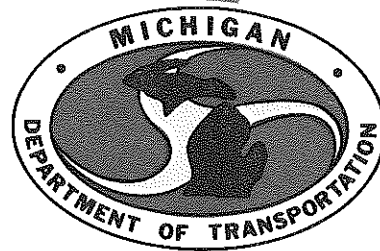
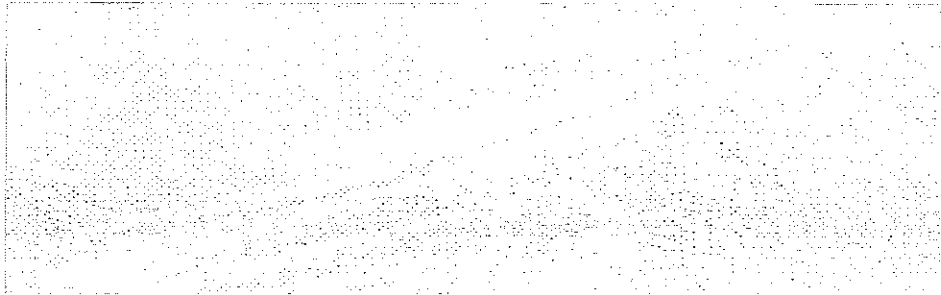


USE OF RECYCLED ASPHALT MATERIAL
IN THE CONSTRUCTION OF A BITUMINOUS
STABILIZED BASE, I 75, CHEBOYGAN COUNTY



**TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION**



TE270 .D33 1982 c. 3
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J. H. DeFoe

Research Laboratory Section
Testing and Research Division
Research Project 75 D-30
Research Report No. R-1209

Michigan Transportation Commission
Hannes Meyers, Jr., Chairman; Carl V. Pellonpaa,
Vice-Chairman; Weston E. Vivian, Rodger D. Young,
Lawrence C. Patrick, Jr., William C. Marshall
John P. Woodford, Director
Lansing, November 1982

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This is the final report describing features of Michigan's first large-scale cold recycling project, constructed in 1977 on I 75 in Cheboygan County. A previous report described construction procedures, specifications, and road history along with some test results (1). This final report summarizes material characteristics determined by laboratory tests and measurements of the road's performance over the five-year evaluation period.

The original roadway, an 11-mile portion of I 75 in Cheboygan County (Fig. 1), was constructed between 1960 and 1962 using 25 in. of sand sub-base, 11 in. of aggregate base, and approximately 4-1/2 in. of bituminous concrete binder, leveling, and wearing courses. The bituminous layers were constructed with 60/70 penetration grade asphalt cement which became harder and more brittle with age and during cold weather. Thermal cracks then developed which permitted moisture to enter the base causing localized heaving and general deterioration of the pavement resulting in a low serviceability rating.

Two methods of rehabilitation were considered for the reconstruction of this 11-mile section of highway which would minimize reflective cracking as well as provide a smooth riding surface. The southbound roadway was selected for reconstruction utilizing a 2-in. separation course (a hot-mixed bituminous base mixture) surfaced with leveling and wearing courses totaling 2-1/4 in. in thickness.

Recycling, by pulverizing and stabilizing the existing bituminous pavement to create a bituminous base, was selected for the northbound roadway and is the subject of this report. Performance comparisons, however, were made between the experimental recycled northbound roadway and the southbound roadway involving a separation course. Cross-sections for the two reconstructed roadways are shown in Figure 2.

In August 1975, the Federal Highway Administration approved Experimental Work Plan No. 41, MDOT Research Project 75 D-30, qualifying the job as a Category 2 experimental project. Work on the project was started in April 1977 by the prime contractor, Lake Construction of Indian River, Michigan. Subcontractor for recycling was Woodland Paving of Comstock Park, Michigan.

