APPENDIX F

CORE AND SPECIMEN MEASUREMENTS

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This appendix presents the core and specimen measurements for various rubblized pavement projects. A project may be divided into one or more test sections and each section may be divided into one or more test sites.
The cores and specimens obtained from the field investigation were named according the core and test specimen designation below.

Core designation system

Cores extracted during field investigation are designated by 9-digit code system (xxxxxx-xxxx). The designation system is explained below.

1. The first digit represents road type (1= Interstate, 2=U.S., 3=Michigan. 4= others)
2. The second through the fourth digits represent highway/road number.
3. The fifth digit represents traffic direction along the lane where that core was taken (1=North, 2=East, 3=South, 4=West).
4. The sixth digit represents section number on the highway/road that the core was taken.
5. The seventh digit represents test site number on the section that the core was taken.
6. The eight and ninth digit represent core number.

For example core designation 10692-1123 means that this core was taken form I-69 eastbound, test section 1 site 1 and core number 23.

Test specimen designation system

One core might be sawn into several test specimens. The test specimens are designated by 2 additional digits (the tenth and eleventh digits) representing 2 courses that made of the sample. Each number represents:

Number 1 represents first base course
Number 2 represents second base course
Number 3 represents leveling course
Number 4 represents surface course
Number 5 represents overlay base course
Number 6 represents overlay surface course

For example test specimen designation 10692-1123-43 means that this specimen was taken form I-69 eastbound, test section 1 site 1,core number 23 and consists of AC surface and leveling courses.

Table F.1 Core measurements for I-69 EB – section 1 test site 1

Core Designation	Total core thickness (in)					Courses thickness (in)			Core diameter (in)	Crack/ defect
	1	2	3	4	Average	Surface	Leveling	Base		
10692-1101	7.8	7.3	7.8	7.8	7.6	1.3	1.8	4.6	5.9	None
10692-1104	7.5	7.5	7.5	7.8	7.6	1.4	2.0	4.2	5.8	None
10692-1107	8.4	8.3	8.5	8.5	8.4	1.5	2.0	4.9	5.9	None
10692-1110	8.4	8.8	8.6	8.8	8.6	1.8	2.0	4.9	5.9	None
10692-1115	8.4	8.5	8.4	8.3	8.4	1.6	2.0	4.8	5.9	None
10692-1116	7.8	8.0	8.0	8.3	8.0	1.3	2.3	4.5	5.9	None
10692-1117	8.5	8.3	9.0	8.3	8.5	1.5	2.3	4.8	5.9	None
10692-1118	8.6	8.8	8.8	8.8	8.7	2.0	2.3	4.5	5.9	None
10692-1123	7.8	8.0	7.6	8.0	7.8	1.3	2.4	4.2	5.9	None
10692-1124	7.9	8.1	8.0	7.6	7.9	1.3	2.6	4.0	5.9	None
10692-1125	8.5	8.5	9.0	8.5	8.6	1.5	2.5	4.6	5.9	None
10692-1126	8.5	8.5	8.5	8.8	8.6	1.8	2.5	4.3	5.8	None
Average					8.2	1.5	2.2	4.5	5.9	
CV (%)					5	16	12	6	0	

Table F.2 Core measurements for I-69 EB – section 1 test site 2

Core Designation	Total core thickness (in)					Courses thickness (in)			Core diameter (in)	Crack/ defect
	1	2	3	4	Average	Surface	Leveling	Base		
10692-1201	7.5	7.6	7.7	7.6	7.6	1.5	2.5	3.6	5.8	None
10692-1204	7.3	7.3	7.3	7.4	7.3	1.6	1.9	3.8	5.8	None
10692-1207	7.9	7.8	7.8	7.9	7.8	1.6	2.1	4.1	5.9	None
10692-1210	7.7	7.7	7.6	7.6	7.6	1.8	2.6	3.3	5.8	None
10692-1215	7.6	7.7	7.6	7.8	7.7	1.4	2.0	4.3	5.8	None
10692-1216	8.0	8.1	8.3	8.1	8.1	1.6	1.8	4.8	5.8	None
10692-1217	8.4	8.4	8.4	8.4	8.4	1.8	2.3	4.4	5.8	None
10692-1218	8.3	8.3	8.3	8.3	8.3	1.8	2.3	4.3	5.9	None
10692-1223	7.8	7.8	7.8	7.7	7.8	1.5	2.5	3.8	5.9	None
10692-1224	8.6	8.6	8.5	8.6	8.6	1.5	2.8	4.3	5.9	None
10692-1225	8.3	8.2	8.3	8.4	8.3	1.5	2.8	4.1	5.8	None
10692-1226	8.3	8.3	8.4	8.4	8.4	1.8	2.3	4.4	5.9	None
Average					8.0	1.6	2.3	4.1	5.8	
CV (%)					5	8	14	10	1	

Table F.3 Core measurements for I-75 SB – section 1 test site 1

Core Designation	Total core thickness (in)					Courses thickness (in)			Core diameter (in)	Crack/ defect
	1	2	3	4	Average	Surface	Leveling	Base		
10753-1101	4.2	4.4	4.5	4.2	4.3	1.5	1.1	1.7	5.7	None
10753-1104	4.1	4.1	4.3	4.1	4.2	1.5	1.0	1.7	5.7	None
10753-1107	4.8	4.5	4.4	4.8	4.6	1.6	1.0	2.0	5.7	None
10753-1110	4.0	4.1	4.1	4.0	4.1	1.4	1.0	1.7	5.7	None
10753-1115	4.6	4.6	4.8	4.6	4.7	1.8	1.4	1.5	5.7	Crack
10753-1116	4.8	4.6	4.6	4.7	4.7	1.6	1.1	2.0	5.7	None
10753-1117	4.8	4.7	4.8	4.8	4.7	1.8	1.1	1.8	5.7	None
10753-1118	4.3	4.4	4.5	4.3	4.3	1.6	1.0	1.7	5.7	None
10753-1123	4.8	4.8	4.8	5.0	4.8	1.8	1.0	2.0	5.6	None
10753-1124	4.5	4.5	4.6	4.5	4.5	1.7	1.0	1.8	5.7	None
10753-1125	4.8	4.5	4.8	4.6	4.7	1.8	1.0	1.9	5.7	None
10753-1126	4.5	4.5	4.5	4.5	4.5	1.7	0.9	1.9	5.6	None
10753-1150	4.8	4.8	4.5	4.6	4.7	1.8	1.0	1.9	N.A.	Broken
10753-1151	4.6	4.5	4.4	4.5	4.5	1.8	1.0	1.8	5.7	Crack
Average					4.5	1.7	1.0	1.8	5.7	
CV (%)					5	8	11	8	0	

Table F.4 Core measurements for I-75 SB – section 1 test site 2

Core Designation	Total core thickness (in)					Courses thickness (in)			Core diameter (in)	Crack/ defect
	1	2	3	4	Average	Surface	Leveling	Base		
10753-1201	3.8	3.8	3.8	3.9	3.8	1.4	1.0	1.4	5.7	None
10753-1204	4.0	4.0	4.1	4.3	4.1	1.6	1.0	1.5	5.7	None
10753-1207	3.5	3.6	3.5	3.5	3.5	1.0	1.5	1.0	5.7	Crack
10753-1210	3.6	3.8	3.8	4.0	3.8	1.6	1.1	1.1	5.7	None
10753-1215	4.3	4.3	4.4	4.3	4.3	1.6	1.1	1.6	5.7	None
10753-1216	4.5	4.3	4.4	4.5	4.4	1.7	1.0	1.7	5.7	None
10753-1217	4.0	3.8	3.9	4.0	3.9	1.5	1.0	1.4	N.A.	Broken
10753-1218	4.2	4.2	4.2	4.2	4.2	1.6	1.0	1.6	5.7	None
10753-1223	4.4	4.4	4.4	4.5	4.4	1.7	1.1	1.6	5.6	None
10753-1224	4.5	4.8	4.6	4.5	4.6	1.9	1.0	1.7	5.7	None
10753-1225	4.3	4.3	4.4	4.3	4.3	1.7	1.0	1.6	5.7	None
10753-1226	4.3	3.9	3.9	4.0	4.0	1.6	1.1	1.3	5.7	None
10753-1250	3.6	3.5	3.5	3.5	3.5	1.5	0.9	1.1	5.7	None
10753-1251	4.4	4.3	4.3	4.4	4.3	1.7	1.0	1.6	5.7	None
10753-1252	3.5	3.5	3.5	3.5	3.5	1.0	1.4	1.1	N.A.	Broken
Average					4.1	1.6	1.1	1.4	5.7	
CV (%)					8	13	13	16	0	

Table F.5 Core measurements for I-194 NB – section 2 test site 1

Core designation	Total Thickness (in)					Courses Thickness (in)				Diameter (in)	Crack/ defect
	1	2	3	4	Average	Overlay	Surface	Leveling	Base		
11941-2101	8.0	8.0	8.2	8.0	8.1	1.5	1.8	2.5	2.3	5.9	None
11941-2104	8.0	7.9	8.0	7.9	8.0	1.4	1.5	2.2	2.9	5.9	None
11941-2107	7.9	7.9	8.0	7.9	7.9	1.5	1.4	2.1	2.9	5.9	None
11941-2110	7.9	7.8	7.8	7.8	7.8	1.6	1.4	2.5	2.3	5.9	None
11941-2115	8.0	7.9	7.9	8.0	8.0	1.5	1.6	2.1	2.7	5.9	Crack
11941-2116	7.7	7.7	7.8	7.7	7.7	1.3	1.6	2.3	2.6	5.9	Crack
11941-2117	7.9	7.7	7.8	7.8	7.8	1.4	1.4	2.3	2.7	5.9	None
11941-2118	7.8	7.9	7.9	7.9	7.9	1.5	1.5	2.3	2.6	5.9	None
11941-2123	7.9	7.9	7.8	8.0	7.9	1.5	1.8	1.9	2.7	5.9	None
11941-2124	7.8	7.9	8.0	8.0	7.9	1.3	1.6	2.3	2.7	5.9	None
11941-2125	7.8	7.9	7.9	8.0	7.9	1.4	1.5	2.2	2.8	5.9	None
11941-2126	8.1	7.9	7.9	8.1	8.0	1.5	1.6	2.3	2.6	5.9	None
11941-2150	7.8	7.8	7.8	7.8	7.8	1.4	1.6	2.5	2.3	N.A.	Broken
11941-2151	7.2	7.2	7.3	7.3	7.3	1.4	1.5	2.3	2.1	N.A.	Broken
11941-2152	7.9	8.0	7.9	7.9	7.9	1.4	1.6	2.3	2.7	6.0	
Average					7.8	1.4	1.6	2.3	2.6	5.9	
CV (%)					2	7	8	7	9	0	

