POST CONSTRUCTION EVALUATION
OF
SAND-ASPHALT-SULPHUR
TEST SECTION, KENEDY COUNTY, TEXAS

Interim Report No. 6

Project RF 3644

Period: 1 April to 31 August, 1979

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The Sulphur Institute and The U. S. Bureau of Mines

Texas Transportation Institute

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Introduction and Background:

During the month of April, 1977, a 3,000 ft. (915 m) section of U.S.77 in Kenedy County, Texas, five miles (8 km) south of Sarita was set aside for a demonstration of sand-asphalt-sulphur paving mixtures. The experimental sections were placed in the two north-bound lanes between stations 1985+00 and 2015+00 in conjunction with Highway Project TQF 913(13) under the jurisdiction of District 21, Texas State Department of Highways and Public Transportation (SDHPT). The pavement was constructed under a concept which was developed and patented by Shell Canada Limited. This concept involves the utilization of sulphur as a structuring agent in paving mixtures which contain poorly graded sands. These sand are plentiful in many areas of the United States, particularly along the Gulf Coast States.

Through efforts initiated by the Sulphur Institute, and co-sponsored by the U. S. Bureau of Mines, the Texas Transportation Institute (TTI) has, during the past six years, conducted an extensive laboratory program to verify the sand-asphalt-sulphur (SAS) concept developed by Shell Canada. This effort is directed toward promoting the use of sulphur in asphaltic - aggregate mixtures in the United States. The construction of this test section represents the next stage of verification through field evaluation.

A construction report describing the details of design and placement of the test section is available upon request. The report includes details of materials, mix designs, equipment, materials handling, quality control, and evolved gas analyses (1).

Field-Laboratory Tests

Upon completion of the test sections, cores were obtained by District 21 personnel and a series of tests were run (2). Data were processed and a report was prepared. This testing period was designated as initial (I). At six-month intervals following construction, TTI personnel took cores and performed a series of tests on these cores. During the same six-month intervals SDHPT personnel collected field data in the form of Dynaflect deflections, Mays Ride Meter roughness measurements, and visual distress evaluations. Both in-situ testing and core testing have been performed in accordance with the Test Matrix presented in Figure 1. A detailed layout of the test sections is presented in Figure 2.

Purpose:

To conduct post-construction testing and evaluation of an SAS experimental test section located on U.S.77 in Kenedy County, Texas in District 21 of the SDHPT.

Test Results and Discussion:

Table 1 shows the results of all core testing through June, 1979. Specific methods of testing are listed below:

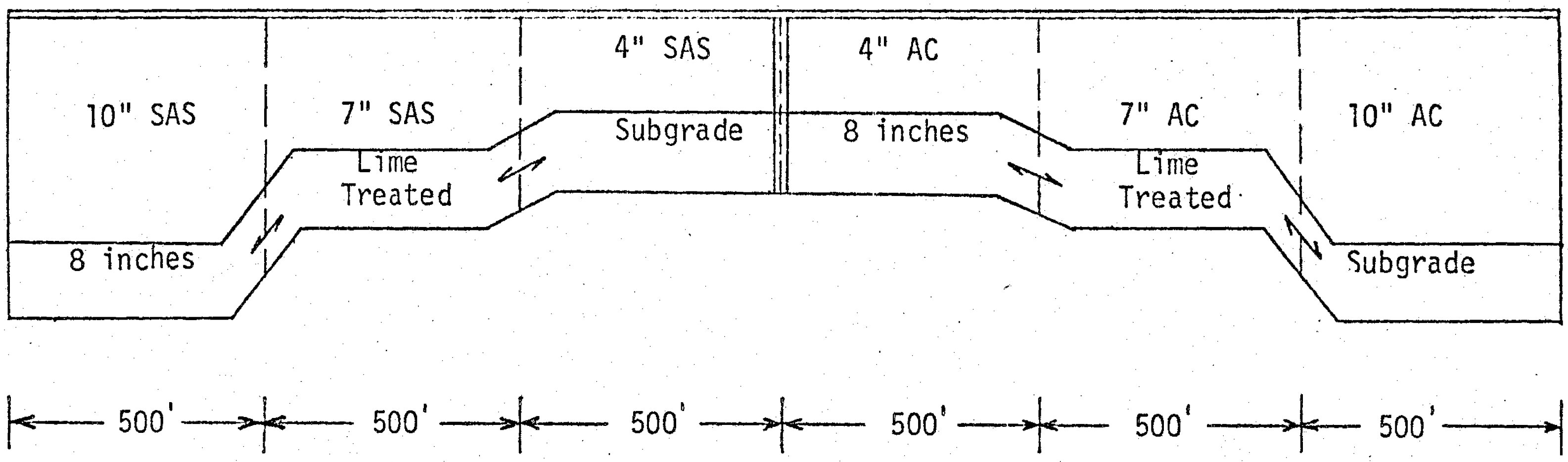
Bulk Specific Gravity	ASTM D 2041-71
Marshall Stability and Flow	ASTM D 1559-73
Hveem Stability	ASTM D 1560-65
Resilient Modulus, 68°F	as per Schmidt (3)
Indirect (Splitting) Tension	ASTM C 496-71
Rise Maximum Specific Gravity	ASTM D 2041-71

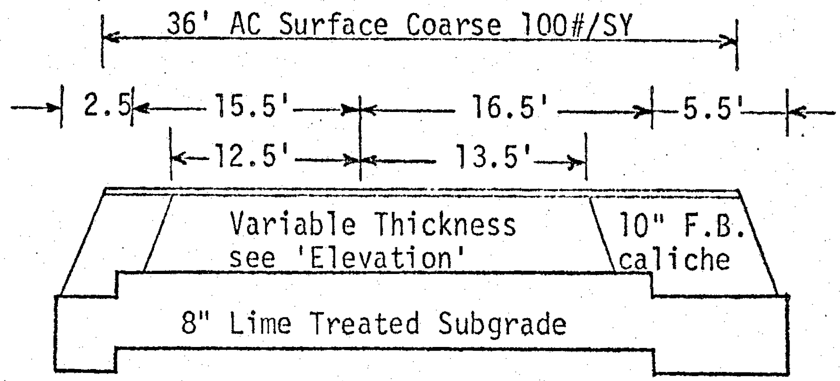
Figure 3 shows that the bulk specific gravity of the conventional hot-mixed asphaltic concrete material (HMAC) is consistently higher than that of the SAS. The HMAC maintains values of about 2.3 while the SAS mixture has a bulk specific gravity of 2.0 to 2.1.