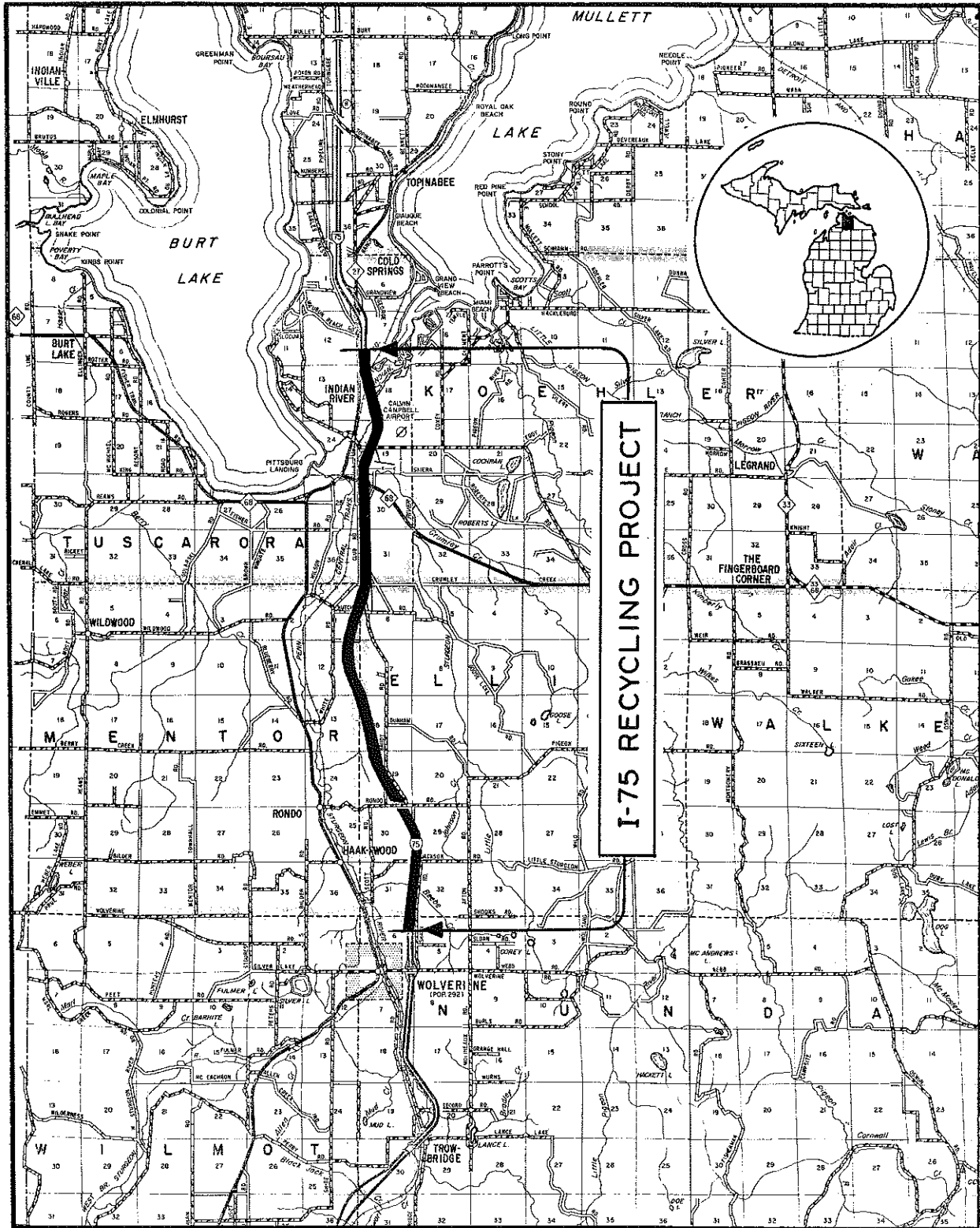
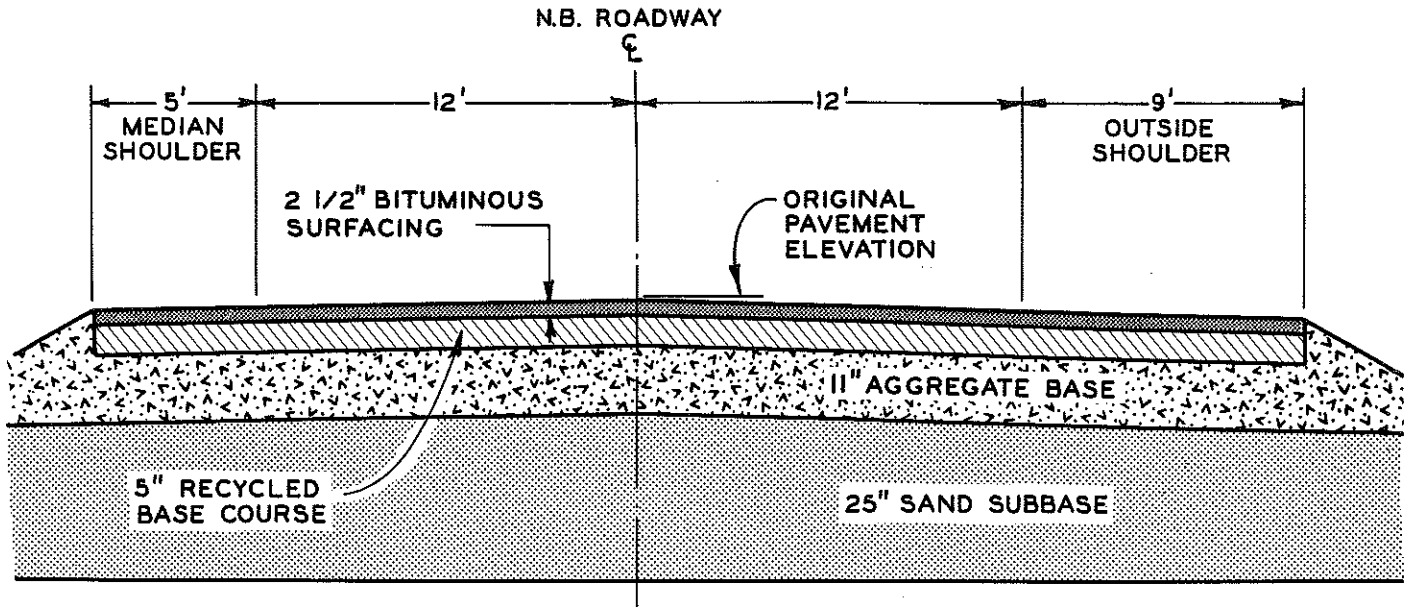
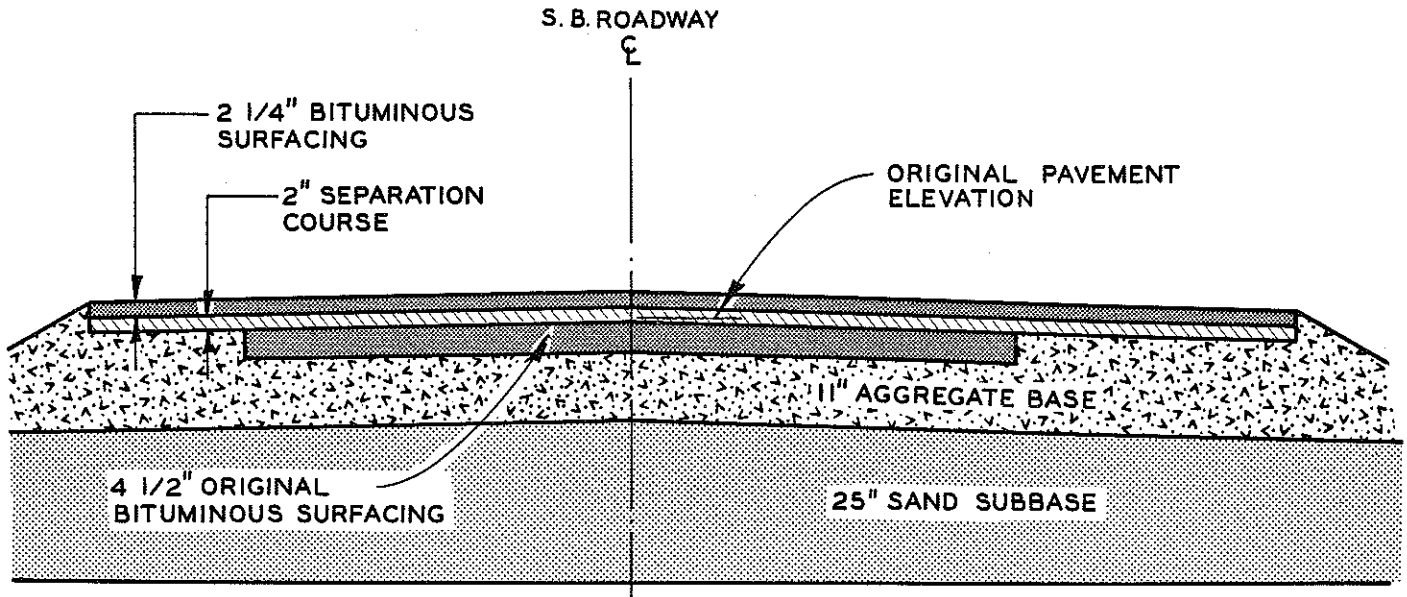


Figure 1. Location of recycling project, I 75 in Cheboygan County.



RECYCLED BASE SECTION



SEPARATION COURSE SECTION

Figure 2. Cross-sections for recycled and separation course reconstruction, I 75 in Cheboygan County.