Table F.6 Core measurements for I-194 NB – section 2 test site 2

Core designation	Total Thickness (in)					Courses Thickness (in)				Diameter (in)	Crack/ defect
	1	2	3	4	Average	Overlay	Surface	Leveling	Base		
11941-2201	7.7	7.7	7.7	7.7	7.7	1.5	1.5	2.1	2.6	5.9	None
11941-2204	7.2	7.2	7.2	7.1	7.2	1.5	1.2	2.1	2.4	5.9	None
11941-2207	7.5	7.5	7.4	7.4	7.5	1.5	1.4	2.1	2.5	5.9	None
11941-2210	7.0	7.0	6.9	7.0	7.0	1.4	1.5	2.0	2.1	5.9	None
11941-2215	7.8	7.7	7.7	7.7	7.7	1.5	1.4	2.3	2.5	5.9	None
11941-2216	7.3	7.3	7.3	7.3	7.3	1.5	1.3	2.0	2.5	5.9	None
11941-2217	7.5	7.6	7.6	7.6	7.6	1.5	1.5	2.1	2.5	5.9	Defect
11941-2218	7.1	7.0	7.1	7.1	7.1	1.4	1.5	2.0	2.2	5.9	Crack
11941-2223	7.8	7.9	7.7	7.8	7.8	1.5	1.4	2.2	2.7	5.9	Crack
11941-2224	7.4	7.3	7.3	7.4	7.4	1.5	1.4	2.3	2.2	5.9	None
11941-2225	7.6	7.6	7.5	7.3	7.5	N.A.	N.A.	N.A.	N.A.	5.9	Defect
11941-2226	7.4	7.4	7.3	7.3	7.4	1.4	1.4	2.0	2.6	5.9	None
11941-2250	N.A	N.A	N.A	N.A	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Broken
11941-2251	7.5	7.5	7.3	7.3	7.4	1.5	1.5	1.8	2.7	6.0	Broken
Average					7.4	1.5	1.4	2.1	2.4	5.9	
CV (%)					4	3	7	5	8	0	

Table F.7 Core measurements for US-10 EB – section 1 test site 1

Core Designation	Total core thickness (in)					Courses thickness (in)			Core diameter (in)	Crack/ defect
	1	2	3	4	Average	Surface	Leveling	Base		
20102-1101	6.5	6.3	6.4	6.2	6.3	1.4	2.3	2.7	5.8	None
20102-1104	6.2	5.9	6.1	6.1	6.1	1.4	2.1	2.5	5.8	None
20102-1107	6.5	6.4	6.3	6.3	6.4	1.4	2.1	2.9	5.8	None
20102-1110	6.6	6.5	6.2	6.8	6.5	1.5	2.1	2.9	5.8	None
20102-1115	6.8	6.6	6.6	6.6	6.7	1.5	2.1	3.0	5.8	None
20102-1116	6.3	6.3	6.3	6.1	6.2	1.4	2.1	2.8	5.8	None
20102-1117	6.4	6.5	6.5	6.6	6.5	1.4	1.9	3.1	5.8	None
20102-1118	6.6	6.8	6.5	6.8	6.6	1.4	2.1	3.1	5.8	None
20102-1123	6.9	6.6	6.6	6.7	6.7	1.5	2.3	3.0	5.8	None
20102-1124	6.3	6.4	6.3	6.4	6.3	1.4	1.9	2.9	5.8	None
20102-1125	6.8	6.5	6.3	6.3	6.5	1.4	1.9	3.1	5.8	None
20102-1126	6.7	6.6	6.7	6.4	6.6	1.5	1.9	3.2	5.8	None
Average					6.5	1.4	2.1	2.9	5.8	
CV (%)					3	3	6	7	0	

Table F.8 Core measurements for US-10 EB – section 1 test site 2

Core Designation	Total core thickness (in)					Courses thickness (in)			Core diameter (in)	Crack/ defect
	1	2	3	4	Average	Surface	Leveling	Base		
20102-1201	6.3	6.4	6.4	6.4	6.5	1.6	2.1	2.9	5.8	None
20102-1204	6.3	6.3	6.3	6.3	6.3	1.4	2.3	2.5	5.8	None
20102-1207	6.5	6.3	6.4	6.4	6.4	1.6	2.2	2.6	5.8	None
20102-1210	6.0	5.9	6.0	6.1	6.0	1.5	2.2	2.3	5.8	None
20102-1215	6.4	6.4	6.5	6.3	6.4	1.4	2.1	2.9	5.8	None
20102-1216	6.1	6.3	6.3	6.3	6.2	1.5	2.0	2.7	5.8	None
20102-1217	6.6	6.4	6.5	6.5	6.5	1.6	2.1	2.8	5.8	None
20102-1218	6.1	6.1	6.2	6.2	6.1	1.5	2.1	2.5	5.8	None
20102-1223	6.8	6.8	6.6	6.7	6.7	1.6	1.9	3.1	5.8	None
20102-1224	6.4	6.3	6.8	6.0	6.4	1.6	1.9	2.9	5.8	None
20102-1225	6.8	6.5	6.4	6.5	6.5	1.6	2.3	2.7	5.8	None
20102-1226	7.0	7.0	6.6	6.8	6.8	1.6	2.1	3.1	5.8	None
Average					6.4	1.5	2.1	2.8	5.8	
CV (%)					4	4	6	9	0	

Table F.9 Core measurements for US-23 SB – section 1 test site 1

Core Designation	Total core thickness (in)					Courses thickness (in)			Core diameter (in)	Crack/ defect
	1	2	3	4	Average	Surface	Leveling	Base		
20233-1101	5.3	5.2	5.3	5.3	5.3	1.5	1.3	2.5	5.9	None
20233-1105	4.9	4.9	4.9	4.9	4.9	1.4	1.7	2.3	5.9	None
20233-1106	5.6	5.5	5.6	5.6	5.6	1.3	2.6	1.6	5.9	None
20233-1110	5.5	5.4	5.4	5.5	5.5	1.7	1.9	1.5	5.9	None
20233-1115	5.6	5.6	5.8	5.8	5.7	1.4	1.7	2.5	5.9	None
20233-1116	5.1	5.1	5.1	5.1	5.1	1.5	1.8	1.8	5.9	None
20233-1117	5.5	5.4	5.4	5.5	5.4	1.4	1.8	2.7	5.9	None
20233-1120	5.4	5.4	5.4	5.3	5.4	1.8	1.9	2.2	5.9	None
20233-1125	6.0	5.9	5.9	6.1	6.0	1.5	1.8	2.7	5.9	None
20233-1127	5.7	5.9	6.0	5.9	5.9	1.5	1.9	2.5	5.9	None
Average					5.5	1.5	1.8	2.2	5.9	
CV (%)					6	8	19	20	1	

Table F.10 Core measurements for US-23 SB – section 1 test site 2

Core Designation	Total core thickness (in)					Courses thickness (in)			Core diameter (in)	Crack/ defect
	1	2	3	4	Average	Surface	Leveling	Base		
20233-1206	5.4	5.4	5.4	5.4	5.4	1.1	2.3	2.0	5.9	None
20233-1210	6.1	6.1	6.0	6.0	6.0	1.8	2.8	1.5	5.9	None
20233-1215	5.3	5.2	5.2	5.3	5.2	1.1	2.4	1.7	5.9	Crack
20233-1217	4.8	4.8	4.9	4.9	4.8	1.0	2.4	1.5	5.9	None
20233-1220	5.6	5.6	5.6	5.8	5.6	1.5	2.8	1.4	5.9	None
20233-1227	5.6	5.4	5.5	5.6	5.5	1.5	1.9	2.2	5.9	None
20233-1230	6.0	5.9	5.9	6.0	6.0	1.3	2.8	2.0	5.9	None
Average					5.5	1.3	2.4	1.7	5.9	
CV (%)					8	20	13	17	1	

Table F.11 Core measurements for US-27 SB – section 2 test site 1

Core Designation	Total core thickness (in)					Courses thickness (in)			Core diameter (in)	Crack/ defect
	1	2	3	4	Average	Surface	Leveling	Base		
20273-2101	4.5	4.5	4.3	4.5	4.4	N.A	N.A	N.A	5.8	None
20273-2104	4.6	4.6	4.6	4.6	4.6	N.A	N.A	N.A	5.8	None
20273-2107	4.6	4.5	4.5	4.6	4.6	1.3	1.3	2.1	5.8	Crack
20273-2110	4.6	4.6	4.5	4.8	4.6	N.A	N.A	N.A	5.8	None
20273-2115	4.5	4.5	4.5	4.4	4.5	N.A	N.A	N.A	5.9	None
20273-2116	4.5	4.6	4.4	4.3	4.5	N.A	N.A	N.A	5.8	None
20273-2117	4.5	4.6	4.5	4.5	4.5	N.A	N.A	N.A	5.8	None
20273-2118	4.5	4.5	4.5	4.6	4.5	N.A	N.A	N.A	5.5	None
20273-2123	4.5	4.3	4.4	4.4	4.4	N.A	N.A	N.A	5.8	None
20273-2124	4.8	4.6	4.6	4.6	4.7	N.A	N.A	N.A	5.8	None
20273-2125	4.8	4.8	5.0	5.0	4.9	N.A	N.A	N.A	5.8	None
20273-2126	4.5	4.5	4.5	4.5	4.5	N.A	N.A	N.A	5.8	None
20273-21TD1	4.8	4.8	4.8	4.7	4.7	1.1	1.6	2.0	5.9	Crack
20273-21TD2	5.0	4.5	4.9	4.9	4.8	1.4	1.6	1.8	Broken	Crack
20273-21TD3	4.6	4.6	4.6	4.6	4.6	1.3	1.4	2.0	Broken	Crack
Average					4.6	1.3	1.5	2.0	5.8	
CV (%)					3	8	13	5	2	

Table F.12 Core measurements for US-27 SB – section 3 test site 1

Core Designation	Total core thickness (in)					Courses thickness (in)			Core diameter (in)	Crack/ defect
	1	2	3	4	Average	Surface	Leveling	Base		
20273-3101	6.9	6.5	6.9	7.1	6.8	1.8	2.5	2.6	5.9	None
20273-3104	6.5	6.3	6.6	6.5	6.5	1.8	2.7	2.0	5.9	None
20273-3107	6.9	6.5	7.0	6.5	6.7	1.9	2.4	2.5	5.9	None
20273-3110	7.0	6.4	6.8	6.5	6.7	1.9	2.3	2.5	5.9	None
20273-3115	6.9	7.3	7.3	7.3	7.2	1.8	2.6	2.8	5.9	None
20273-3116	6.8	7.0	6.9	7.0	6.9	1.9	2.6	2.4	5.9	None
20273-3117	7.1	7.0	7.1	6.7	7.0	1.9	2.6	2.5	5.9	None
20273-3118	7.1	7.4	6.9	6.8	7.0	1.9	2.4	2.8	5.9	None
20273-3123	7.6	7.6	7.3	7.8	7.6	1.8	2.8	3.1	5.9	None
20273-3124	7.5	7.4	7.5	7.4	7.4	1.9	2.9	2.7	5.9	None
20273-3125	7.0	6.6	7.1	7.0	6.9	1.8	2.5	2.6	5.9	None
20273-3126	7.0	6.9	7.1	7.0	7.0	1.8	2.4	2.8	5.9	None
Average					7.0	1.8	2.5	2.6	5.9	
CV (%)					4	4	7	10	0	