Test Description	Initial* I	6 mo.	12 mo.	24 mo.	36 mo.
			Time Intervals		
1. Traffic Analysis					
a. Average Daily Traffic Count	←		continuous		→
b. Truck and Axle Weight Distribution	○				○
2. Visual Evaluation	△	△	△	△	△
3. Mays Meter (PSI)	△	△	△	△	△
4. Dynaflect Deflections	△	△	△	△	△
5. Core Samples**					
a. Field Density and Rice Specific Gravity	△	△	△	△	△
b. Stability, Marshall	△	△	△	△	△
c. Stability, Hveem	△	△	△	△	△
d. Resilient Modulus	△	△	△	△	△
e. Indirect Tension	△	△	△	△	△
6. Interim Reports	△	△	△	△	△

○ Loadometer Survey, 1-Week Duration
△ Evaluations on Both Sand-Asphalt-Sulphur Mixes and Conventional Asphaltic Concrete Sections
* Initial Testing Performed One Week After Pavement Opened To Traffic
** Set of 3 Cores (minimum) at Each Test Section Per Sampling Period (Each Lane)

Figure 1 Testing matrix for SAS Trials, US 77, Kenedy County, Texas





Cross-Section

N-S Right Lanes

SAS Sand-Asphalt-Sulphur Pavement Material

AC Asphaltic Concrete Pavement, Type D

Schematic Does Not Scale

1 in = 25.4 mm

1 ft = 0.305 m

1 lbm = 0.454 kg

1 yd^2 = 0.836 m^2

Figure 2 Layout of field test section in Kenedy County on U.S. 77

Table 1. Field core test results for U. S. 77

Base Type	Binder Content, percent	Specific Gravity	Marshall Stability lbf	Marshall Flow 0.01 in.	Hveem Stability, percent	Resilient Modulus at 68°F, psi x 10^6	Splitting Tensile, psi	Date	Rice Max. Specific Gravity
		2.02	1350	17	25	0.46	155	4/77(0)**	
10" SAS	6.2/13*	2.20	1445	8	31	0.70	160	12/77(6)	2.29
		2.04	2070	10	42	0.48	200	6/78(12)	
		2.02	1725	9	30	0.73	178	12/78(18)	
		2.04	1535	9	38	0.57	169	6/79(24)	
		2.01	1885	15	34	0.44	145	4/77(0)	
7" SAS	6.2/13*	2.04	1740	9	30	0.64	150	12/77(6)	2.24
		1.99	1210	10	28	0.48	205	6/78(12)	
		2.04	1975	9	36	0.77	168	12/78(18)	
		2.02	1430	9	29	0.52	160	6/79(24)	
		2.01	1890	14	32	0.45	155	4/77(0)	
4" SAS	6.2/13*	2.05	1875	10	38	0.77	185	12/77(6)	2.31
		2.05	1450	9	30	0.55	235	6/78(12)	
		2.05	1785	10	30	0.91	183	12/78(18)	
		2.05	1190	10	33	0.56	184	6/79(24)	
		2.13	340	11	36	0.73	215	4/77(0)	
4" AC	6.2	2.25	580	13	26	1.28	290	12/77(6)	2.38
		2.25	930	14	27	1.16	325	6/78(12)	
		2.29	660	13	25	1.52	291	12/78(18)	
		2.29	730	18	31	1.10	278	6/79(24)	
		2.26	675	18	*	0.81	240	4/77(0)	
7" AC	6.2	2.26	665	11	27	1.23	255	12/77(6)	2.38
		2.25	685	14	26	0.99	273	6/78(12)	
		2.29	520	11	28	1.41	279	12/78(18)	
		2.31	500	9	29	0.74	247	6/79(24)	
		*	*	*	*	*	*	4/77(0)**	
10" AC	6.2	2.24	2.24	12	29	1.12	255	12/77(6)	2.40
		2.27	2.27	12	24	1.02	310	6/78(12)	
		2.29	2.29	11	29	1.54	262	12/78(18)	
		2.32	2.32	12	22	0.75	256	6/79(24)	

*The mix design established for these systems was 6.2 weight percent asphalt and 13 weight percent sulphur.
**Pavement age in months.

1 lbf = 4.45N
1 in = 25.4 mm
1 psi = 6.89 kPa

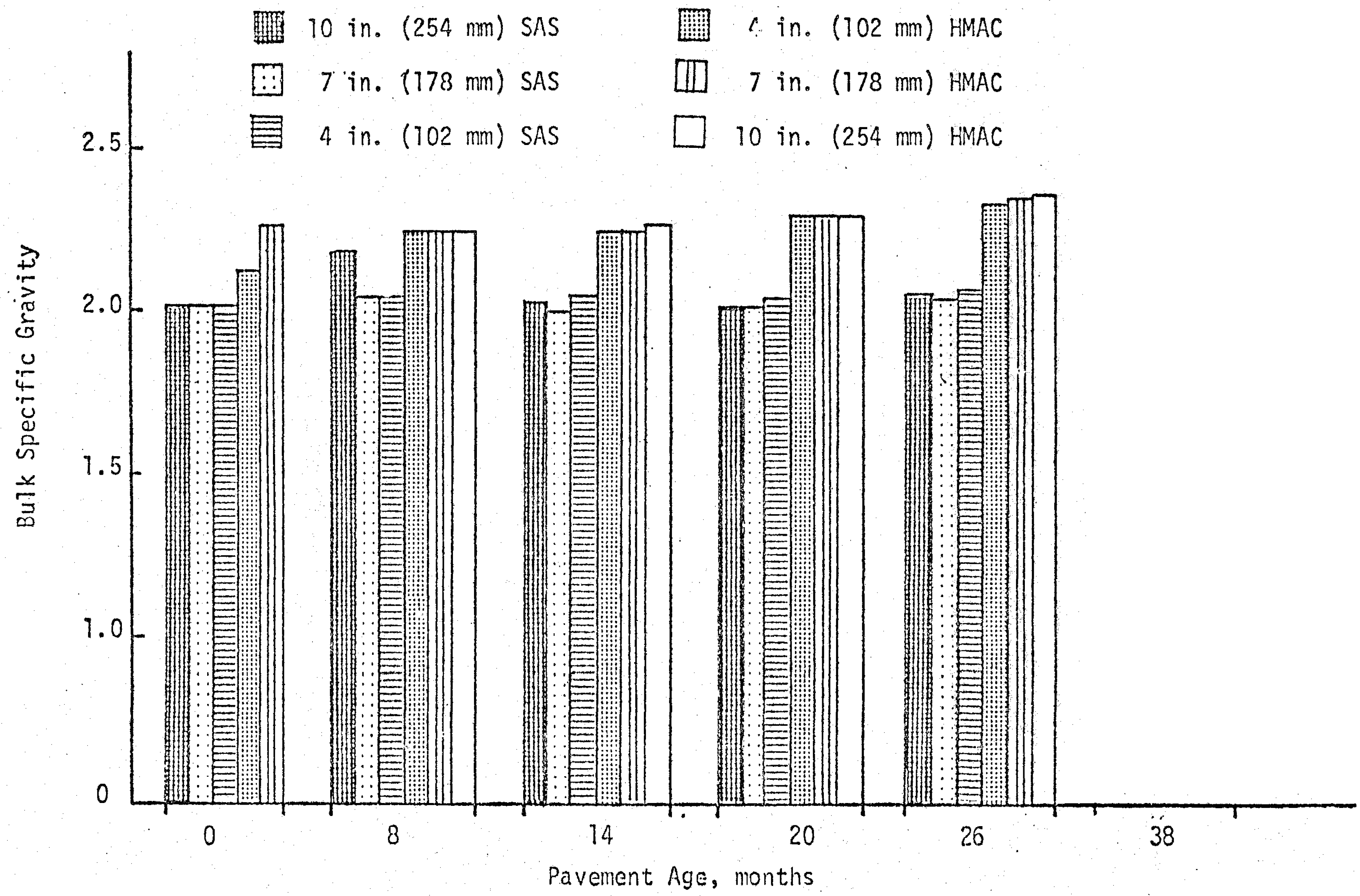


Figure 3. Bulk specific gravity versus pavement age for U. S. 77.

In Figure 4, it can be seen that the SAS mixture has maintained a higher Marshall stability than the HMAC mixture throughout the course of the study. For the last testing period, the SAS material had an average Marshall stability of about 1390 lbs. (6190 N) and the HMAC had a value of about 655 lbs. (2910N). Both of these values are above the 500 lbs. (2230N) minimum recommended by the Asphalt Institute. Figure 5 shows that the Marshall flow values for all of the paving mixtures have not fallen outside of the Asphalt Institute's recommended range of from 8 to 18 (2 to 5 mm). In general, the flow has been greater for the HMAC mixture.