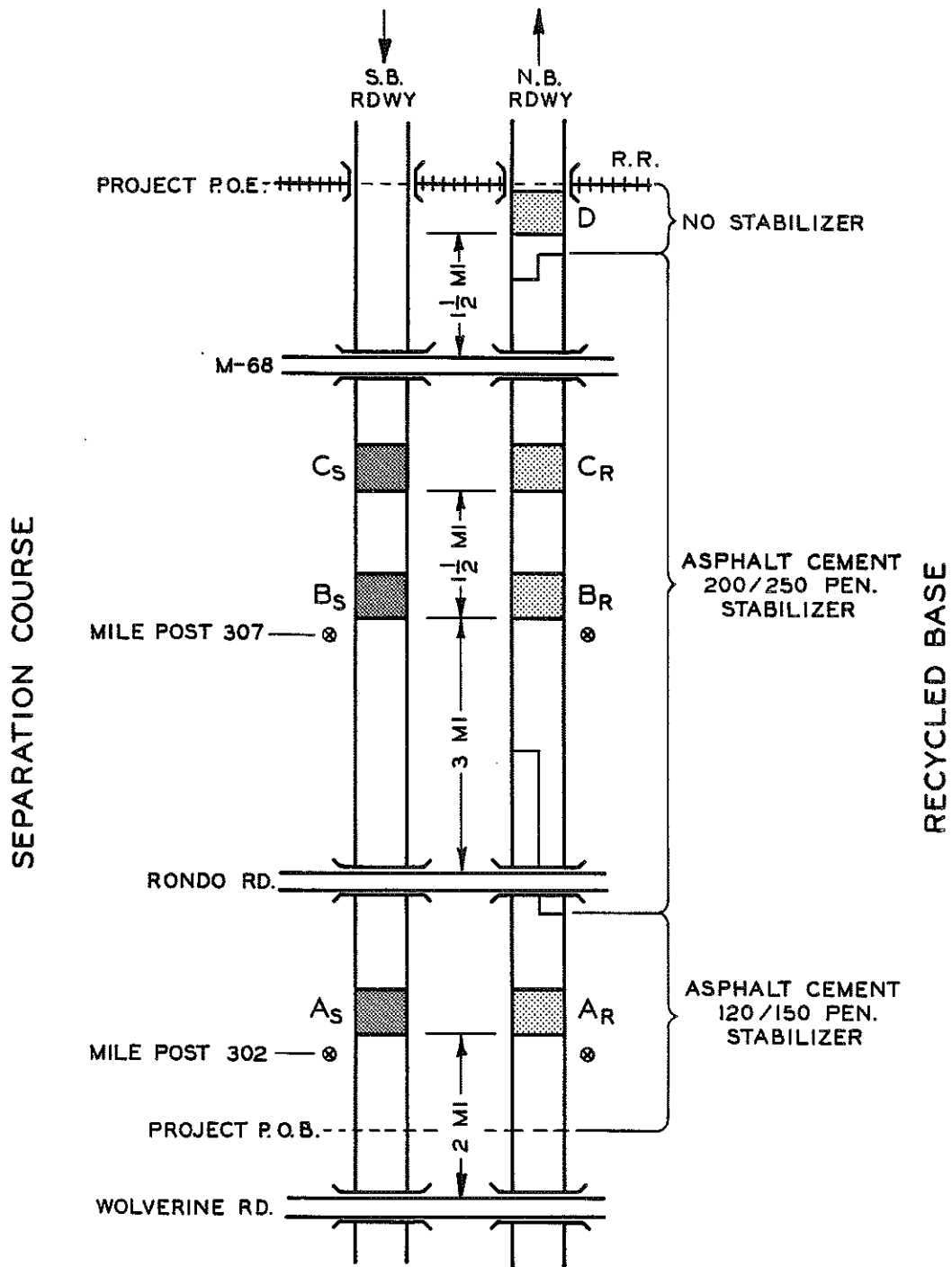


Figure 3. Location of test sections within experimental recycled base and separation course construction project.

Performance Measurements

Deflection, rut depth, and condition survey measurements have been made periodically since construction in order to evaluate the performance of the recycled pavement. The four 1/2-mile long test sections where measurements were made are shown in Figure 3. Comparative measurements were also made on the conventional separation course construction at three adjacent test sections in the southbound roadway (Fig. 3).

Rebound deflection measurements were made using a Benkelman beam and an 18-kip single axle load. In this test, the load truck is parked at the test site while the Benkelman beam is placed in position with its pointer between the dual wheels and several inches ahead of the axle (Fig. 4). Deflection of the pavement surface is continuously recorded as the load truck is driven forward at about 1/2 mph. A deflection basin as recorded in the field is shown in Figure 5. Deflection values at 1-ft intervals were used to analyze the deflection basin. The shape of the deflection basin was then used to evaluate the structural stiffness of the pavement layers including that of the stabilized base layer. Deflection basins measured at the four recycled base test sections and at the three adjacent separation course sections are shown in Figure 6 for comparison. Also included in Figure 6 are data from previous studies of black base sections on M 66 and I 75 (2).

Deflection basin measurements have been used in connection with other Departmental research for measuring the stiffness of layered pavement systems (3). In this procedure, the shape of the deflection basin is expressed as spreadability, S, given by the equation

$$S = \frac{d_0 + d_1 + d_2 + d_3 + d_4}{5d_0}$$

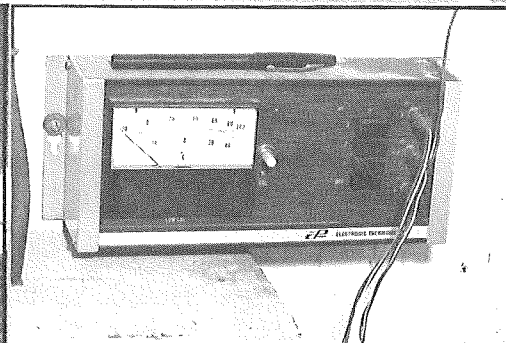
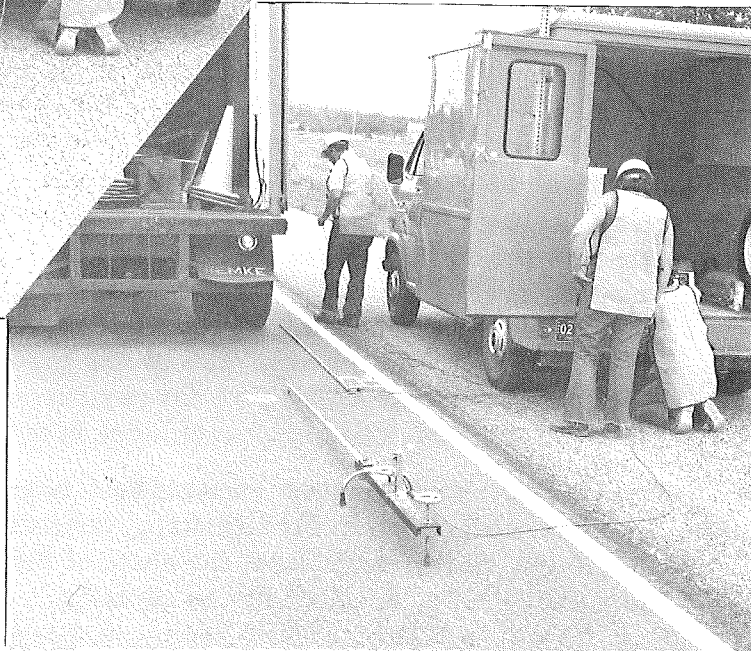
where: d_0 = maximum deflection under the wheel load, in.
 d_1, d_2, \dots, d_4 = deflection at 1, 2, 3, and 4 ft from the load.