Table F.13 Core measurements for US-27 SB – section 4 test site 1

Core Designation	Total core thickness (in)					Courses thickness (in)			Core diameter (in)	Crack/ defect
	1	2	3	4	Average	Surface	Leveling	Base		
20273-4101	6.3	6.4	6.4	6.0	6.3	1.6	1.9	2.8	5.9	None
20273-4104	6.3	6.0	6.3	6.3	6.2	1.8	1.8	2.7	5.9	None
20273-4107	6.5	6.6	6.4	6.5	6.5	1.6	2.0	2.9	5.9	None
20273-4110	6.3	6.5	6.5	6.3	6.4	1.6	2.1	2.6	5.8	None
20273-4115	6.5	6.3	6.4	6.6	6.4	1.6	2.0	2.8	5.9	None
20273-4116	6.4	6.3	6.3	6.1	6.3	1.8	1.8	2.8	5.9	None
20273-4117	6.5	6.5	6.5	6.5	6.5	1.6	2.1	2.8	5.9	None
20273-4118	6.8	6.8	6.5	6.6	6.7	1.6	1.9	3.2	5.9	None
20273-4123	6.8	6.5	6.6	6.5	6.6	1.8	2.0	2.8	5.9	None
20273-4124	6.3	6.4	6.4	6.5	6.4	1.6	2.1	2.6	5.9	None
20273-4125	6.8	6.6	6.8	6.8	6.7	1.6	2.0	3.1	5.9	None
20273-4126	6.8	6.9	6.6	6.8	6.8	1.6	2.4	2.8	5.9	None
Average					6.5	1.7	2.0	2.8	5.9	
CV (%)					3	3	9	6	0	

Table F.14 Core measurements for US-31 SB – section 1 test site 1

Core Designation	Total core thickness (in)					Courses thickness (in)			Core diameter (in)	Crack/ defect
	1	2	3	4	Average	Surface	Leveling	Base		
20311-1101	6.5	6.3	6.6	6.8	6.5	1.2	1.8	3.5	5.9	None
20311-1104	7.2	7.0	7.2	7.3	7.2	1.3	1.8	4.2	5.9	None
20311-1107	6.5	6.6	6.6	6.5	6.6	1.3	1.8	3.6	5.9	None
20311-1110	6.0	6.0	6.0	6.1	6.0	1.3	1.8	3.0	5.9	None
20311-1115	7.1	7.1	7.0	7.1	7.1	1.1	1.9	4.1	5.9	None
20311-1116	7.5	7.6	7.7	7.6	7.6	1.3	1.8	4.6	5.9	None
20311-1117	7.3	7.3	7.3	7.2	7.2	1.3	1.7	4.2	5.9	None
20311-1118	6.2	6.3	6.1	6.0	6.1	1.3	1.8	3.1	5.9	None
20311-1123	7.1	7.1	7.1	7.1	7.1	1.1	1.8	4.2	5.9	None
20311-1124	7.1	7.3	7.4	7.3	7.3	1.3	1.8	4.3	5.9	None
20311-1125	7.3	7.3	7.3	7.3	7.3	1.4	1.6	4.3	5.9	None
20311-1126	6.8	6.6	6.6	6.8	6.7	1.3	1.8	3.7	5.9	None
Average					6.9	1.2	1.8	3.9	5.9	
CV (%)					7	6	3	13	0	

Table F.15 Core measurements for M-15 SB – section 1 test site 1

Core Designation	Total core thickness (in)					Courses thickness (in)			Core diameter (in)	Crack/ defect
	1	2	3	4	Average	Surface	Leveling	Base		
30153-1101	5.2	4.9	5.1	5.3	5.1	N.A	N.A	N.A	5.8	None
30153-1104	5.4	5.6	5.4	5.4	5.5	N.A	N.A	N.A	5.8	None
30153-1107	5.3	5.2	5.3	5.2	5.3	N.A	N.A	N.A	5.8	None
30153-1110	5.4	5.3	5.2	5.3	5.3	N.A	N.A	N.A	5.9	None
30153-1115	5.3	4.9	5.1	5.3	5.2	N.A	N.A	N.A	5.8	None
30153-1116	5.9	5.5	5.6	5.9	5.7	N.A	N.A	N.A	5.8	None
30153-1117	5.7	5.4	5.4	5.7	5.6	N.A	N.A	N.A	5.8	None
30153-1118	5.6	6.1	5.6	5.6	5.7	N.A	N.A	N.A	5.9	None
30153-1123	4.9	5.5	5.2	5.2	5.2	N.A	N.A	N.A	5.8	None
30153-1124	5.8	5.5	5.7	5.5	5.6	N.A	N.A	N.A	5.8	None
30153-1125	5.3	5.5	5.2	5.3	5.3	N.A	N.A	N.A	5.8	None
30153-1126	5.9	5.6	5.6	5.5	5.7	N.A	N.A	N.A	5.8	None
30153-1150	4.4	4.7	4.5	4.7	4.6	1.1	1.9	1.6	5.8	TDC
30153-1151	4.9	5.0	4.8	4.8	4.9	1.5	1.8	1.6	5.8	TDC
30153-1152	5.3	5.7	5.5	5.5	5.5	1.6	1.9	2.0	5.8	TDC
30153-1153	5.2	5.2	5.3	4.9	5.2	1.5	1.8	1.9	5.8	TDC
Average					5.3	1.4	1.8	1.8	5.8	
CV (%)					6	15	4	12	0	

Table F.16 Core measurements for M-37 SB – section 5 test site 1

Core Designation	Total core thickness (in)					Courses thickness (in)			Core diameter (in)	Crack/ defect
	1	2	3	4	Average	Surface	Leveling	Base		
30373-5101	6.3	6.4	6.3	6.5	6.4	1.6	1.8	3.3	5.9	None
30373-5104	6.4	6.5	6.2	6.3	6.3	1.4	1.9	3.4	5.9	None
30373-5107	6.6	6.3	6.5	6.5	6.5	1.6	1.8	3.4	5.9	None
30373-5110	6.0	5.9	5.5	5.8	5.8	1.6	1.8	3.2	5.9	None
30373-5115	7.1	7.1	6.8	6.9	7.0	1.6	1.7	3.4	5.9	None
30373-5116	7.0	6.8	6.9	6.9	6.9	1.5	1.8	3.4	5.9	None
30373-5117	3.8	6.6	6.6	6.9	5.9	1.5	1.8	3.4	5.9	None
30373-5118	6.3	6.6	6.4	6.3	6.4	1.5	1.8	3.3	5.9	None
30373-5123	6.9	6.9	7.2	7.5	7.1	1.4	1.8	3.6	5.9	None
30373-5124	7.4	7.1	7.1	7.1	7.2	1.5	1.7	3.4	5.9	None
30373-5125	7.0	6.9	6.9	6.9	6.9	1.5	1.7	3.4	5.9	None
30373-5126	6.3	6.5	6.1	6.6	6.4	1.5	1.6	3.3	5.9	None
Average					6.6	1.5	1.8	3.4	5.9	
CV (%)					7	3	4	3	0	

Table F.17 Core measurements for M-37 SB – section 5 test site 2

Core Designation	Total core thickness (in)					Courses thickness (in)			Core diameter (in)	Crack/ defect
	1	2	3	4	Average	Surface	Leveling	Base		
30373-5201	6.1	6.2	6.2	6.4	6.2	1.3	1.9	3.0	5.9	None
30373-5204	6.1	6.0	6.0	6.0	6.0	1.5	1.6	2.9	5.9	None
30373-5207	6.4	5.9	6.4	6.4	6.3	1.4	1.9	2.9	5.9	None
30373-5210	6.4	5.9	5.8	6.0	6.0	1.4	1.9	2.7	5.9	None
30373-5215	6.5	6.3	6.4	6.2	6.3	1.3	1.8	3.2	5.9	None
30373-5216	6.5	6.2	6.3	6.7	6.4	1.5	1.7	3.2	5.9	None
30373-5217	5.9	6.0	6.1	6.1	6.0	1.5	1.8	2.7	5.9	None
30373-5218	6.2	5.9	6.1	5.8	6.0	1.4	1.8	2.9	5.9	None
30373-5223	6.8	6.9	6.8	6.8	6.8	1.4	1.7	3.8	5.9	None
30373-5224	6.9	6.6	6.8	7.0	6.8	1.5	1.6	3.7	5.9	None
30373-5225	6.8	6.9	6.5	7.8	7.0	1.4	1.8	3.8	5.9	None
30373-5226	6.6	6.6	6.5	6.8	6.6	1.4	1.6	3.6	5.9	None
Average					6.4	1.4	1.8	3.2	5.9	
CV (%)					6	6	7	13	0	

Table F.18 Core measurements for M-37 SB – section 6 test site 1

Core Designation	Total core thickness (in)					Courses thickness (in)			Core diameter (in)	Crack/ defect
	1	2	3	4	Average	Surface	Leveling	Base		
30373-6101	6.3	6.2	6.4	6.5	6.4	1.6	2.1	2.7	5.9	None
30373-6104	5.7	6	5.8	5.8	5.8	1.6	2.1	2.1	5.9	None
30373-6107	5.3	5.4	5.4	5.5	5.4	1.5	2.2	1.7	5.9	TDC
30373-6108	5.4	5.3	5.2	5.6	5.4	1.5	2.3	1.6	5.9	None
30373-6110	5.6	5.8	5.7	5.5	5.7	1.6	2.2	1.9	5.9	None
30373-6113	6	5.9	5.9	6.1	6.0	1.6	2.2	2.2	5.9	None
30373-6115	6.3	6.3	6.5	6.3	6.4	1.6	2.3	2.5	5.9	None
30373-6116	6	5.9	5.8	5.7	5.9	1.7	2.1	2.1	5.9	None
30373-6117	5.7	5.8	5.7	5.6	5.7	1.7	2.2	1.8	5.9	None
30373-6118	5.8	5.7	5.7	5.9	5.8	1.8	2.2	1.8	5.9	None
30373-6123	6	6.1	6.1	6.2	6.1	1.6	2.2	2.3	5.9	None
30373-6124	5.7	5.5	5.5	5.5	5.6	1.5	1.6	2.5	5.9	None
30373-6125	5.5	5.6	5.7	5.5	5.6	1.6	2.0	2.0	5.9	None
30373-6126	5.8	5.8	5.7	5.7	5.8	1.6	2.0	2.2	5.9	None
30373-6141	5.5	5.5	5.4	5.3	5.4	1.4	2.3	1.7	5.9	None
30373-6142	5.5	5.5	5.5	5.4	5.5	1.6	2.2	1.7	5.9	TDC
30373-6143	5.4	5.6	5.6	5.5	5.5	1.5	2.4	1.6	5.9	None
30373-6144	5.5	5.4	5.5	5.5	5.5	1.7	2.0	1.8	5.9	None
Average					5.7	1.6	2.1	2.0	5.9	
CV (%)					5	6	8	16	0	