It may be noted from Figure 6 that the Hveem stability for the SAS mixture has been slightly but consistently higher than that of the HMAC material. For the latest testing period, the SAS mixture had an average Hveem stability value of 33 whereas the HMAC material had an average of 27. The Asphalt Institute recommends a minimum value of 35 for medium traffic roads such as U. S. 77.

Figure 7 shows that throughout the course of the study the HMAC mixture has had a consistently higher resilient modulus that the SAS mixture. For this testing period, the SAS material had an average resilient modulus of 0.55 X 10^6psi (3.80 X 10^6kPa). The HMAC material had an average value of 0.86 X 10^6psi (5.93 X 10^6 kPa). It should be recalled that the SAS mixture consists of fine sand as the aggregate, whereas, the HMAC utilizes a graded aggregate sized from 1/2-inch (13 mm) to No. 200 (75 microns).

Figure 8 shows that the average splitting tensile strength for the HMAC sections continues to be higher, at 260 psi (1791 kPa), than the SAS sections, at 171 psi (1178 kPa).

Personnel of the SDHPT took Dynaflect measurements in accordance

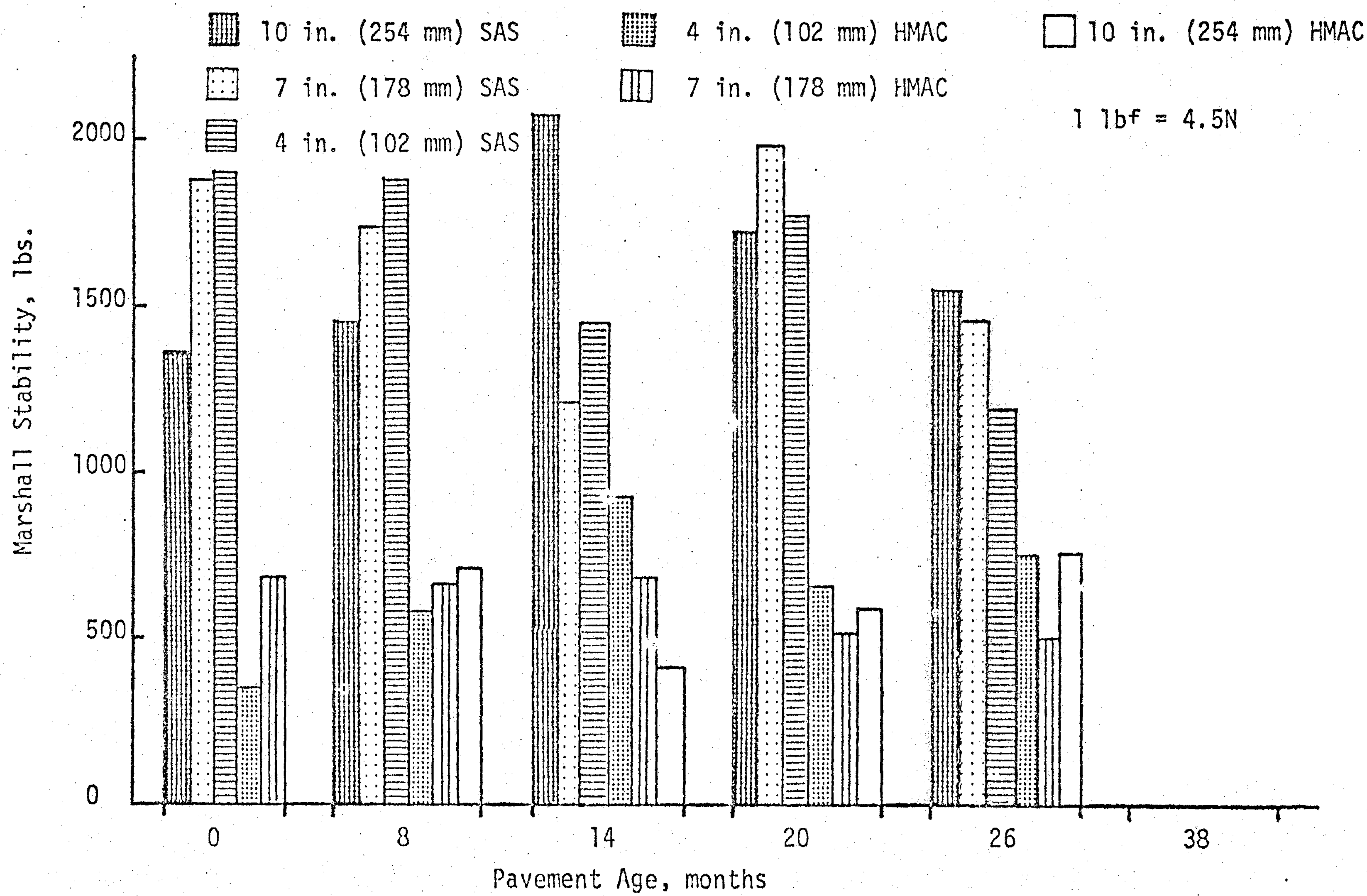


Figure 4. Marshall stability versus pavement age for U. S. 77.