Spreadability values are a measure of the area under the load deflection curve and provide an indication of the relative ability of different pavement sections to distribute vehicle loads to the foundation soils. Spreadability values alone can be used to directly compare different pavement sections but more importantly can be used along with computerized layer analysis methods to compare pavement performance in terms of fatigue life and rutting life due to traffic loadings (3). Spreadability values for the test sections are given in Table 1 along with the other performance parameters. Material characteristics which were measured during the evaluation are given in Table 2.



Recording the initial deflection with probe between the dual wheels of the load truck.

Recording deflections while the load truck is creeping forward.



Oil-filled hole for pavement temperature measurements. Temperature recorder above.

Figure 4. Benkelman beam deflection testing.

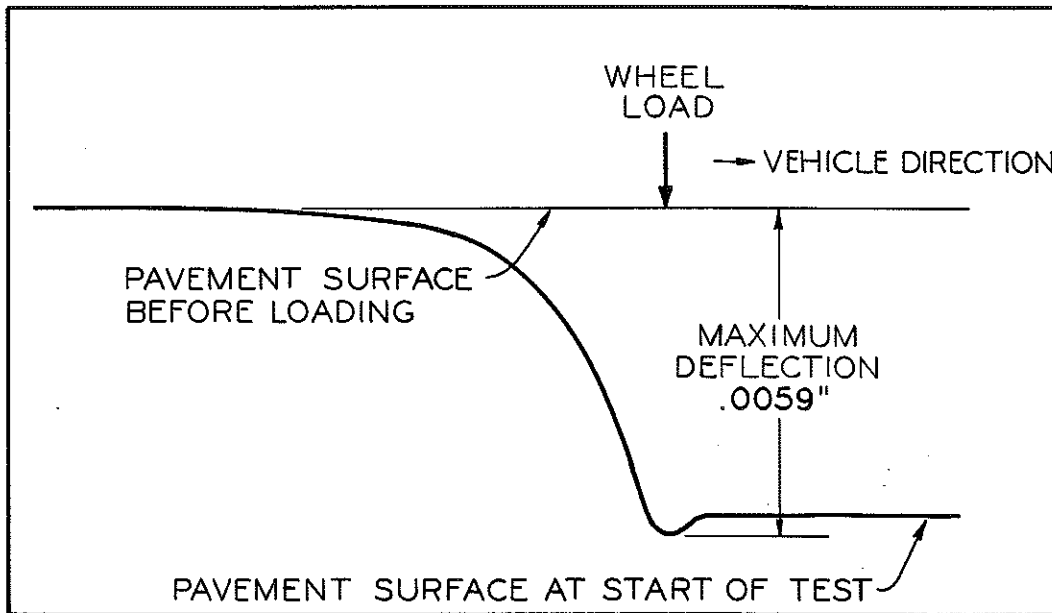


Figure 5. Benkelman beam deflection recording with the beam pointer and wheel load shown as the truck is moving forward.

TABLE 1
CONDITION SURVEY AND DEFLECTION MEASUREMENTS

Section No.	Maximum Deflection, in.	Spreadability, percent	Rut Depth Outer Wheelpath, in.	Cracking Index, CI*
AR (2)	0.0090	56.1	0.050	1.2
BR (3)	0.0109	55.8	0.100	0
CR (4)	0.0122	56.1	0.070	0.1
DR (9)	0.0120	52.6	0.070	2.7
AS (7)	0.0062	72.2	0.140	13.1
AS (6)	0.0072	69.3	0.030	9.3
AS (5)	0.0076	63.7	0.045	9.8
B.Base I 75	0.0093	65.6	0.040	--
B.Base M 66	0.0102	60.8	0.092	0

* Cracking Index, CI, is defined as the number of full width (two lanes) plus one half of the half width (one lane) transverse cracks per 500 ft section of two lane roadway (4).