Table F.19 Core measurements for M-53 NB – section 1 test site 1

Core Designation	Total core thickness (in)					Courses thickness (in)			Core diameter (in)	Crack/ defect
	1	2	3	4	Average	Surface	Leveling	Base		
30531-1101	6.0	6.0	6.0	6.0	6.0	1.3	2.6	2.1	5.9	None
30531-1102	5.9	6.0	5.9	5.8	5.9	1.4	2.4	2.1	5.9	None
30531-1103	6.0	6.0	5.9	6.0	6.0	1.3	2.6	2.1	5.9	Crack
30531-1104	6.0	6.3	6.0	6.0	6.1	1.4	2.4	2.3	5.9	None
30531-1105	5.6	5.9	5.4	6.0	5.7	0.9	2.6	2.3	N.A.	None
30531-1106	6.0	6.0	6.0	6.0	6.0	1.0	2.4	2.6	N.A	Broken
30531-1107	6.0	6.3	5.8	6.0	6.0	1.1	2.8	2.1	5.9	None
30531-1108	6.0	6.0	5.8	6.1	6.0	1.0	2.8	2.1	5.9	None
30531-1109	6.0	6.0	6.0	6.0	6.0	1.1	2.9	2.0	5.9	None
30531-1110	5.8	6.0	6.0	5.8	5.9	1.1	2.8	2.0	5.9	Crack
30531-1111	6.0	5.8	6.0	6.0	5.9	1.0	2.7	2.3	5.9	None
30531-1112	5.4	5.4	5.1	5.0	5.2	1.3	1.7	2.3	5.9	None
30531-1113	4.5	4.4	4.0	4.3	4.3	1.4	0.0	2.9	5.9	None
30531-1114	4.5	4.5	4.3	4.8	4.5	1.4	1.1	2.0	N.A.	Broken
30531-1115	5.5	5.5	5.6	5.8	5.6	1.1	2.1	2.4	5.9	None
30531-1116	4.8	4.8	4.8	4.9	4.8	1.4	1.3	2.1	5.9	None
30531-1117	5.0	5.0	4.8	4.8	4.9	1.4	1.4	2.1	5.9	Crack
30531-1118	5.0	5.0	5.0	5.0	5.0	1.3	1.5	2.3	5.9	None
30531-1119	4.3	4.5	4.8	4.4	4.5	1.3	1.1	2.1	5.9	None
30531-1120	4.9	4.9	4.8	4.9	4.8	1.4	2.0	1.5	N.A.	Broken
30531-1121	5.8	5.5	5.5	5.5	5.6	1.3	2.1	2.3	5.9	None
Average					5.5	1.2	2.1	2.2	5.9	
CV (%)					11	13	37	12	0	

Table F.20 Specimen measurements for I-69 SB – section 1 test site 1

Specimen designation	Thickness of the upper course (in)				Total specimen thickness (in)				Thickness (in)		
	1	2	3	4	1	2	3	4	Upper course	Lower course	Total
10692-1104-43	1.3	1.3	1.3	1.3	3.1	3.0	3.0	3.1	1.3	1.8	3.1
10692-1107-43	1.5	1.5	1.5	1.5	3.1	3.1	3.3	3.3	1.5	1.7	3.2
10692-1110-43	1.8	1.8	1.9	1.8	3.2	3.0	3.0	3.3	1.8	1.3	3.1
10692-1115-43	1.5	1.5	1.5	1.5	3.3	3.3	3.1	3.1	1.5	1.7	3.2
10692-1116-20	2.9	2.9	3.0	2.9					2.9		2.9
10692-1116-30	2.3	2.4	2.4	2.3					2.3		2.3
10692-1118-43	1.9	1.9	1.9	1.8	3.1	3.3	3.1	3.0	1.8	1.3	3.1
10692-1123-20	2.8	2.8	3.0	3.0					2.9		2.9
10692-1123-30	2.3	2.4	2.5	2.5					2.4		2.4
10692-1124-20	2.3	2.4	2.4	2.4					2.4		2.4
10692-1124-30	2.6	2.8	2.7	2.5					2.6		2.6
10692-1125-20	2.8	2.8	2.8	2.8					2.8		2.8
10692-1125-30	2.6	2.5	2.4	2.4					2.5		2.5
10692-1126-20	2.9	3.0	3.0	2.9					3.0		3.0
10692-1126-30	2.5	2.4	2.4	2.6					2.5		2.5

Table F.21 Specimen measurements for I-69 SB – section 1 test site 2

Specimen designation	Thickness of the upper course (in)				Total specimen thickness (in)				Thickness (in)		
	1	2	3	4	1	2	3	4	Upper course	Lower course	Total
10692-1201-20	3.1	3.1	3.0	2.9					3.0		3.0
10692-1201-30	2.3	2.2	2.0	2.1					2.2		2.2
10692-1201-40	1.5	1.4	1.6	1.7					1.6		1.6
10692-1204-32	0.4	0.3	0.5	0.4	4.0	4.1	4.3	4.1	0.4	3.7	4.1
10692-1204-43	1.6	1.6	1.6	1.6	3.0	2.9	3.1	3.2	1.6	1.4	3.0
10692-1207-32	0.1	0.3	0.4	0.4	4.4	4.3	4.4	4.5	0.3	4.1	4.4
10692-1207-43	1.8	1.7	1.8	1.8	3.2	3.4	3.4	3.3	1.7	1.6	3.3
10692-1210-20	2.8	2.9	3.1	3.1					3.0		3.0
10692-1210-30	2.3	2.5	2.5	2.3					2.4		2.4
10692-1210-40	1.7	1.7	1.6	1.5					1.6		1.6
10692-1215-40	1.4	1.4	1.4	1.4					1.4		1.4
10692-1216-40	1.6	1.6	1.6	1.6					1.6		1.6
10692-1218-32	0.6	0.8	0.8	0.6	4.8	5.1	5.0	4.8	0.7	4.3	4.9
10692-1218-43	1.9	1.8	1.8	1.8	3.2	3.2	3.2	3.3	1.8	1.4	3.2
10692-1223-20	3.1	3.4	3.3	3.1					3.2		3.2
10692-1223-30	2.4	2.2	2.2	2.3					2.3		2.3
10692-1223-40	1.6	1.8	1.6	1.5					1.6		1.6
10692-1224-20	3.0	3.0	2.9	2.7					2.9		2.9
10692-1224-30	2.4	2.5	2.6	2.6					2.5		2.5
10692-1224-40	1.4	1.6	1.8	1.6					1.6		1.6
10692-1225-20	3.1	3.3	3.4	3.2					3.2		3.2
10692-1225-30	2.3	2.4	2.5	2.3					2.4		2.4
10692-1225-40	1.6	1.8	1.9	1.8					1.7		1.7
10692-1226-32	1.0	0.9	0.8	0.9	5.1	5.1	5.1	5.0	0.9	4.2	5.1
10692-1226-43	1.6	1.6	1.4	1.4	3.2	3.1	3.1	3.2	1.5	1.6	3.1

Table F.22 Specimen measurements for I-75 SB – section 1 test site 1

Specimen designation	Thickness of the upper course (in)				Thickness of the upper and the middle course (in)				Total specimen thickness (in)				Thickness (in)			
	1	2	3	4	1	2	3	4	1	2	3	4	Upper course	Middle course	Lower course	Total
10753-1101-43	4.0	4.1	4.0	4.0	7.1	7.2	7.5	7.4					4.0	3.3		2.9
10753-1126-432	4.4	4.4	4.4	4.5	6.5	6.8	6.8	6.7	7.5	7.9	7.9	7.6	4.4	2.3	1.0	3.0
10753-1125-43	4.6	4.5	4.5	4.5	7.4	7.5	7.7	7.5					4.5	3.0		3.0
10753-1110-432	3.9	3.7	3.7	3.7	6.4	6.2	6.2	5.7	7.2	7.5	7.5	7.4	3.8	2.4	1.3	2.9

Table F.23 Specimen measurements for I-75 SB – section 1 test site 2

Specimen designation	Thickness of the upper course (in)				Total specimen thickness (in)				Thickness (in)		
	1	2	3	4	1	2	3	4	Upper course	Lower course	Total
10753-1210-43	3.9	3.7	3.8	4.0	7.5	7.3	7.4	7.4	3.9	3.6	2.9
10753-1218-43	4.0	4.0	4.0	4.1	7.7	7.8	7.2	7.1	4.0	3.4	2.9
10753-1224-43	4.5	4.4	4.5	4.6	7.1	7.4	7.6	7.5	4.5	2.9	2.9
10753-1226-43	4.1	4.3	4.3	4.3	7.4	7.1	6.9	7.1	4.3	2.9	2.8

Table F.24 Specimen measurements for I-194 NB – section 2 test site 1

Specimen designation	Thickness of the upper course (in)				Total specimen thickness (in)				Thickness (in)		
	1	2	3	4	1	2	3	4	Upper course	Lower course	Total
11941-2101-32	2.0	2.1	2.0	1.9	3.0	2.9	2.8	2.9	2.0	0.9	2.9
11941-2101-54	1.5	1.6	1.6	1.6	3.1	3.0	3.1	3.1	1.6	1.5	3.1
11941-2110-32	1.4	1.5	1.5	1.5	3.0	3.0	3.0	3.0	1.5	1.5	3.0
11941-2110-54	1.5	1.5	1.5	1.5	3.0	2.9	3.0	3.0	1.5	1.5	3.0
11941-2118-32	1.9	2.0	2.0	1.9	2.4	2.5	2.5	2.4	2.0	0.5	2.5
11941-2118-43	1.5	1.5	1.5	1.5	3.0	3.1	3.1	3.0	1.5	1.6	3.1
11941-2118-50	1.4	1.4	1.4	1.4					1.4		1.4
11941-2123-32	1.7	1.6	1.7	1.7	3.1	3.2	3.1	3.0	1.7	1.4	3.1
11941-2123-54	1.5	1.5	1.6	1.5	3.3	3.4	3.3	3.2	1.5	1.8	3.3
11941-2124-20	1.2	1.3	1.4	1.3					1.3		1.3
11941-2124-43	0.6	0.8	0.7	0.7	2.9	3.0	3.0	2.9	0.7	2.3	3.0
11941-2124-54	1.3	1.3	1.3	1.2	2.0	2.0	2.1	2.2	1.3	0.8	2.1
11941-2126-20	1.9	1.9	1.9	1.8					1.9		1.9
11941-2126-43	0.8	0.8	1.0	1.0	2.9	3.0	3.1	3.0	0.9	2.1	3.0
11941-2126-50	1.5	1.5	1.5	1.6					1.5		1.5