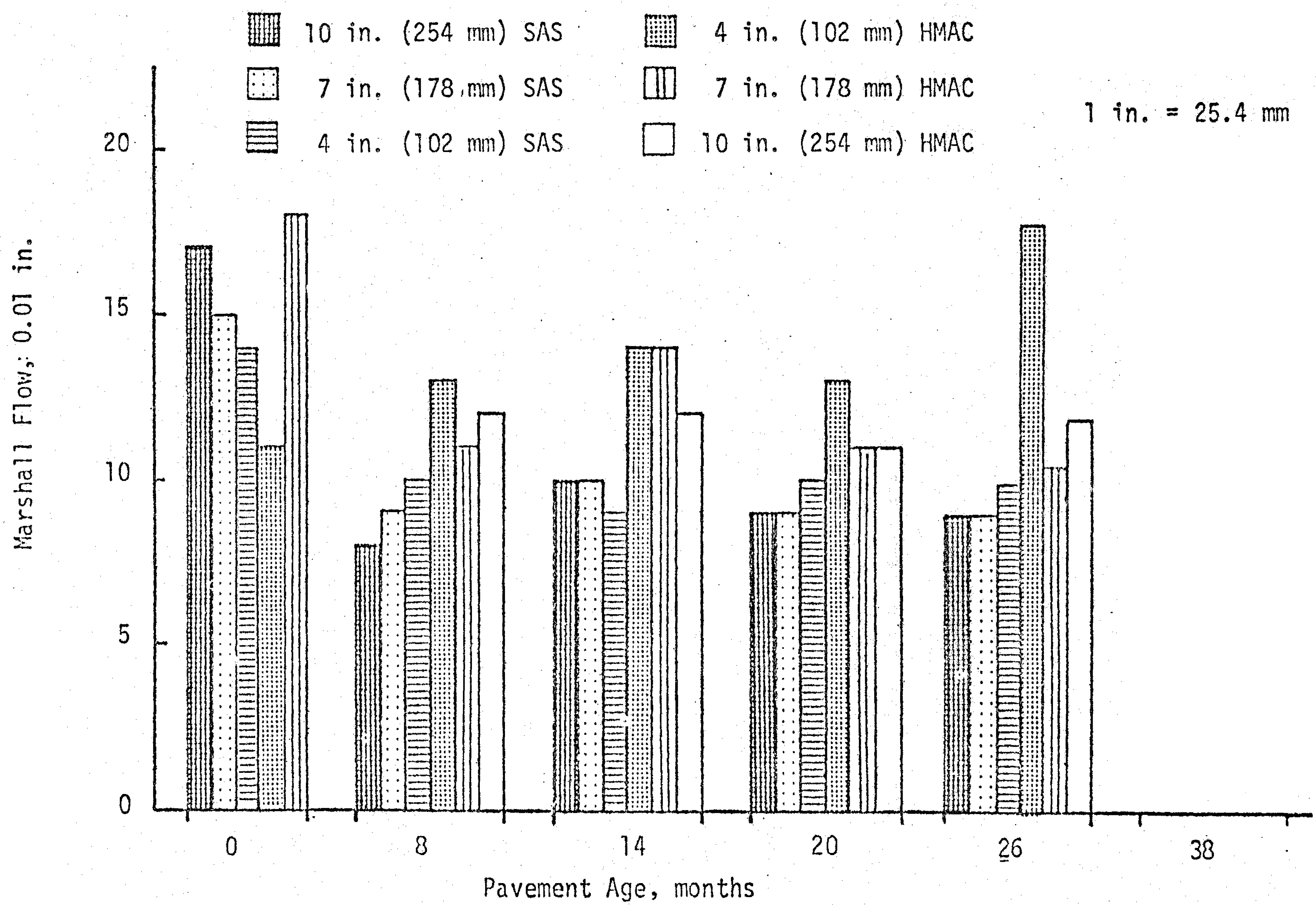


Figure 5. Marshall flow versus pavement age for U S. 77.

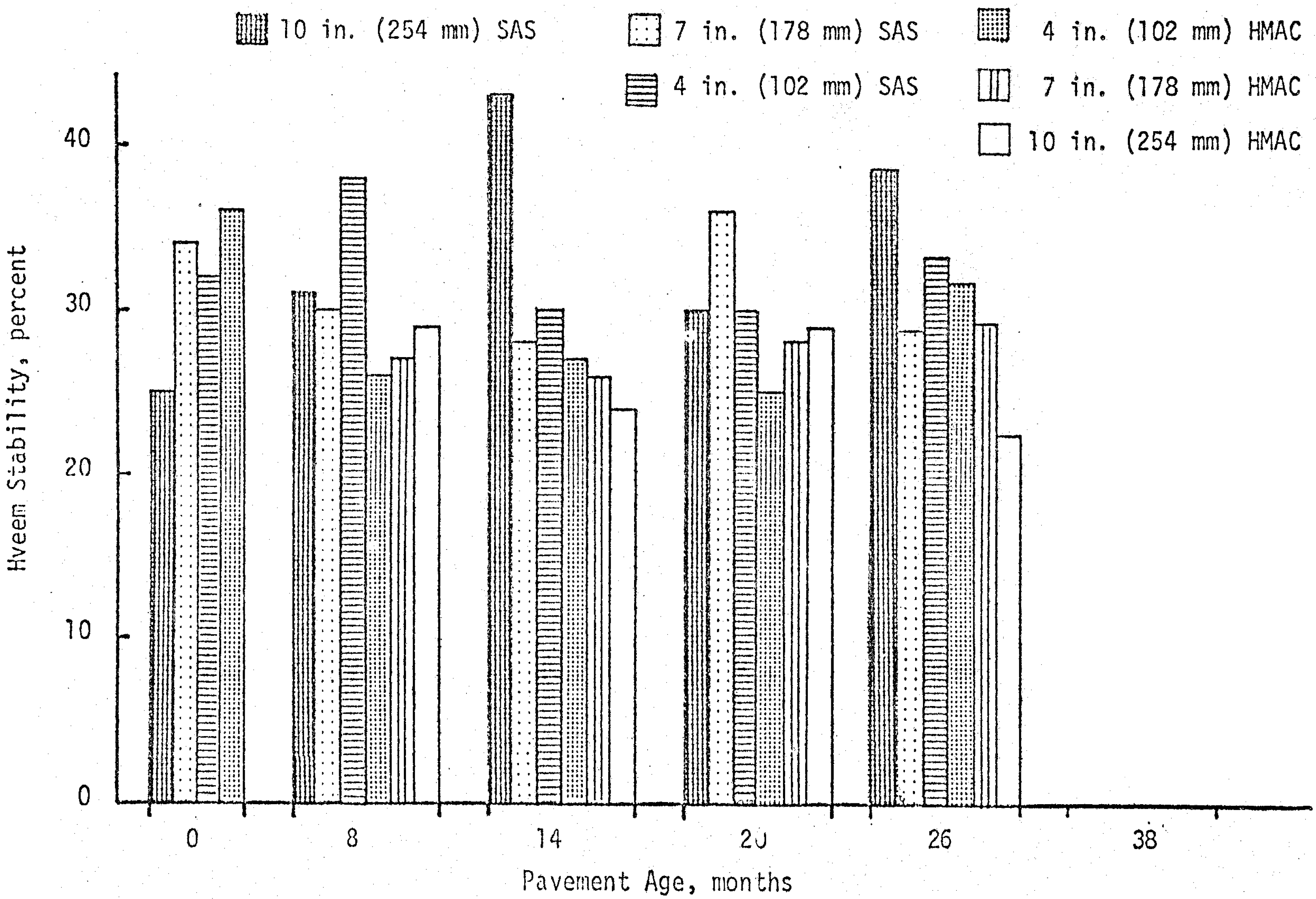


Figure 6. Hveem stability versus pavement age for U. S. 77.