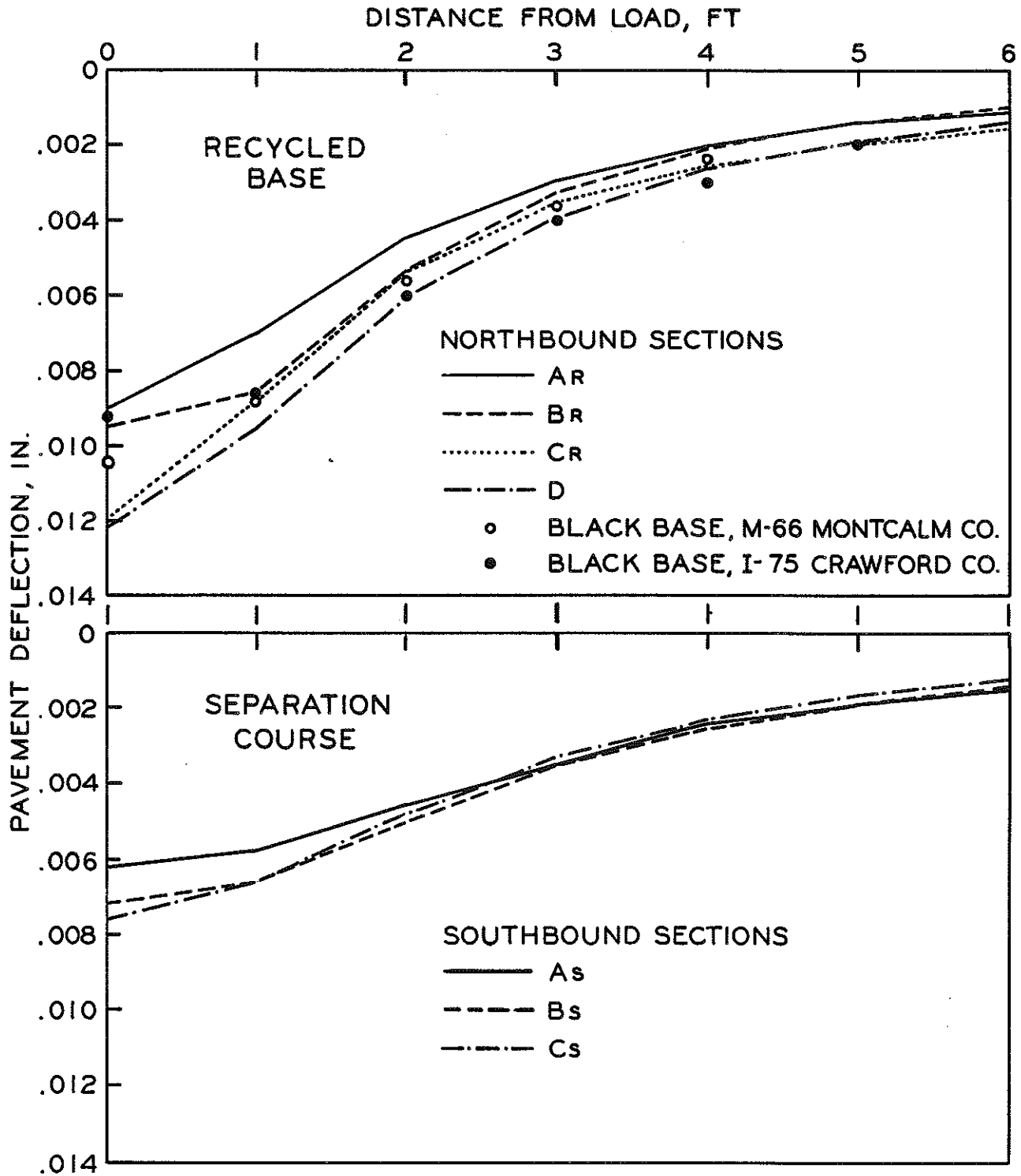


Figure 6. Benkelman beam deflection basins for recycled base test sections and for separation course reconstruction measured in adjacent locations in the southbound roadway.

TABLE 2
MATERIAL PROPERTIES OF RECYCLED BASE MIXTURES

Section No.	Asphalt				In-Place Compacted Unit Weight, (total) pcf	Resilient Modulus, Cores, psi (at 72 F)		Marshall Stability, flow*		Tensile Strength, psi*
	Total Recovered, percent	Stabilizer Added, percent	Recovered Penetration 0.1 mm			1.0 second	0.1 second	lb	1/100 in.	
			Old Bituminous	Recycled Bituminous						
AR	8.0	2.6	25	44	134.6	145,000	284,000	881	35	55.5
BR	7.5	2.1	25	59	142.1	82,000	150,000	883	34	55.0
CR	7.5	2.1	25	59	132.6	185,000	318,000	883	34	55.0
DR	5.4	0	25	--	130.8	---	---	---	--	--
Old Surfacing Wearing Leveling			25			307,000	598,000			
						191,000	339,000			

* Remolded specimens

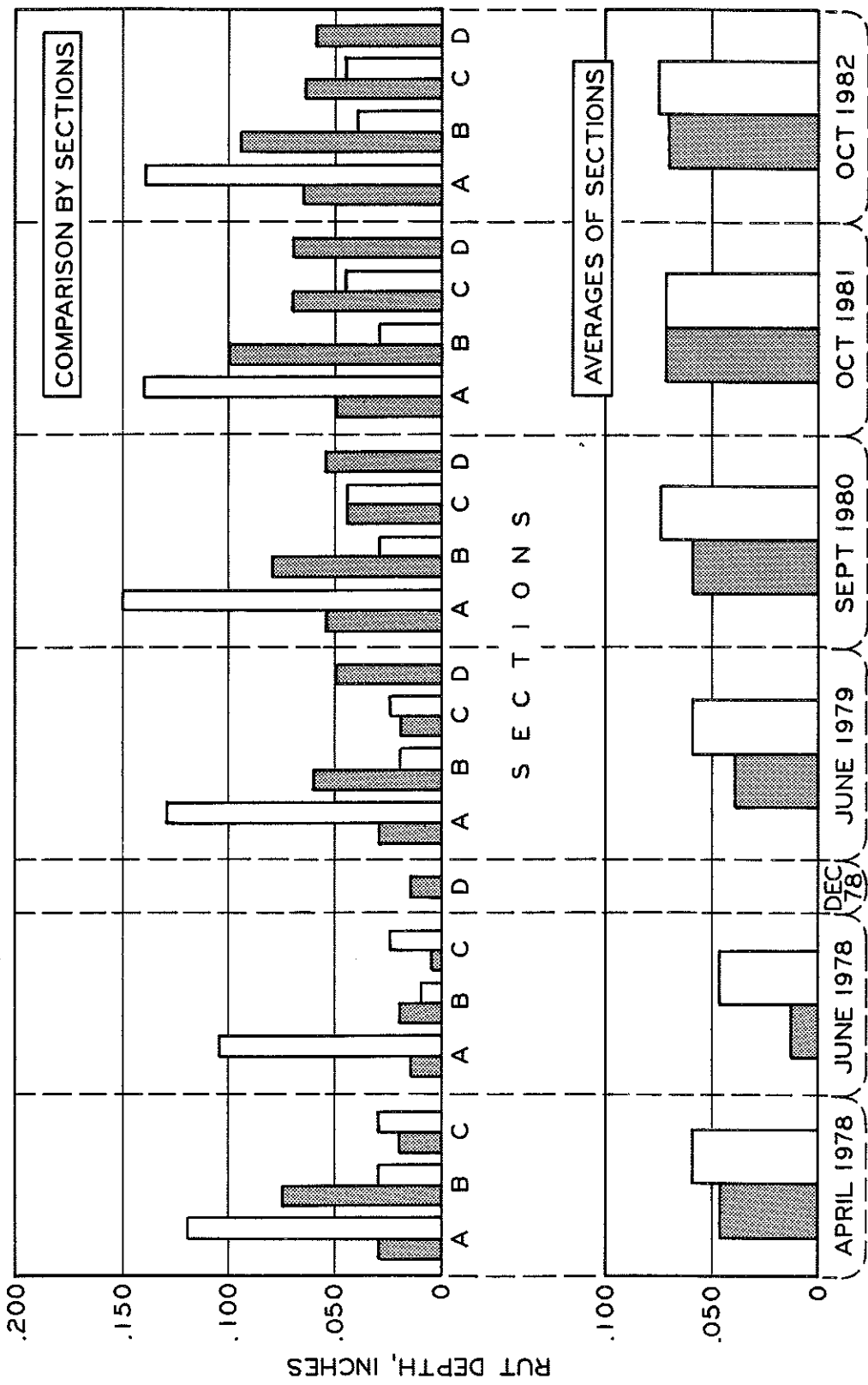


Figure 7. Rut depth history for comparable sections of roadways constructed with recycled bases and with a separation course. The rut depths shown are those measured in the outer wheelpath of the traffic lane.

Results of rut depth measurements are shown in Figure 7. These measurements were made in order to compare performance with that of the separation course construction. Performance measurements which were previously made on two black base sections on I 75 and M 66 are included in the performance results of the subject test roadways summarized in Table 1. These values provide a comparison between the two base constructions in addition to comparing the recycled base with the separation course method.