Table F.25 Specimen measurements for I-194 NB – section 2 test site 2

Specimen designation	Thickness of the upper course (in)				Total specimen thickness (in)				Thickness (in)		
	1	2	3	4	1	2	3	4	Upper course	Lower course	Total
11941-2215-32	2.2	2.2	2.2	2.2	3.1	3.0	3.1	3.2	2.2	0.9	3.1
11941-2204-43	1.3	1.2	1.2	1.2	3.2	3.0	3.0	3.1	1.2	1.9	3.1
11941-2207-43	1.3	1.2	1.0	1.2	3.4	3.3	3.3	3.3	1.2	2.1	3.3
11941-2224-54	1.5	1.5	1.4	1.4	2.8	3.0	3.0	2.8	1.4	1.4	2.9
11941-2201-32	2.0	2.0	2.0	2.1	3.1	3.0	3.0	3.1	2.0	1.1	3.1
11941-2224-32	1.7	1.9	1.8	1.9	3.1	3.1	3.0	3.1	1.8	1.3	3.1
11941-2201-54	1.6	1.6	1.6	1.6	3.1	3.0	2.9	3.0	1.6	1.4	3.0
11941-2215-54	1.5	1.5	1.4	1.5	3.1	3.0	2.9	2.9	1.4	1.5	3.0
11941-2210-43	1.3	1.2	1.3	1.4	3.1	3.0	3.1	3.3	1.3	1.9	3.1

Table F.26 Specimen measurements for US-10 EB – section 1 test site 1

Specimen designation	Thickness of the upper course (in)				Total specimen thickness (in)				Thickness (in)		
	1	2	3	4	1	2	3	4	Upper course	Lower course	Total
20102-1101-32	2.1	2.0	2.1	2.2	3.2	3.2	3.3	3.3	2.1	1.1	3.2
20102-1101-40	1.4	1.3	1.4	1.4					1.4		1.4
20102-1104-20	1.2	1.1	0.9	1.1					1.1		1.1
20102-1104-32	2.0	2.0	1.8	1.8	2.8	2.8	2.5	2.5	1.9	0.8	2.6
20102-1104-40	1.5	1.5	1.5	1.5					1.5		1.5
20102-1104-43	1.5	1.5	1.4	1.5	2.5	2.6	2.6	2.5	1.5	1.1	2.6
20102-1107-20	1.6	1.4	1.5	1.7					1.5		1.5
20102-1107-32	2.1	2.1	2.2	2.1	2.8	2.6	2.8	2.9	2.1	0.6	2.8
20102-1107-40	1.3	1.4	1.4	1.3					1.3		1.3
20102-1117-20	2.8	2.8	2.8	2.8					2.8		2.8
20102-1117-43	1.5	1.5	1.5	1.5	3.0	3.1	3.1	2.9	1.5	1.5	3.0
20102-1125-20	2.8	2.6	2.8	2.9					2.8		2.8
20102-1125-43	1.4	1.4	1.4	1.5	2.9	2.9	3.7	3.0	1.4	1.7	3.1
20102-1126-20	2.5	2.5	2.5	2.5					2.5		2.5
20102-1126-43	1.2	1.3	1.1	1.9	2.9	2.9	2.9	2.9	1.4	1.5	2.9

Table F.27 Specimen measurements for US-10 EB – section 1 test site 1

Specimen designation	Thickness of the upper course (in)				Total specimen thickness (in)				Thickness (in)		
	1	2	3	4	1	2	3	4	Upper course	Lower course	Total
20102-1204-32	0.9	0.9	1.1	1.0	2.9	3.0	3.1	3.0	1.0	2.0	3.0
20102-1223-20	2.5	2.5	2.5	2.5					2.5		2.5
20102-1223-43	1.1	1.4	1.2	1.2	3.0	3.0	2.9	3.0	1.2	1.8	3.0
20102-1225-32	0.9	0.5	0.5	0.8	3.1	2.9	2.9	3.1	0.7	2.3	3.0
20102-1225-43	1.3	1.5	1.5	1.3	2.8	3.0	2.9	2.8	1.4	1.5	2.8
20102-1226-20	2.6	2.5	2.6	2.6					2.6		2.6
20102-1226-43	0.6	0.6	0.6	0.6	2.4	2.4	2.6	2.1	0.6	1.8	2.4

Table F.28 Specimen measurements for US-23 SB – section 1 test site 1

Specimen designation	Thickness of the upper course (in)				Total specimen thickness (in)				Thickness (in)		
	1	2	3	4	1	2	3	4	Upper course	Lower course	Total
20233-1106-30	2.5	2.5	2.6	2.3					2.5		2.5
20233-1106-20	1.6	1.5	1.5	1.6					1.5		1.5
20233-1106-40	1.4	1.3	1.3	1.3					1.3		1.3
20233-1127-43	1.4	1.4	1.4	1.4	2.8	3.0	2.9	2.8	1.4	1.5	2.9
20233-1127-32	1.8	1.8	1.7	1.6	2.9	2.9	2.9	2.8	1.7	1.2	2.9
20233-1120-32	1.8	1.8	1.8	1.8	2.9	2.9	2.8	2.8	1.8	1.0	2.8
20233-1120-40	1.6	1.8	1.6	1.6					1.7		1.7
20233-1120-20	0.8	0.8	0.6	0.8					0.7		0.7
20233-1110-32	2.0	1.9	1.9	2.0	3.0	2.8	2.8	2.9	1.9	0.9	2.9
20233-1110-20	0.8	0.8	1.0	0.9					0.8		0.8
20233-1110-40	1.6	1.6	1.6	1.5					1.6		1.6
20233-1117-32	0.4	0.5	0.6	0.5	2.5	2.9	2.8	2.5	0.5	2.2	2.7
20233-1117-43	1.4	1.5	1.5	1.4	2.8	2.8	2.8	2.5	1.5	1.3	2.7
20233-1125-20	3.0	3.1	2.9	2.9					3.0		3.0
20233-1125-43	1.5	1.5	1.5	1.5	2.9	3.0	2.9	2.8	1.5	1.4	2.9
20233-1116-40	1.4	1.5	1.5	1.5					1.5		1.5
20233-1116-32	1.8	1.8	1.6	1.6	2.9	2.8	2.6	2.8	1.7	1.1	2.8
20233-1116-20	0.8	0.6	0.6	0.8					0.7		0.7

Table F.29 Specimen measurements for US-23 SB – section 1 test site 1

Specimen designation	Thickness of the upper course (in)				Total specimen thickness (in)				Thickness (in)		
	1	2	3	4	1	2	3	4	Upper course	Lower course	Total
20233-1210-32	1.5	1.4	1.4	1.6	3.0	2.9	3.0	3.1	1.5	1.5	3.0
20233-1210-43	1.5	1.6	1.5	1.5	3.0	3.0	2.9	2.8	1.5	1.4	2.9
20233-1217-20	1.6	1.5	1.3	1.4					1.5		1.5
20233-1217-40	0.8	0.8	0.9	0.9					0.8		0.8
20233-1217-43	1.6	1.5	1.3	1.5	2.5	2.3	2.1	2.3	1.5	0.8	2.3
20233-1220-32	1.1	1.3	1.5	1.3	2.6	2.7	3.0	2.8	1.3	1.5	2.8
20233-1220-43	1.5	1.4	1.2	1.4	2.9	2.9	2.6	2.9	1.4	1.5	2.8
20233-1227-32	0.8	0.8	0.8	0.8	2.8	2.9	3.1	2.8	0.8	2.1	2.9
20233-1227-43	1.6	1.4	1.6	1.5	2.5	2.4	2.5	2.6	1.5	1.0	2.5
20233-1230-20	1.8	1.8	2.0	2.1					1.9		1.9
20233-1230-40	1.4	1.5	1.5	1.4					1.4		1.4
20233-1230-43	0.5	0.5	0.6	0.5	2.3	2.3	2.6	2.5	0.5	1.9	2.4

Table F.30 Specimen measurements for US-27 SB– section 2 test site 1

Specimen designation	Thickness of the upper course (in)				Total specimen thickness (in)				Thickness (in)		
-	1	2	3	4	1	2	3	4	Upper course	Lower course	Total
20273-2115-43	0.6	0.7	0.8	0.7	2.0	2.1	2.2	2.1	0.7	1.4	2.1
20273-2123-43	1.2	1.4	1.4	1.2	2.4	2.5	2.5	2.4	1.3	1.2	2.5
20273-2125-43	0.7	0.6	0.7	0.8	2.3	2.3	2.3	2.4	0.7	1.6	2.3
20273-2126-43	0.8	1.0	0.9	1.0	2.1	2.2	2.2	2.2	0.9	1.3	2.2

Table F.31 Specimen measurements for US-27 SB– section 3 test site 1

Specimen designation	Thickness of the upper course (in)				Total specimen thickness (in)				Thickness (in)		
	1	2	3	4	1	2	3	4	Upper course	Lower course	Total
20273-3101-32	1.3	1.3	1.5	1.4	3.2	3.3	3.3	3.3	1.3	1.9	3.2
20273-3101-43	1.6	1.8	1.8	1.6	2.6	2.8	2.9	2.8	1.7	1.1	2.8
20273-3104-20	1.9	1.8	1.4	1.6					1.6		1.6
20273-3104-30	2.3	2.6	2.6	2.3					2.4		2.4
20273-3104-40	1.6	1.8	2.1	1.8					1.8		1.8
20273-3107-32	1.1	1.0	1.0	1.0	2.8	2.9	2.6	2.6	1.0	1.7	2.7
20273-3107-43	1.6	1.9	1.8	1.8	3.3	3.1	3.1	3.3	1.8	1.4	3.2
20273-3110-32	0.8	0.8	0.8	0.8	2.8	2.8	2.4	2.5	0.8	1.9	2.6
20273-3110-43	1.8	1.8	1.8	1.8	3.3	3.3	3.1	3.1	1.8	1.4	3.2
20273-3116-20	1.8	2.0	1.9	1.5					1.8		1.8
20273-3116-30	2.3	2.5	2.6	2.5					2.5		2.5
20273-3116-40	1.9	1.9	1.8	1.9					1.9		1.9
20273-3117-32	1.5	1.4	1.6	1.6	3.1	3.2	3.4	3.4	1.5	1.8	3.3
20273-3117-43	1.9	1.8	1.9	1.9	2.8	3.0	2.9	2.8	1.8	1.0	2.8
20273-3118-32	1.5	1.5	1.5	1.3	3.5	3.5	3.5	3.4	1.4	2.0	3.5
20273-3118-43	1.8	1.8	1.9	1.8	3.1	3.0	3.1	3.3	1.8	1.3	3.1
20273-3124-20	2.2	2.1	2.1	2.3					2.2		2.2
20273-3124-30	2.5	2.6	2.8	2.8					2.7		2.7
20273-3124-40	1.8	1.8	1.9	1.8					1.8		1.8
20273-3126-32	0.9	0.9	1.1	1.0	3.1	3.1	3.1	3.1	1.0	2.2	3.1
20273-3126-43	1.6	1.8	1.8	1.9	2.9	2.8	2.8	2.9	1.8	1.1	2.8

