	6.25×10^5	6.54×10^5	—	—
	0.9	1.54×10^5	1.44×10^5	1.45×10^5	—	—
Indirect tensile strength (at 20 F), psi		327	256	210	—	—
Stiffness Modulus, psi x 10^{-6}		0.89	0.74	0.52	—	—
Loading time to failure, sec.		38.1	40.9	44.0	—	—

*Surface course not placed when samples were obtained.

TABLE 6
SUMMARY OF BENKELMAN BEAM
DEFLECTION DATA

	Section				
	1	2	3	4*	5*
Maximum Deflection Inches	.0155	.0147	.0094	.0118	.0141
Deflection at 4 ft from load, in.	.0016	.0014	.0007	.0032	.0032
Spreadability, Percent	46.7	47.6	43.1	63.0	58.2
Pavement Temp., F	77	78	79	50	50
Radius of Curvature, ft					
High	1310	1235	1601	5787	2465
Average	1108	1045	1242	4558	2131
Low	992	791	1042	2101	1850

*Surface course not placed when measurements were made.

in Table 6. Rut depth measurements, Table 7, were made to provide reference values for any follow-up evaluations that might be made on this project. These initial rut depths cannot be considered as a measure of performance of the base or paving since, other than construction vehicles, there had been no traffic over the road when the measurements were made.

TABLE 7
RUT DEPTH MEASUREMENTS

Section	Rut Depths, In.			
	Passing Lane		Driving Lane	
	OWT	IWT	IWT	OWT
1	0	0	0.108	0
2	0	0.017	0.050	0.025
3	0	0	0.017	0.008
4*	0.025	0.017	0.008	0
5*	0	0	0	0

*Surface course not placed when measurements were made.

RESULTS

Elastic layer analysis methods were used to estimate the load carrying capacity of the pavement as constructed (3). Using stiffness modulus values measured in the laboratory for the bituminous base and surfacing, along with deflection values, it was shown that the pavement would experience excessive rutting after 13 years in Section 1. Sections 2 and 3, however, are predicted to fail after 20 and 31 years, respectively.

The differences in the predicted pavement life for the three sections are due, in part, to different base and subbase thicknesses as well as to the differing base stabilities and stiffness values.

Gradation analysis of aggregates recovered from the mix shows an excess amount of sand passing the No. 30 sieve and retained on the No. 200 sieve (Fig. 1). Even though this gradation was within the job mix formula tolerance range, the excess of fine sand caused the material to deviate from a straight line gradation necessary for maximum stability by nearly 15 percent on the No. 30 sieve (4). How much this deviation influences stability, however, needs further study.

CONCLUSIONS

Using elastic layer theory, the weakest section was shown to be Section 1 with an expected life of 13 years and that it will fail from rutting rather than fatigue; a fatigue life of 54 years was predicted for all sections.

RECOMMENDATIONS

Results of this investigation show that no corrective action is needed at the present time. It is recommended, however, that additional surfacing be placed when rut depths reach 1/2 in. in order to prolong the useful life of the pavement and to prevent degradation of surface drainage.

REFERENCES

1. MDOT Office Memorandum from R. A. Welke to H. B. LaFrance, August 29, 1983.

2. 1984 Standard Specifications for Construction. MDOT, §7.10.06.

3. DeFoe, J. H., "Use of Deflection Basin Characteristics for Flexible Pavement Analysis and Overlay Design," MDOT Research Report No. R-1204, September 1982.

4. "Evaluation of the Straight Line Gradation Chart and the Particle Index Test," MDOT Research Report No. R-1210, April, 1983.