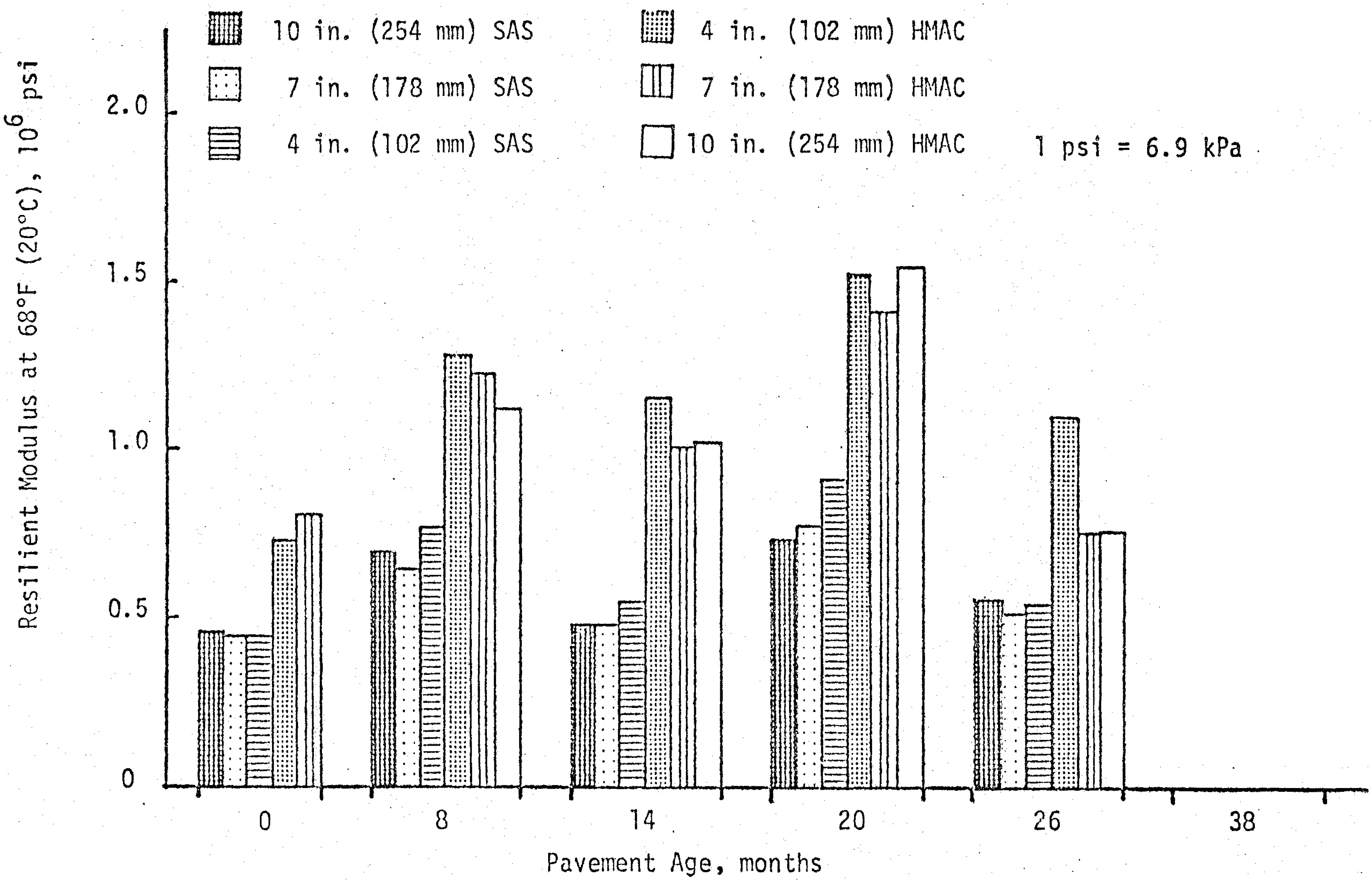


Figure 7. Resilient modulus at 68°F (20°C) versus pavement age for U. S. 77.

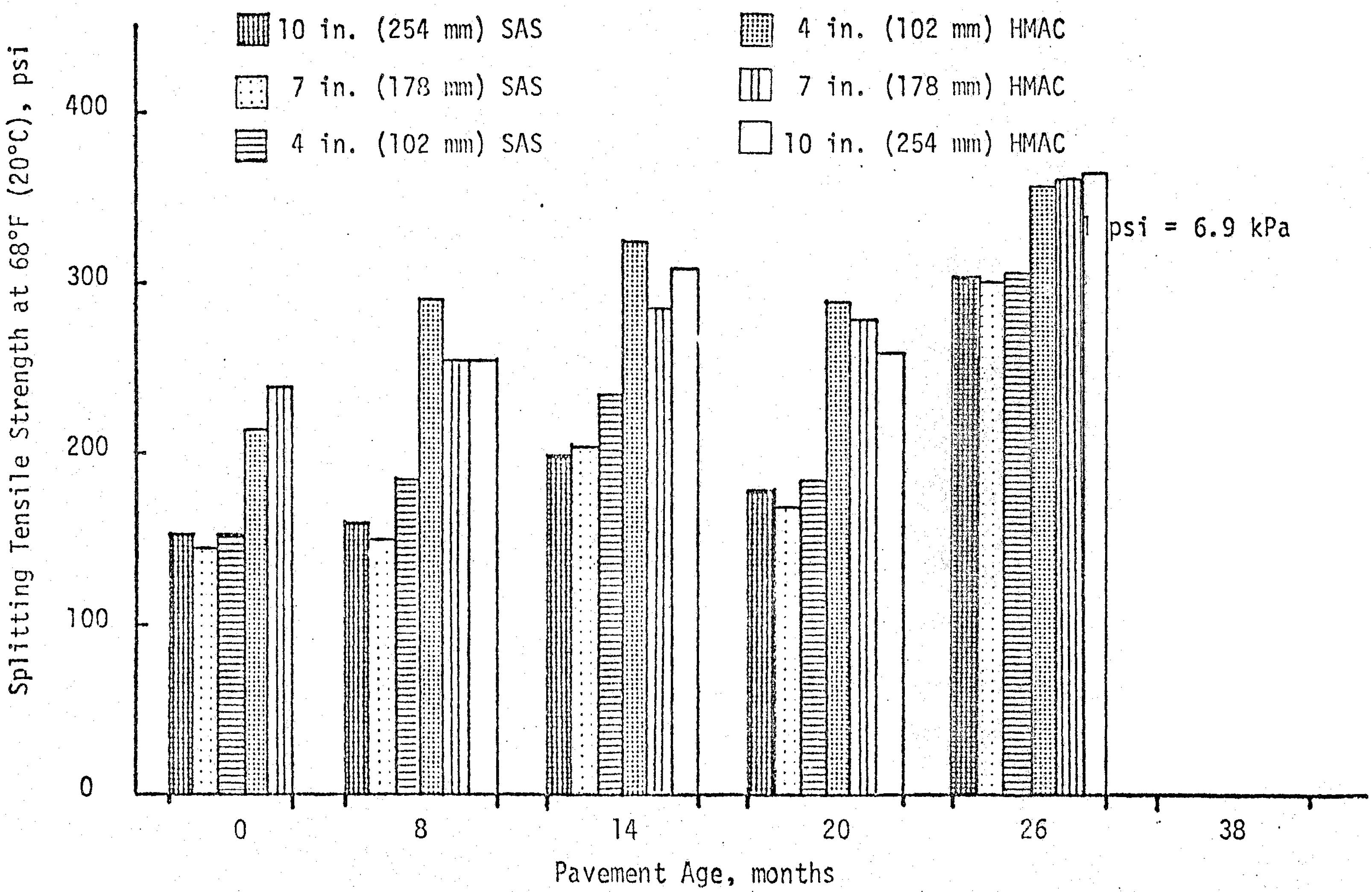


Figure 8. Splitting tensile strength at 68°F (20°C) versus pavement age for U. S. 77.

with the procedure set forth by Moore and Scrivner (4). A tabulation of Maximum Dynaflect Deflection results collected up to this time is presented in Table 2. As Figure 9 shows, Dynaflect measurements for June 1979 continue to follow the trend established by the first three measurements. The 10 in. (254 mm) and 7 in. (178 mm) HMAC sections have higher deflections than the equivalent depth SAS sections; whereas the 4 in. (102 mm) HMAC section is consistently lower than the 4 in. (102 mm) SAS section.

Table 3 presents a summary of the Serviceability Index for each wheel path as computed from the Mays Ride Meter test performed by District 21 personnel. The Mays Ride Meter and its operations are described in Reference 5.

The pavement rating score presented in Table 4 was arrived at from a visual distress survey conducted by the SDHPT as per the procedure for pavement rating as established by Epps, et. al. (6). In this rating, the serviceability index was not included in order to give a more nearly accurate representation of any visual distress. The rating given in Table 4 reflects only the cracking and rutting which have occured. Slight amounts of longitudinal cracking have been noted in the 7 in. (178 mm) SAS base section as shown in Figure 11. Figures 10 and 12 show that neither of the other two SAS sections have any sort of cracking. Figures 13 through 15 illustrate that all of the HMAC sections show slight amounts of cracking. In addition, the SDHPT reported that rutting is starting to take place in the 7 in. (178 mm) and 10 in. (254 mm) HMAC base sections (controls).

Distress in Flexible Base Section

The contract specifications on this entire job call for flexible

Table 2. Maximum Dynaflect deflections for US 77.