Table F.32 Specimen measurements for US-27 SB– section 4 test site 1

Specimen designation	Thickness of the upper course (in)				Total specimen thickness (in)				Thickness (in)		
	1	2	3	4	1	2	3	4	Upper course	Lower course	Total
20273-4107-20	2.0	2.1	2.5	2.3					2.2		2.2
20273-4107-30	3.0	2.9	2.9	3.1					3.0		3.0
20273-4110-32	2.2	2.1	1.9	2.1	3.2	2.9	2.8	3.1	2.5	0.5	3.0
20273-4110-40	1.1	1.3	1.1	0.9					1.1		1.1
20273-4115-32	2.0	1.8	1.9	2.0	3.1	3.1	3.1	3.1	2.5	0.6	3.1
20273-4115-40	0.9	0.9	1.1	1.2					1.0		1.0
20273-4116-20	2.3	2.2	2.3	2.3					2.2		2.2
20273-4116-43	1.5	1.5	1.5	1.5	3.5	3.5	3.5	3.5	1.5	2.0	3.5
20273-4117-32	2.3	2.2	2.1	2.3	3.1	3.1	3.3	3.3	2.7	0.5	3.2
20273-4117-40	1.2	1.3	1.4	1.2					1.3		1.3
20273-4118-20	2.5	2.7	2.9	2.6					2.7		2.7
20273-4118-43	1.0	1.0	1.1	1.0	2.9	3.0	2.9	2.8	1.0	1.8	2.9
20273-4123-20	2.6	2.8	2.5	2.3					2.5		2.5
20273-4123-43	1.5	1.5	1.6	1.5	3.1	3.4	3.3	3.0	1.5	1.7	3.2
20273-4124-32	2.8	2.1	2.0	2.1	3.1	3.1	3.1	3.1	2.7	0.4	3.1
20273-4124-40	1.4	1.4	1.1	1.3					1.3		1.3
20273-4125-20	3.0	3.0	3.1	3.0					3.0		3.0
20273-4125-43	1.3	1.1	1.1	1.1	2.9	3.0	3.1	3.0	1.2	1.8	3.0
20273-4126-32	2.1	2.1	2.1	2.1	2.9	3.0	3.1	3.0	2.6	0.4	3.0
20273-4126-40	1.4	1.5	1.4	1.5					1.4		1.4

Table F.33 Specimen measurements for US-31 NB– section 1 test site 1

Specimen designation	Thickness of the upper course (in)				Total specimen thickness (in)				Thickness (in)		
	1	2	3	4	1	2	3	4	Upper course	Lower course	Total
20311-1101-20	2.1	2.1	2.1	2.1					2.1		2.1
20311-1101-32	1.6	1.6	1.8	1.8	3.1	3.0	2.9	3.0	1.7	1.3	3.0
20311-1101-40	1.3	1.1	1.2	1.3					1.2		1.2
20311-1104-20	3.1	3.1	3.1	3.1					3.1		3.1
20311-1104-43	1.3	1.3	1.3	1.3	2.8	3.0	2.8	2.6	1.3	1.5	2.8
20311-1107-20	3.4	3.3	3.5	3.6					3.5		3.5
20311-1107-43	1.3	1.4	1.6	1.4	3.0	3.0	3.0	3.0	1.4	1.6	3.0
20311-1115-20	3.1	3.1	3.0	3.0					3.0		3.0
20311-1115-32	1.8	1.8	1.8	1.8	2.8	2.6	2.6	2.8	1.8	0.9	2.7
20311-1115-40	1.2	1.2	1.2	1.2					1.2		1.2
20311-1116-20	2.9	2.8	3.0	3.1					2.9		2.9
20311-1116-32	1.8	1.6	1.6	1.5	3.1	3.0	3.0	3.1	1.6	1.4	3.1
20311-1116-40	1.3	1.3	1.3	1.3					1.3		1.3
20311-1118-20	1.6	1.8	2.0	1.9					1.8		1.8
20311-1118-32	1.8	1.8	1.8	1.8	2.8	2.9	2.9	2.8	1.8	1.1	2.8
20311-1118-40	1.3	1.3	1.3	1.3					1.3		1.3
20311-1123-20	2.8	2.9	3.2	3.0					3.0		3.0
20311-1123-32	1.3	1.4	1.5	1.4	2.5	2.5	2.5	2.5	1.4	1.1	2.5
20311-1123-40	1.3	1.4	1.6	1.4					1.4		1.4
20311-1124-20	2.8	2.9	3.1	2.9					2.9		2.9
20311-1124-43	1.1	1.2	1.3	1.3	2.9	3.0	3.1	3.0	1.2	1.8	3.0
20311-1125-20	2.8	2.6	2.9	2.9					2.8		2.8
20311-1125-43	1.5	1.5	1.3	1.1	3.3	3.5	3.3	3.1	1.3	1.9	3.3
20311-1126-20	2.8	2.9	3.0	2.9					2.9		2.9
20311-1126-43	1.3	1.3	1.2	1.3	3.1	3.0	3.0	3.1	1.2	1.8	3.1

Table F.34 Specimen measurements for M-37 SB– section 5 test site 1

Specimen designation	Thickness of the upper course (in)				Total specimen thickness (in)				Thickness (in)		
	1	2	3	4	1	2	3	4	Upper course	Lower course	Total
30373-5104-20	1.5	1.4	1.3	1.1					1.3		1.3
30373-5104-32	1.9	1.8	1.6	1.8	2.9	2.8	2.6	2.8	1.8	1.0	2.8
30373-5104-40	1.6	1.5	1.4	1.6					1.5		1.5
30373-5117-20	1.6	1.5	1.4	1.5					1.5		1.5
30373-5117-32	1.4	1.6	1.8	1.5	2.5	2.8	2.6	2.6	1.6	1.1	2.6
30373-5117-40	1.8	1.5	1.5	1.8					1.6		1.6
30373-5123-20	1.6	1.8	2.0	2.0	3.1	3.0	3.3	3.3	1.8	1.3	3.2
30373-5123-43	1.5	1.5	1.4	1.5	3.3	3.1	3.0	3.1	1.5	1.7	3.1
30373-5124-20	1.6	1.8	1.5	1.5	3.3	3.1	3.0	3.1	1.6	1.5	3.1
30373-5124-43	1.5	1.4	1.5	1.5	3.1	3.3	3.4	3.3	1.5	1.8	3.3
30373-5125-20	1.6	1.6	1.8	1.8	2.9	2.8	2.8	3.0	1.7	1.2	2.8
30373-5125-43	1.3	1.1	1.0	1.1	2.8	2.8	2.5	2.5	1.1	1.5	2.6

Table F.35 Specimen measurements for M-37 SB– section 5 test site 2

Specimen designation	Thickness of the upper course (in)				Total specimen thickness (in)				Thickness (in)		
	1	2	3	4	1	2	3	4	Upper course	Lower course	Total
30373-5201-20	1.6	1.5	1.5	1.6					1.6		1.6
30373-5201-32	1.6	1.8	2.0	1.9	2.3	2.4	2.4	2.5	1.8	0.6	2.4
30373-5201-40	1.5	1.5	1.3	1.4					1.4		1.4
30373-5207-20	1.2	1.0	0.9	1.0					1.0		1.0
30373-5207-32	1.9	2.0	1.9	1.8	2.5	2.9	2.6	2.5	1.9	0.8	2.6
30373-5207-40	1.5	1.6	1.6	1.5					1.6		1.6
30373-5215-20	1.5	1.5	1.3	1.3					1.4		1.4
30373-5215-32	1.8	1.8	2.1	1.9	2.8	2.5	2.5	2.8	1.9	0.8	2.6
30373-5215-40	1.4	1.3	1.4	1.4					1.3		1.3
30373-5223-20	1.6	1.6	1.6	1.6	3.1	3.0	3.0	3.1	1.6	1.4	3.1
30373-5223-43	1.4	1.3	1.4	1.3	3.0	2.9	2.9	3.0	1.3	1.6	2.9
30373-5225-20	1.9	2.0	2.0	1.8	2.9	3.1	3.0	2.8	1.9	1.0	2.9
30373-5225-43	1.5	1.5	1.5	1.5	3.0	2.9	3.0	3.1	1.5	1.5	3.0

Table F.36 Specimen measurements for M-37 SB– section 6 test site 1

Specimen designation	Thickness of the upper course (in)				Total specimen thickness (in)				Thickness (in)		
	1	2	3	4	1	2	3	4	Upper course	Lower course	Total
30373-6107-32	1.7	1.6	1.7	1.7	2.9	2.8	2.9	3.0	1.7	1.3	2.9
30373-6107-43	1.5	1.4	1.3	1.5	2.0	2.0	1.8	1.8	1.4	0.5	1.9
30373-6110-32	0.9	0.7	0.6	0.8	2.0	1.9	1.8	2.0	0.8	1.2	1.9
30373-6110-43	1.5	1.8	1.7	1.7	3.1	3.0	3.0	3.0	1.6	1.3	3.0
30373-6117-32	0.9	0.9	0.9	0.8	1.9	2.0	2.0	1.8	0.9	1.1	1.9
30373-6117-43	1.7	1.7	1.7	1.6	3.0	2.9	2.9	3.0	1.7	1.3	3.0
30373-6118-32	1.0	1.1	1.3	1.4	2.3	2.4	2.6	2.6	1.2	1.3	2.5
30373-6118-43	1.9	1.9	1.9	1.9	2.8	2.6	2.7	2.9	1.9	0.9	2.8
30373-6123-32	1.3	1.2	1.1	1.2	2.9	2.8	2.8	2.8	1.2	1.6	2.8
30373-6123-43	1.6	1.6	1.6	1.6	2.6	2.5	2.4	2.5	1.6	0.9	2.5
30373-6124-32	0.5	0.6	0.7	0.6	1.9	2.0	2.0	1.9	0.6	1.4	2.0
30373-6124-43	1.5	1.6	1.6	1.5	3.0	3.0	2.8	2.8	1.6	1.3	2.9
30373-6125-32	1.8	1.7	1.6	1.6	3.0	3.0	2.9	2.9	1.7	1.3	2.9
30373-6125-43	1.6	1.5	1.5	1.6	1.9	2.0	2.0	1.9	1.6	0.4	2.0
30373-6144-32	1.3	1.5	1.4	1.4	2.7	2.8	2.8	2.8	1.4	1.4	2.8
30373-6144-43	1.8	1.7	1.6	1.8	2.2	2.3	2.4	2.3	1.7	0.6	2.3