Material Characteristics

Material characteristics necessary for structural evaluation include resilient modulus, layer thickness and density, and asphalt content of the bituminous surfacing courses including the stabilized base layer. Layer thickness and unit weights were determined by direct measurement of cores taken from the road immediately after construction. Asphalt contents were obtained by extraction tests in the laboratory.

Resilient modulus is a measure of the stiffness of a bituminous mixture under dynamic loadings of short duration. A method for measuring resilient modulus in the laboratory, using either core samples or molded Marshall specimens, has recently been developed (5). Samples are 4 in. thick and 2-1/2 in. in diameter when Marshall specimens are used. Core samples will be the thickness of the paving layer being tested, generally from 1 to 3 in. and 4 in. in diameter. The method is based on the indirect tensile test and is used by the Research Laboratory for bituminous mixtures research. The method involves the repeated application of a 75-lb load of 1/10 second duration repeated every three seconds. Tests were also performed using a one-second load duration to more completely describe the time dependency of the mixture stiffness. The load is applied vertically, across one diameter of the sample and the resultant horizontal deflection across the other diameter is measured to determine the resilient modulus, M_R , from the following equation

$$M_R = \frac{P (\nu + 0.2732)}{t \cdot \Delta H}$$

where: M_R = resilient modulus, psi
P = load, lb
 ν = Poisson's ratio
t = sample thickness, in.
 ΔH = horizontal deflection, in.

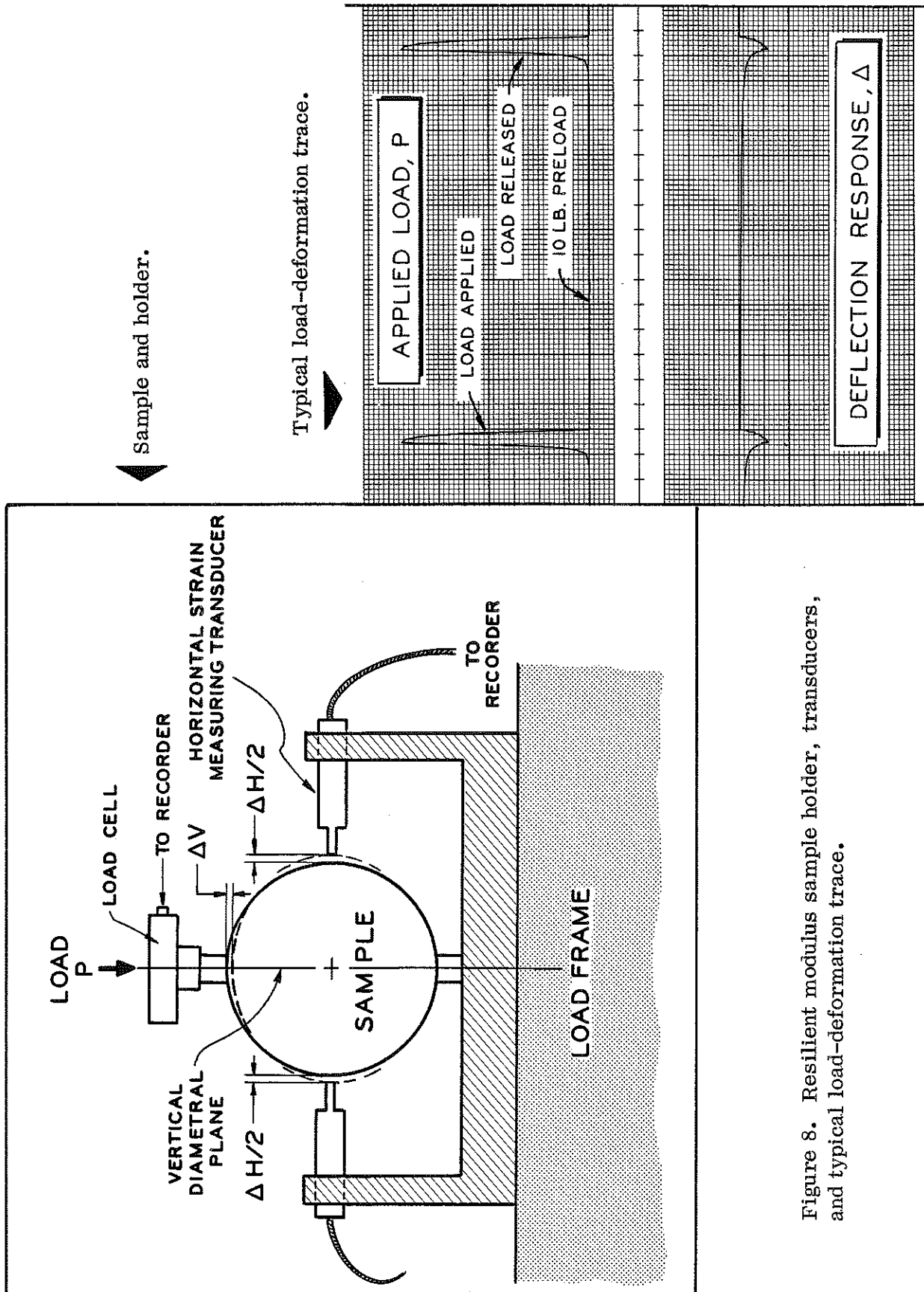


Figure 8. Resilient modulus sample holder, transducers, and typical load-deformation trace.

The sample holder and transducers for measuring load and sample deformation during the resilient modulus test are shown in Figure 8 along with a typical load-deflection recording. Figure 9 shows the complete laboratory test set-up for resilient modulus measurements. Resilient modulus values for the recycled material are listed in Table 2 which summarizes the properties of the recycled base mixture as measured in the laboratory.

Marshall stability and flow values were also measured (Table 2) to provide for comparisons based on the more conventional mixture design measurements. Marshall tests were performed at room temperature, however, since the stabilized base material was mixed and compacted at temperatures of 100 F or less. Furthermore, the base should not experience the same high in-service temperatures as the surface course materials which are normally tested at 140 F.