Percent Binder and Mix Type	Station	Pavement Thickness,* in.	Maximum Dynaflect Deflection, 10-3 in.	Date
6.2/13 SAS**	1985+00 to 1990+00	11	0.44 0.48 0.40 0.37	12/13/77(6)*** 6/6/78(12) 12/4/78(18) 6/5/79(24)
6.2/13 SAS	1990+00 to 1995+00	8	0.56 0.61 0.53 0.46	12/13/77(6) 6/6/78(12) 12/4/78(18) 6/5/79(24)
6.2/13 SAS	1995+00 to 2000+00	5	0.88 0.90 0.86 0.67	12/13/77(6) 6/6/78(12) 12/4/78(18) 6/5/79(24)
6.2 AC	2000+00 to 2005+00	5	0.72 0.73 0.74 0.55	12/13/77(6) 6/6/78(12) 12/4/78(18) 6/5/79(24)
6.2 AC	2005+00 to 2010+00	8	0.68 0.78 0.75 0.59	12/13/77(6) 6/6/78(12) 12/4/78(18) 6/5/79(24)
6.2 AC	2010+00 to 2015+00	11	0.44 0.60 0.44 0.40	12/12/77(6) 6/6/78(12) 12/4/78(18) 6/5/ 79(24)

*All sections have 1 inch asphaltic concrete wear course and 8 inch lime treated subgrade.

**6.2/13 = weight percent of asphalt and sulphur in the paving mixture.

***Pavement age in months. 1 in. = 25.4 mm

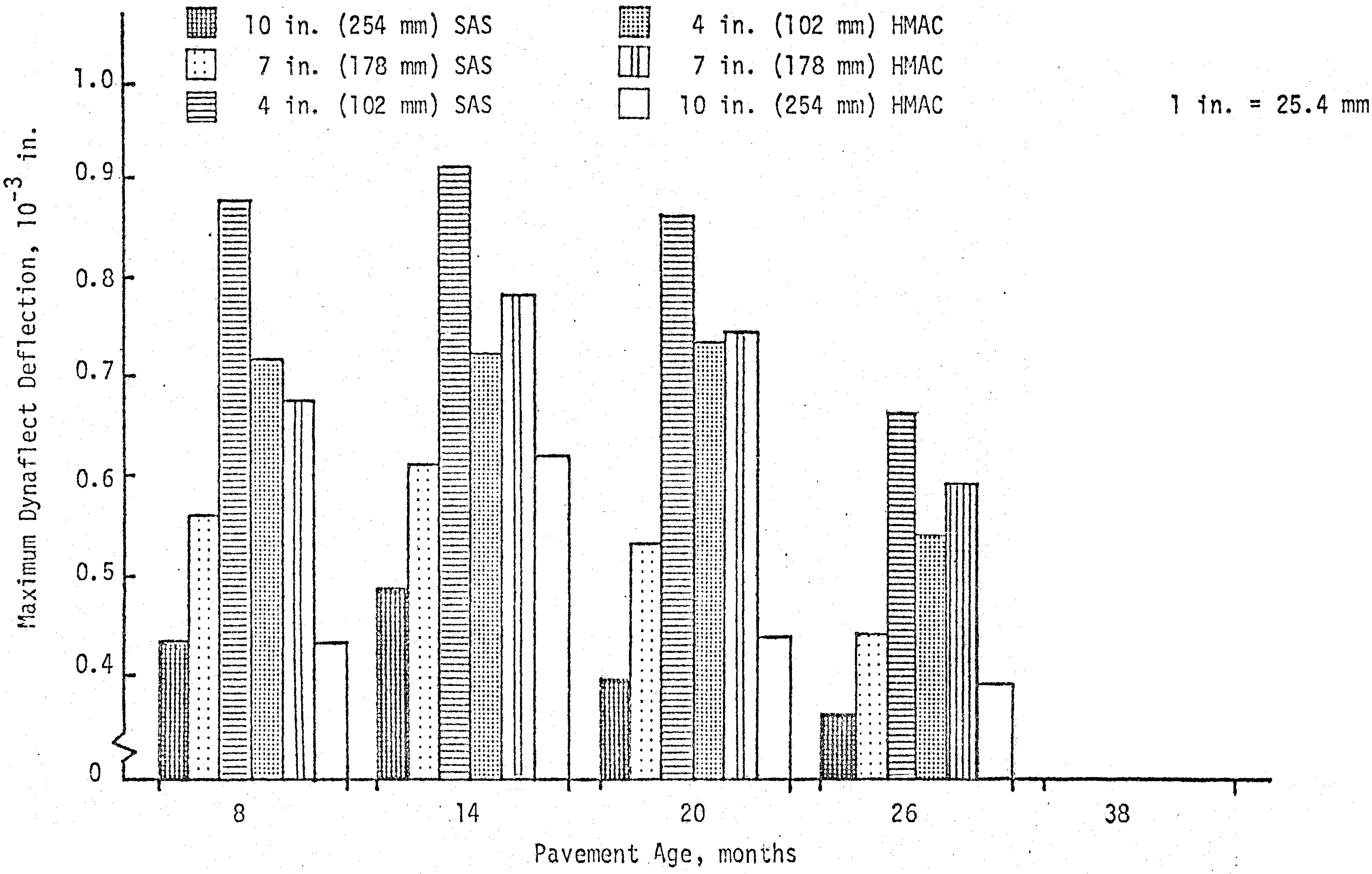


Figure 9. Maximum Dynaflect deflection versus pavement age for U. S. 77.

Table 3 Mays Ride Meter test results for road serviceability index

	1985+00					Station No.					2015+00
			SAS					AC			
	Mays Ride Meter readings taken at 264 ft (80.5 m) intervals										
* Wheel Path No. 1											
6/15/77 (0)***	3.1	3.8	2.8	3.2	2.8	2.9	3.1	3.3	3.2	3.7	3.7
11/15/77 (6)	3.6	3.8	3.8	3.8	3.3	3.2	3.6	3.9	3.8	4.2	3.9
6/16/78 (12)	3.6	3.9	3.8	3.9	3.6	3.8	4.0	4.1	4.1	4.4	4.4
12/28/78 (18)	3.4	3.9	3.8	3.6	2.9	3.3	3.5	4.1	4.0	4.2	4.1
6/01/79 (24)	3.4	4.0	3.8	3.7	3.4	3.4	3.8	4.4	4.1	4.1	4.3
**12/28/78 (18)	3.4	4.0	3.8	3.9	3.6	3.5	3.9	4.4	4.3	4.4	4.3
6/01/79 (24)	3.7	4.0	3.9	3.9	3.8	3.6	3.9	4.2	4.3	4.4	4.3
* Wheel Path No. 2											
6/15/77 (0)	3.1	4.1	2.6	3.2	3.7	2.9	3.9	4.2	3.3	4.1	3.7
11/15/77 (6)	3.3	4.1	3.6	4.2	4.1	3.8	4.5	4.4	4.1	4.5	4.5
6/16/78 (12)	3.4	3.9	3.8	4.1	4.1	3.4	4.3	4.4	4.2	4.6	4.4
12/28/78 (18)	2.8	3.6	3.9	4.0	3.9	3.6	4.1	3.9	3.4	4.0	3.9
6/01/79 (24)	2.8	3.9	3.3	3.4	3.3	3.3	3.9	3.9	3.6	3.9	3.9
* Wheel Path No. 3											
6/15/77 (0)	2.5	3.2	2.7	2.9	3.1	2.3	3.9	3.4	2.8	3.3	3.7
11/15/77 (6)	3.0	3.9	3.5	4.1	3.8	3.0	4.5	4.0	4.0	4.2	4.5
6/16/78 (12)	3.0	3.2	3.5	3.6	3.3	2.7	4.4	4.1	4.2	4.1	3.9
12/28/78 (18)	2.6	3.7	3.4	3.3	3.4	3.0	3.8	3.7	4.0	3.9	3.8
6/01/79 (24)	3.3	3.9	3.8	3.9	3.8	3.3	4.4	3.9	3.9	3.9	4.3
**12/28/78 (18)	3.0	3.4	3.8	3.0	3.1	2.8	4.5	4.2	4.1	4.3	4.1
6/01/79 (24)	2.7	2.7	3.4	3.6	3.4	3.3	4.2	4.2	3.9	3.9	3.9
* Wheel Path No. 4											
6/15/77 (0)	2.5	2.9	2.9	2.5	2.9	2.1	3.6	3.9	3.7	3.1	-
11/15/77 (6)	3.8	3.7	3.9	2.9	3.0	2.9	4.1	3.9	4.2	3.1	3.9
6/16/78 (12)	3.6	3.6	3.6	2.8	2.9	2.7	3.9	3.9	4.1	4.1	3.9
12/28/78 (18)	3.5	3.0	3.8	3.1	3.3	2.9	4.1	3.9	4.3	3.9	3.8
6/01/79 (24)	3.5	3.0	3.6	2.8	2.8	2.6	3.9	3.6	3.7	3.5	3.6