Table F.37 Specimen measurements for M-53 SB– section 1 test site 1

Specimen designation	Thickness of the upper course (in)				Total specimen thickness (in)				Thickness (in)		
	1	2	3	4	1	2	3	4	Upper course	Lower course	Total
30531-1101-20	1.1	1.0	0.9	1.0					1.0		1.0
30531-1101-32	2.0	1.9	2.0	2.0	2.8	2.8	2.9	2.9	2.0	0.8	2.8
30531-1101-40	1.4	1.3	1.3	1.4					1.3		1.3
30531-1102-20	0.6	0.8	0.9	0.8					0.8		0.8
30531-1102-32	2.0	2.0	2.0	2.0	2.9	2.9	2.9	3.0	2.0	0.9	2.9
30531-1102-40	0.9	0.8	0.8	0.9					0.8		0.8
30531-1104-32	0.6	0.6	0.5	0.8	2.8	2.9	2.9	2.8	0.6	2.2	2.8
30531-1104-43	1.3	1.4	1.3	1.3	2.8	2.8	2.9	2.9	1.3	1.5	2.8
30531-1107-20	2.0	1.8	1.9	2.1					1.9		1.9
30531-1107-43	1.4	1.2	1.2	1.1	2.4	2.1	2.4	2.5	1.2	1.1	2.3
30531-1108-20	2.5	2.5	2.6	2.6					2.5		2.5
30531-1108-43	1.1	1.1	1.1	1.1	3.0	2.9	2.8	3.0	1.1	1.8	2.9
30531-1109-20	2.7	2.5	2.6	2.8					2.6		2.6
30531-1109-43	1.1	1.2	1.1	1.1	2.6	2.6	2.9	2.8	1.1	1.6	2.7
30531-1111-20	2.5	2.5	2.4	2.4					2.5		2.5
30531-1111-43	1.1	1.4	1.1	1.1	2.9	3.0	3.0	2.9	1.2	1.8	3.0
30531-1112-32	2.3	2.9	2.3	2.2	2.9	2.9	2.9	2.9	2.4	0.5	2.9
30531-1112-40	1.3	1.3	1.3	1.3					1.3		1.3
30531-1113-43	1.4	1.3	1.4	1.3	2.9	2.9	3.0	2.9	1.3	1.6	2.9
30531-1115-20	0.9	1.0	0.8	0.8					0.9		0.9
30531-1115-32	2.3	2.3	2.3	2.3	2.9	2.8	2.9	2.9	2.3	0.6	2.9
30531-1115-40	1.3	1.1	1.1	1.2					1.2		1.2
30531-1116-32	0.7	0.5	0.5	0.6	1.1	0.9	0.9	1.1	0.6	0.4	1.0
30531-1116-43	1.4	1.4	1.3	1.4	2.9	2.8	2.8	2.9	1.4	1.5	2.9
30531-1118-32	0.8	0.4	0.3	0.5	1.9	1.7	1.5	1.6	0.5	1.2	1.7
30531-1118-43	1.3	1.3	1.3	1.3	3.0	2.9	2.8	2.9	1.3	1.6	2.9
30531-1119-20	1.0	0.8	0.8	1.1					0.9		0.9
30531-1119-43	1.3	1.4	1.5	1.3	2.7	2.8	2.9	2.9	1.4	1.4	2.8
30531-1121-20	0.6	0.7	0.6	0.6					0.6		0.6
30531-1121-32	2.2	2.2	2.1	2.0	2.8	2.9	2.9	2.8	2.1	0.7	2.8
30531-1121-40	1.3	1.3	1.4	1.3					1.3		1.3

APPENDIX G

BULK SPECIFIC GRAVITY AND PERCENT AIR VOIDS

APPENDIX G
BULK SPECIFIC GRAVITY AND PERCENT AIR VOIDS

This appendix presents the bulk specific gravity and the percent air voids calculated from cores and specimens obtained from various rubblized pavement projects. A project may be divided into one or more test sections and each section may be divided into one or more test sites.

Table G.1 Specific gravity and air voids of cores obtained from I-69 EB –section 1 test site 1

Core Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
10692-1101	7304.9	4182.0	7312.0	70.4	2.34	6.6
10692-1104	7221.3	4149.6	7219.3	70.4	2.35	5.8
10692-1107	7912.9	4514.0	7919.6	70.4	2.33	7.0
10692-1110	8352.9	4809.7	8349.4	70.4	2.36	5.5
10692-1115	7913.1	4509.7	7937.6	70.4	2.31	7.6
10692-1117	8038.7	4600.9	8051.0	70.4	2.33	6.7
10692-1118	8530.6	4892.6	8570.6	70.4	2.32	7.2
10692-1123	7675.1	4352.8	7681.4	70.4	2.31	7.7
10692-1124	7344.8	4137.9	7357.3	70.4	2.28	8.7
10692-1125	7656.5	4314.0	7679.0	70.4	2.28	8.9
10692-1126	8135.6	4643.5	8183.9	70.4	2.30	8.0
Average					2.32	7.3
CV (%)					1	15

Table G.2 Specific gravity and air voids of cores obtained from I-69 EB - section 1 test site 2

Core Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
10692-1101	7304.9	4182.0	7312.0	70.4	2.34	6.6
10692-1104	7221.3	4149.6	7219.3	70.4	2.35	5.8
10692-1107	7912.9	4514.0	7919.6	70.4	2.33	7.0
10692-1110	8352.9	4809.7	8349.4	70.4	2.36	5.5
10692-1115	7913.1	4509.7	7937.6	70.4	2.31	7.6
10692-1117	8038.7	4600.9	8051.0	70.4	2.33	6.7
10692-1118	8530.6	4892.6	8570.6	70.4	2.32	7.2
10692-1123	7675.1	4352.8	7681.4	70.4	2.31	7.7
10692-1124	7344.8	4137.9	7357.3	70.4	2.28	8.7
10692-1125	7656.5	4314.0	7679.0	70.4	2.28	8.9
10692-1126	8135.6	4643.5	8183.9	70.4	2.30	8.0
Average					2.32	7.3
CV (%)					1	15

Table G.3 Specific gravity and air voids of cores obtained from I-75 SB - section 1 test site 1

Core Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
10753-1101	3561.7	2077.6	3563.8	72.4	2.40	4.1
10753-1104	3551.3	2073.3	3553.4	72.4	2.40	4.0
10753-1107	3815.8	2228.1	3818.6	72.4	2.40	4.0
10753-1110	3550.3	2077.3	3552.9	72.4	2.41	3.7
10753-1116	3930.8	2265.5	3933.0	72.4	2.36	5.7
10753-1117	4117.0	2362.2	4119.2	72.4	2.34	6.2
10753-1118	3728.8	2140.8	3732.4	72.4	2.34	6.2
10753-1123	4302.1	2488.8	4305.2	72.4	2.37	5.2
10753-1124	3935.7	2288.3	3937.8	72.4	2.39	4.5
10753-1125	4048.8	2349.6	4051.6	72.4	2.38	4.8
10753-1126	3862.4	2248.4	3846.4	72.4	2.42	3.3
Average					2.38	4.7
CV (%)					1	22

Table G.4 Specific gravity and air voids of cores obtained from I-75 SB - section 1 test site 2

Core Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
10753-1225	3709.4	2167.9	3713.0	72.2	2.40	3.9
10753-1250	3105.3	1761.6	3017.5	72.2	2.47	1.0
10753-1251	3713.3	2150.8	3717.0	72.2	2.37	5.1
10753-1210	3333.4	1942.1	3335.9	72.2	2.39	4.3
10753-1224	3976.3	2311.2	3979.1	72.2	2.39	4.6
10753-1226	3481.5	2038.8	3484.3	72.2	2.41	3.6
10753-1216	3687.5	2125.5	3690.8	72.2	2.36	5.7
10753-1204	3542.2	2063.7	3545.4	72.2	2.39	4.3
10753-1223	3898.5	2267.3	3902.5	72.2	2.39	4.6
10753-1215	3766.5	2172.4	3769.9	72.2	2.36	5.6
10753-1218	4041.2	2317.5	4051.8	72.2	2.33	6.7
Average					2.39	4.5
CV (%)					2	32

Table G.5 Specific gravity and air voids of cores obtained from I-194 NB - section 2 test site 1

Core Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
11941-2118	7754.7	4517.1	7788.1	70.5	2.37	5.1
11941-2117	7325.0	4279.6	7383.3	70.5	2.36	5.5
11941-2126	7851.2	4587.0	7855.4	70.5	2.40	3.9
11941-2110	7437.4	4365.0	7456.8	70.5	2.41	3.7
11941-2123	7851.6	4603.6	7858.7	70.5	2.41	3.5
11941-2124	7084.2	4136.9	7090.9	70.5	2.40	4.0
11941-2125	7874.8	4584.9	7890.5	70.5	2.38	4.6
11941-2107	7879.3	4625.5	7898.5	70.5	2.41	3.6
11941-2101	8036.6	4729.6	8039.3	70.5	2.43	2.8
11941-2104	7856.4	4608.8	7868.2	70.5	2.41	3.5
Average					2.40	4.0
CV (%)					1	21

Table G.6 Specific gravity and air voids of cores obtained from I-194 NB - section 2 test site 2

Core Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
11941-2201	7850.7	4607.9	7852.7	62.0	2.42	3.1
11941-2204	7422.1	4347.3	7427.8	62.3	2.41	3.5
11941-2207	7739.6	4544.5	7748.8	62.1	2.42	3.3
11941-2210	7089.5	4179.1	7091.7	62.2	2.44	2.5
11941-2215	7865.3	4598.8	7868.6	62.0	2.41	3.7
11941-2216	7192.2	4183.3	7201.2	62.4	2.39	4.6
11941-2217	7459.5	4353.3	7473.0	62.3	2.39	4.2
11941-2218	6899.3	4020.5	6927.8	62.2	2.38	5.0
11941-2223	7753.4	4524.8	7764.7	62.2	2.40	4.2
11941-2224	7384.6	4302.6	7403.6	62.1	2.38	4.6
11941-2226	7082.6	4141.6	7099.7	62.0	2.40	4.1
Average					2.40	3.9
CV (%)					1	19