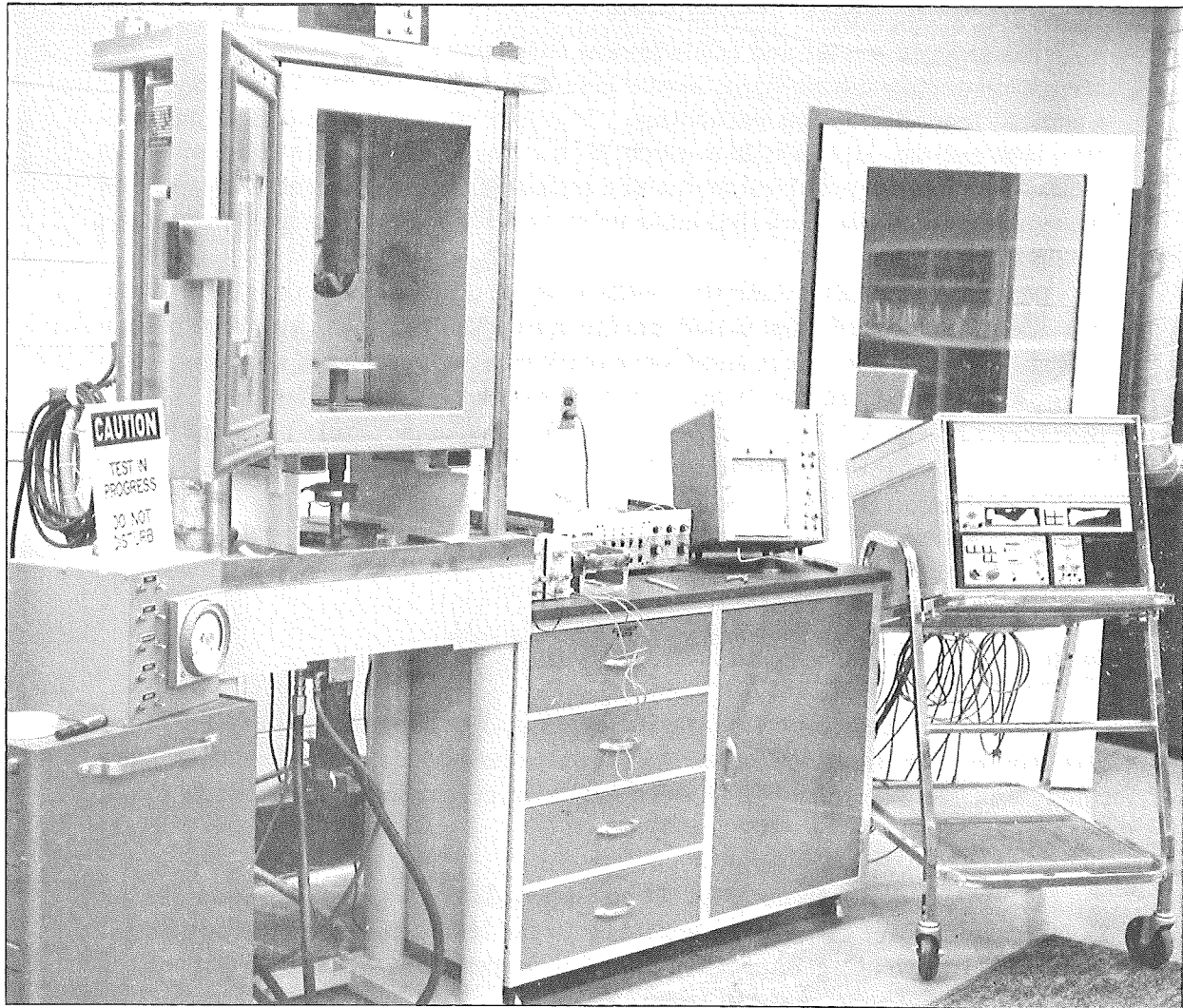
Performance Measurements

Performance measurements, summarized in Table 1, can be compared directly for the recycled base, the separation course reconstruction sections, and for sections which were initially constructed as hot-mix black base roadways.

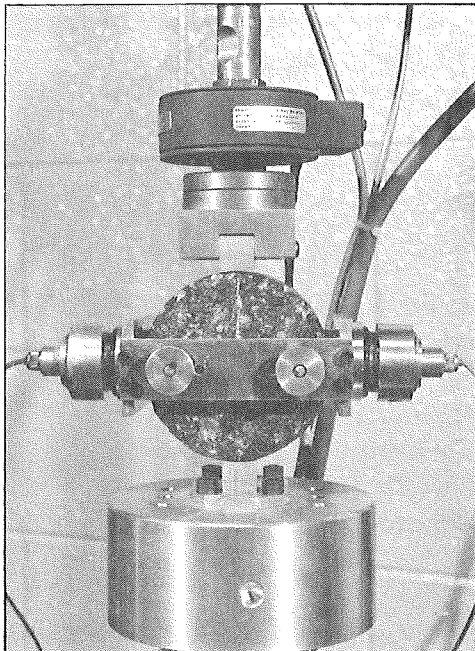
Maximum deflections (Fig. 6) and spreadability measurements (Table 1) indicate the recycled base sections to be less stiff and have somewhat lower load spreading capability than the separation course construction.

Deflection measurements, however, also show the recycled roadway to be nearly equivalent to the highways constructed with hot-mix black bases. Rut depth measurements compared by test sections, upper graph of Figure 7, show the recycled construction to be much better in Section A but poorer in Section B, than the separation course sections. Averaging all sections, lower graph of Figure 7, shows generally less rutting for the recycled than for the separation course roadway.

Cracking Index values (CI), shown in Table 1, show that recycling essentially eliminates transverse cracking, whereas, the separation course did not effectively inhibit reflective cracking. The average Cracking Index for the recycled sections is 1.0 (including the nonstabilized section with a CI of 2.7) as compared to 10.7 for the separation course sections. Cracking Index, CI, is defined as the number of full width transverse cracks (across two lanes) plus one-half of the half-width (across one lane) cracks per 500-ft section of two-lane roadway (4).



▲ Resilient modulus testing apparatus including load controller, environmental chamber and recording equipment.



◀ Sample loading and deflection measurement device used in the resilient modulus test.

Figure 9. Test apparatus for performing the repeated loading resilient modulus test.

Material Properties

The physical properties of the recycled base mixtures are given in Table 2 along with resilient modulus values measured on cores obtained from the old wearing and leveling courses prior to recycling. These results show the stabilized mixture to be softer and more flexible than the old bituminous pavement as indicated by recovered penetration values and by the resilient modulus stiffness measurements.

Structural Evaluation

In addition to evaluating the recycled pavement on the basis of performance and material property measurements, it is informative to consider the expected life of the pavement. Pavement life, i. e., the number of 18-kip equivalent axle loads (18 KEAL) to cause failure, can be predicted on the basis of deflection measurements using layer analysis methods (3). A computer program, CHEV 5L, is used which computes stress, strain, and deformation due to a selected load, at specified locations in the layered pavement system (6). Pavement data required for the CHEV program (for each layer) include thickness, stiffness modulus, and Poisson's ratio. By using the proper values for each of these layer parameters, the program computes a deflection basin which closely matches that obtained by the Benkelman beam. Strain values, also computed, are then used to predict pavement life in terms of the number of 18 KEAL to cause failure by fatigue or rutting. Measured deflection basins for sections C_R and C_G and their respective computer matches are shown in Figure 10. Layer parameters, stiffness, thickness, and Poisson's ratios which were used in computing the deflection basins are also shown in Figure 10. Modulus values for the bituminous surfacing and base layers were those measured in the laboratory. Methods used for estimating subgrade and subbase modulus values involve a systematic trial and error process which has been used in other Departmental studies (3). Fatigue and rutting life estimates are compared in Table 3 for the recycled base and separation course sections. The number of 18 KEAL applications to cause failure are estimated from the following equations (2)

$$N_F = 1.64 \times 10^{-7} \epsilon_t^{-3.67}$$

$$N_R = 3.17 \times 10^{-9} \epsilon_v^{-4.37}$$

where: N_F = number of 18 KEAL to cause fatigue failure
 ϵ_t = horizontal tensile strain at the bottom of bituminous leveling course
 N_R = number of 18 KEAL to cause subgrade rutting failure
 ϵ_v = vertical compressive strain at the top of the subgrade.