*Mays Ride Meter readings taken with vehicle straddling wheel paths.
**Mays Ride Meter readings taken with wheels in wheel paths.
***Pavement age in months.

Table 4. Pavement rating scores exclusive of serviceability index and raveling for U.S. 77.

Station No.	Base Thickness and Type	Pavement Rating Score, Percent
1985+00 - 1990+00	10 in. (254 mm) SAS	100
1990+00 - 1995+00	7 in. (178 mm) SAS	95
1995+00 - 2000+00	4 in. (102 mm) SAS	100
2000+00 - 2005+00	4 in. (102 mm) HMAC	97
2005+00 - 2010+00	7 in. (178 mm) HMAC	93
2010+00 - 2015+00	10 in. (254 mm) HMAC	97

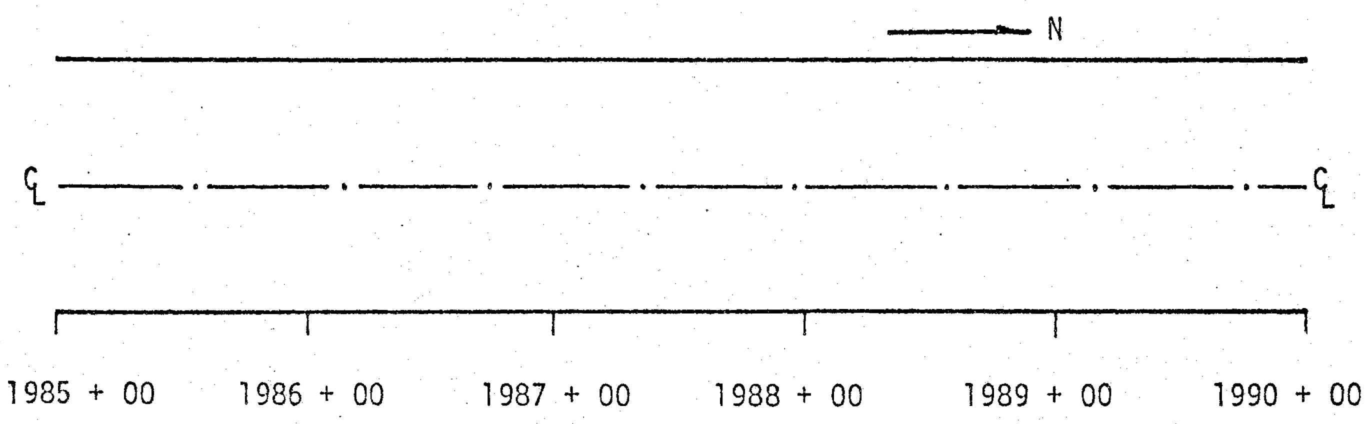


Figure 10. Results of cracking survey for 10 in. (254 mm) SAS base.

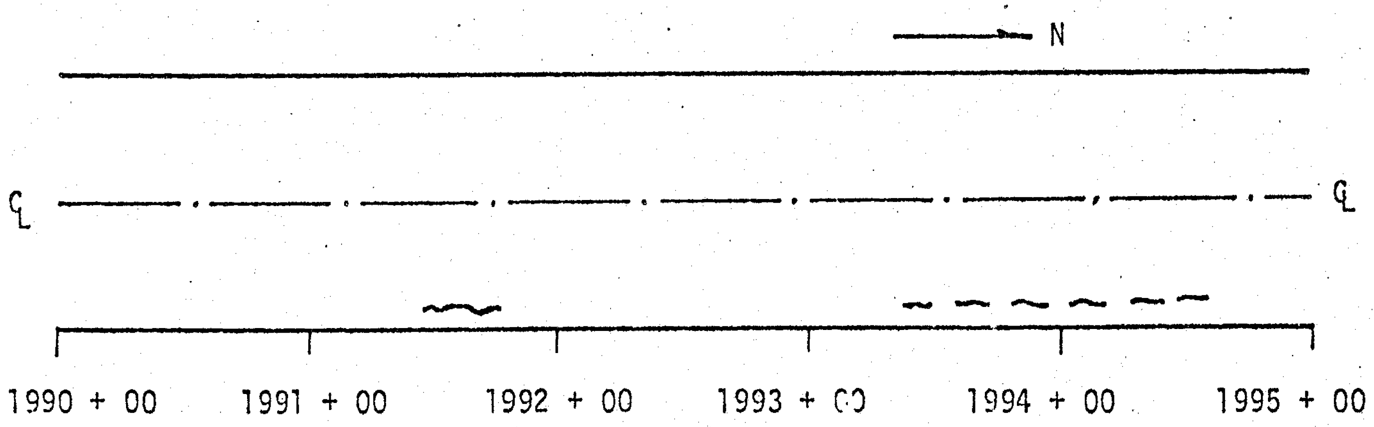


Figure 11. Results of cracking survey for 7 in. (178 mm) SAS base.

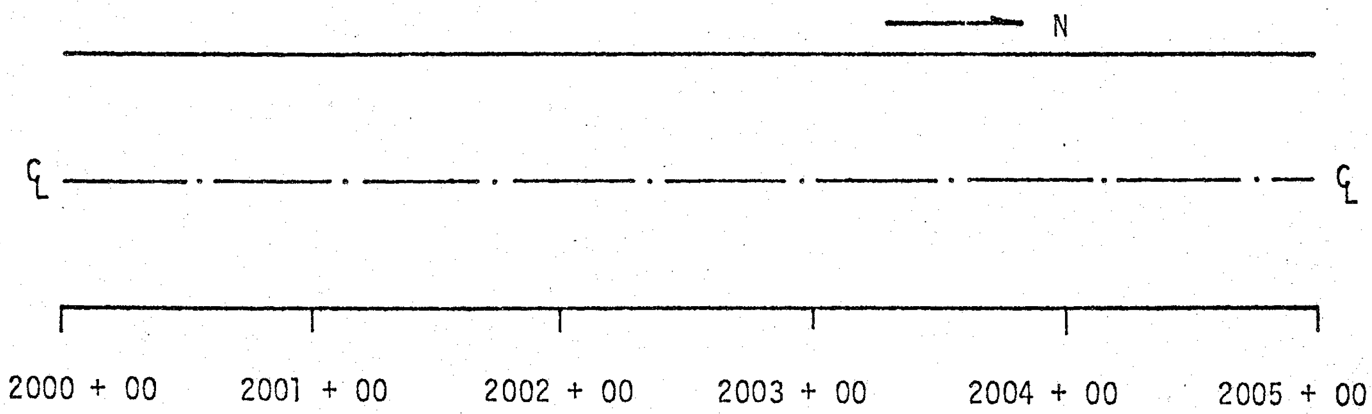


Figure 12. Results of cracking survey for 4 in. (102 mm) SAS base.