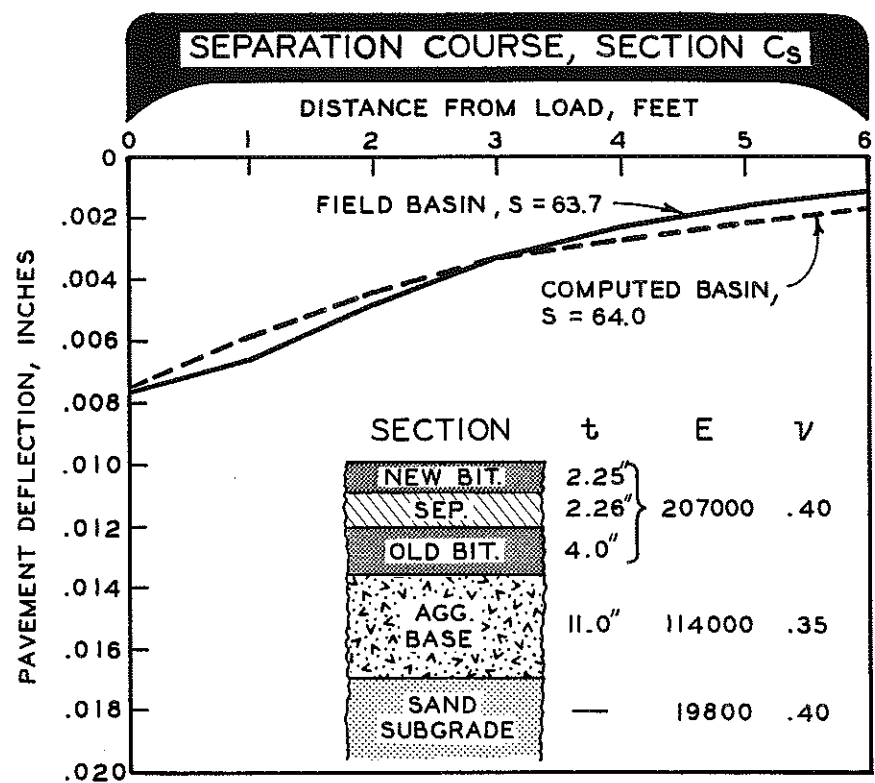
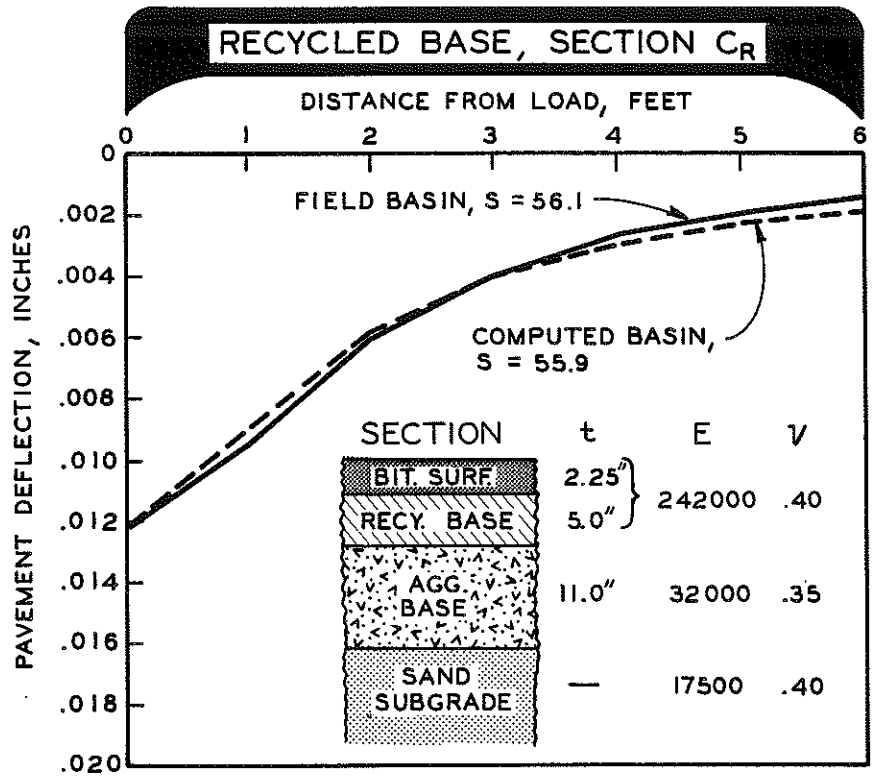


Figure 10. Deflection basins used to compare recycled base and separation course roadways.

The number of 18 KEAL values in Table 3 show that, based on structural factors, both types of pavement construction should perform satisfactorily for a period well beyond a reasonable design life. Environmental effects, however, will tend to reduce pavement life below the values determined from structural factors alone.

TABLE 3
COMPARISON OF STRAIN LEVELS AND
FATIGUE AND RUTTING LIFE ESTIMATES

Section	Tensile Strain, in. x 10 ⁻⁶ *	Fatigue Life N 18 KEAL's	Compressive Strain, in. x 10 ⁻⁴ **	Rutting Life N 18 KEAL's
C _R (Recycled)	116.7	5.6 x 10 ¹⁰	3.0	7.4 x 10 ⁶
C _S (Separation)	43.9	1.6 x 10 ⁹	1.8	8.2 x 10 ⁷

* Horizontal tensile strain at bottom of wearing course.

** Vertical compressive strain at the top of the subgrade.

Conclusions

Cold in-place recycling of an existing bituminous pavement was successfully demonstrated in this study. Specifically, the results of this project show that:

1) The recycled base roadway is structurally equivalent to the roadway reconstructed with a separation course.

2) Pulverizing and recycling of the bituminous surfacing, to provide a stabilized base, essentially eliminated all cracks that otherwise would reflect through an overlay even when a separation course is used.

3) Physical properties of the recycled base material as measured in the laboratory for this project were equivalent to those of hot plant mixed black base materials typically used in Michigan.

It should be emphasized, however, that more than two-thirds of the recycled base material consisted of pulverized bituminous surfacing mixtures. Future projects involving lesser portions of bituminous materials could possibly result in a lower quality product.

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