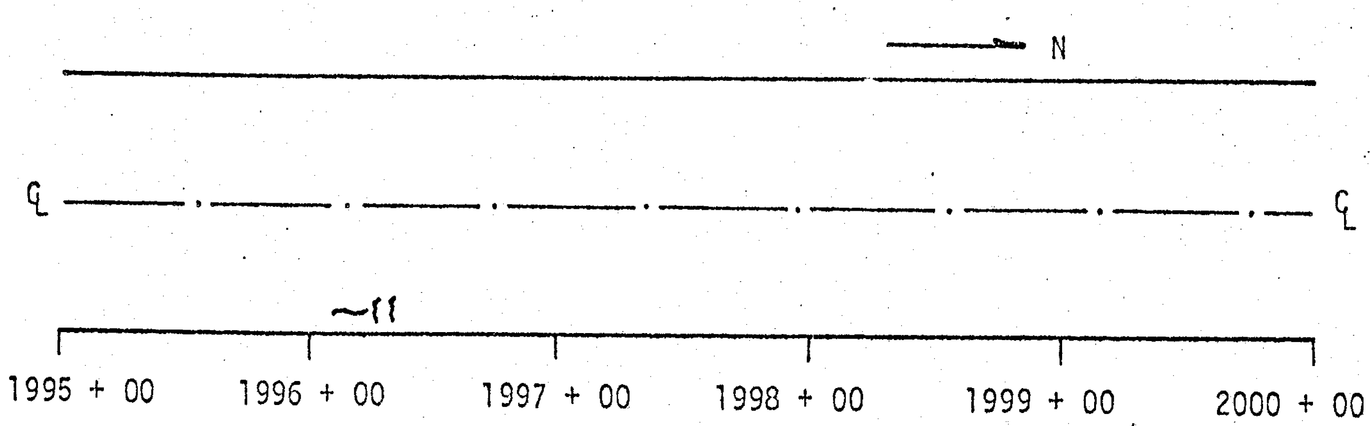


Figure 13. Results of cracking survey for 4 in. (102 mm) SAS base.

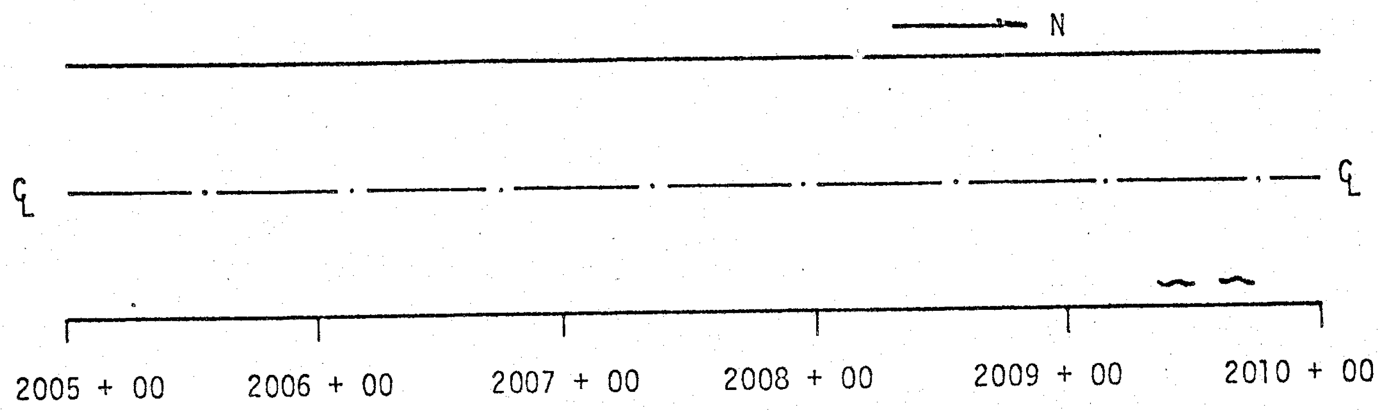


Figure 14. Results of cracking survey for 7 in. (178 mm) HMAC base.

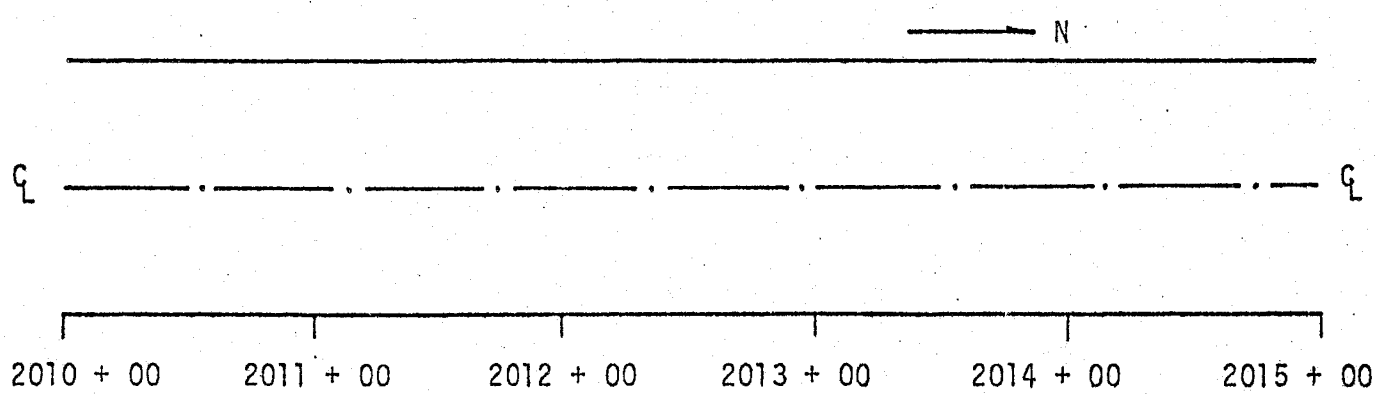


Figure 15. Results of cracking survey for 10 in. (254 mm) HMAC base.

base with a 1-inch Type D hot mix asphalt concrete surface. The SDHPT decided to insert hot mix asphalt concrete base as the control in the segment where SAS was used as a trial section.

During the summer of 1979 cracking in the wheel path of the outside lane of the entire flexible base section became so severe that a chip seal was applied to the entire job including the control and the SAS sections. Covering of the test sections and control was mutually agreed to by both the study supervisor and the SDHPT.

It should be particularly noted that neither the control or the SAS sectioned needed a seal. These sections showed essentially, no distress at age two years.

At the request of Mr. Imants Deme of Shell Canada Ltd., a core sample was taken to include one of the cracks in the 7 in. (178 mm) SAS base section. This core showed that the crack had taken place only in the surface course and not in the base. A photograph of this is shown in Figure 16.

Conclusion

The results of the 24 month post construction tests of the SAS trial section on U. S. 77, Kenedy County, Texas have been presented. Except for the initiation of slight amounts of cracking in one SAS base section and all of the HMAC sections no specific conclusions can be drawn at this time. It can be stated that the SAS base sections are performing as well as and in some cases (such as rutting) are performing better than the HMAC base material.