Table G.7 Specific gravity and air voids of cores obtained from US-10 EB - section 1 test site1

Core Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
20102-1101	4698.3	2668.6	4701.9	67.8	2.31	7.5
20102-1104	5378.1	3054.6	5380.2	67.8	2.31	7.4
20102-1107	5827.2	3330.9	5829.7	67.8	2.33	6.6
20102-1110	5811.9	3317.5	5813.6	67.8	2.33	6.8
20102-1115	5832.9	3319.1	5851.5	67.8	2.31	7.8
20102-1116	5556.1	3170.9	5558.0	67.8	2.33	6.8
20102-1117	5869.5	3344.3	5876.6	67.8	2.32	7.2
20102-1118	5722.5	3262.8	5724.8	67.8	2.33	6.9
20102-1123	5882.8	3349.9	5887.8	67.8	2.32	7.2
20102-1124	5883.3	3368.2	5884.8	67.8	2.34	6.4
20102-1125	5908.3	3390.8	5910.0	67.8	2.35	6.1
20102-1126	6085.5	3486.7	6087.7	67.8	2.34	6.3
Average					2.33	6.9
CV (%)					1	7

Table G.8 Specific gravity and air voids of cores obtained from US-10 EB - section 1 test site2

Core Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
20102-1201	5685.2	3217.5	5662.4	67.9	2.33	6.9
20102-1204	5686.0	3236.2	5687.7	67.9	2.32	7.1
20102-1207	11204.2	6368.3	11213.6	67.9	2.31	7.4
20102-1210	5322.1	3012.3	5326.2	67.9	2.30	7.9
20102-1215	5711.1	3229.3	5719.0	67.9	2.30	8.2
20102-1216	5579.9	3185.1	5581.6	67.9	2.33	6.8
20102-1217	5752.7	3262.2	5760.6	67.9	2.30	7.8
20102-1218	5451.5	3106.1	5453.0	67.9	2.32	7.0
20102-1223	3723.6	2087.3	3732.4	67.9	2.27	9.4
20102-1224	5497.7	3115.0	5506.9	67.9	2.30	8.0
20102-1225	5923.4	3357.0	5943.6	67.9	2.29	8.3
20102-1226	6212.0	3534.9	6217.4	67.9	2.32	7.3
Average					2.31	7.5
CV (%)					1	7

Table G.9 Specific gravity and air voids of cores obtained from US-23 SB - section 1 test site1

Core Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
20233-1115	6008.9	3461.6	6012.3	66.3	2.36	5.7
20233-1106	5948.1	3471.5	5950.0	66.3	2.40	3.9
20233-1127	6286.7	3678.0	6288.3	66.3	2.41	3.6
20233-1116	5454.6	3167.1	5457.4	66.3	2.38	4.6
20233-1117	5776.9	3368.0	5779.1	66.3	2.40	4.1
20233-1105	5292.3	3088.0	5294.3	66.3	2.40	4.0
20233-1110	5830.4	3407.2	5832.1	66.3	2.41	3.7
20233-1120	5746.4	3357.2	5748.2	66.3	2.41	3.8
20233-1101	5637.3	3270.6	5640.5	66.3	2.38	4.8
20233-1125	6423.1	3732.6	6427.2	66.3	2.39	4.6
Average					2.39	4.3
CV (%)					1	15

Table G.10 Specific gravity and air voids of cores obtained from US-23 SB - section 1 test site2

Core Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
20233-1215	5563.9	3222.6	5568.0	66.4	2.37	5.0
20233-1227	5899.3	3438.4	5902.1	66.4	2.40	4.1
20233-1217	5137.4	2972.5	5140.7	66.4	2.37	5.1
20233-1210	6335.5	3655.4	6339.9	66.4	2.36	5.5
20233-1230	6413.8	3745.3	6416.3	66.4	2.40	3.9
20233-1206	5640.0	3262.0	5643.6	66.4	2.37	5.2
20233-1220	6001.3	3486.8	6003.8	66.4	2.39	4.5
Average					2.38	4.8
CV (%)					1	13

Table G.11 Specific gravity and air voids of cores obtained from US-27 SB - section 3 test site1

Core Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
20273-3101	6733.3	3982.0	6736.4	66.3	2.45	2.1
20273-3104	6637.2	3936.1	6641.1	66.3	2.46	1.8
20273-3107	6493.5	3819.8	6496.9	66.3	2.43	2.9
20273-3110	6503.1	3849.9	6505.7	66.3	2.45	2.0
20273-3115	7019.4	4152.3	7022.7	66.3	2.45	2.1
20273-3116	6989.7	4132.4	6992.8	66.3	2.45	2.2
20273-3117	6733.8	3970.7	6736.8	66.3	2.44	2.5
20273-3118	6656.5	3867.3	6674.3	66.3	2.37	5.0
20273-3123	7620.1	4520.1	7624.4	66.3	2.46	1.7
20273-3124	7466.1	4416.2	7469.5	66.3	2.45	2.1
20273-3125	6913.4	4096.0	6916.6	66.3	2.45	1.9
20273-3126	6965.9	4120.2	6968.9	66.3	2.45	2.1
Average					2.44	2.4
CV (%)					1	38

Table G.12 Specific gravity and air voids of cores obtained from US-27 SB - section 4 test site1

Core Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
20273-4101	6185.8	3644.3	6188.9	66.3	2.43	2.7
20273-4104	6190.0	3650.2	6192.5	66.3	2.44	2.5
20273-4107	6397.7	3754.9	6400.5	66.3	2.42	3.2
20273-4110	6240.6	3660.0	6243.9	66.3	2.42	3.3
20273-4115	6598.5	3921.2	6600.9	66.3	2.46	1.4
20273-4116	6415.8	3813.0	6418.1	66.3	2.47	1.4
20273-4117	6636.8	3932.1	6639.1	66.3	2.45	1.8
20273-4118	6725.6	3991.4	6727.7	66.3	2.46	1.6
20273-4123	6800.4	4046.4	6803.2	66.3	2.47	1.2
20273-4124	6651.2	3957.0	6653.8	66.3	2.47	1.2
20273-4125	6973.3	4158.0	6975.4	66.3	2.48	0.9
20273-4126	6813.1	4045.3	6815.2	66.3	2.46	1.5
Average					2.45	1.9
CV (%)					1	43

Table G.13 Specific gravity and air voids of cores obtained from US-31 NB – section 1 test site 1

Core Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
20311-1101	7249.5	4318.6	7251.8	68.4	2.47	1.1
20311-1104	7943.3	4729.4	7949.1	67.8	2.47	1.2
20311-1107	7269.8	4330.9	7272.0	68.0	2.47	1.0
20311-1110	6682.8	3974.0	6684.8	68.4	2.47	1.3
20311-1115	7812.0	4634.8	7817.9	68.0	2.46	1.7
20311-1116	8245.8	4886.5	8251.1	68.4	2.45	1.9
20311-1117	7960.6	4732.9	7963.2	68.4	2.47	1.3
20311-1118	6736.8	3994.6	6740.3	67.8	2.46	1.8
20311-1123	7854.1	4664.3	7856.4	67.8	2.46	1.5
20311-1124	8018.3	4764.5	8023.3	67.8	2.46	1.5
20311-1125	8062.5	4798.0	8065.6	68.4	2.47	1.2
20311-1126	7431.1	4430.4	7433.3	68.0	2.48	0.9
Average					2.47	1.4
CV (%)					0	22

Table G.14 Specific gravity and air voids of cores obtained from M-15 SB – section 1 test site1

Core Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
30153-1101	4789.2	2775.4	4791.6	66.7	2.38	4.8
30153-1104	5210.2	3034.0	5212.4	66.9	2.40	4.1
30153-1107	4625.5	2658.7	4628.3	66.9	2.35	5.8
30153-1110	4987.3	2882.2	4989.4	67.1	2.37	5.1
30153-1115	4667.4	2664.5	4670.9	66.8	2.33	6.7
30153-1116	5243.5	3010.5	5248.1	66.9	2.35	6.0
30153-1117	5094.4	2908.8	5100.7	66.9	2.33	6.8
30153-1118	5238.1	2984.3	5243.2	67.1	2.32	7.0
30153-1123	4750.2	2730.1	4754.1	67.1	2.35	5.9
30153-1124	5058.6	2913.9	5061.9	67.1	2.36	5.6
30153-1125	4978.6	2862.9	4981.6	67.0	2.36	5.8
30153-1126	4953.3	2841.7	4966.2	66.9	2.34	6.5
Average					2.35	5.8
CV (%)					1	15

Table G.15 Specific gravity and air voids of cores obtained from M-37 SB – section 5 test site1

Core Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
30373-5101	5992.9	3466.4	5999.4	65.4	2.37	5.3
30373-5104	6198.7	3587.5	6205.2	65.3	2.37	5.2
30373-5107	6232.5	3606.4	6239.8	65.4	2.37	5.2
30373-5110	5227.1	3017.6	5230.7	65.3	2.36	5.4
30373-5115	6723.9	3884.8	6740.6	65.4	2.36	5.7
30373-5116	6513.5	3754.4	6532.7	65.3	2.35	6.1
30373-5117	6176.3	3558.1	6188.9	65.2	2.35	6.0
30373-5118	6028.3	3463.6	6042.4	65.2	2.34	6.4
30373-5123	6704.0	3884.2	6709.5	65.4	2.38	5.0
30373-5124	6834.2	3958.6	6841.3	65.2	2.37	5.1
30373-5125	6259.3	3623.6	6263.7	65.4	2.37	5.1
30373-5126	5818.9	3357.6	5824.0	65.4	2.36	5.5
Average					2.36	5.5
CV (%)					0	8

Table G.16 Specific gravity and air voids of cores obtained from M-37 SB – section 5 test site2

Core Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
30373-5201	5899.7	3405.8	5904.4	65.5	2.36	5.5
30373-5202	6249.9	3610.5	6267.7	65.7	2.35	5.8
30373-5207	5537.2	3187.9	5544.7	65.5	2.35	5.9
30373-5210	5077.7	2921.6	5085.5	65.6	2.35	6.0
30373-5214	5857.6	3389.0	5860.6	65.5	2.37	5.1
30373-5215	5733.6	3294.8	5746.9	65.7	2.34	6.4
30373-5216	5863.1	3367.3	5875.2	65.6	2.34	6.4
30373-5217	5683.2	3270.7	5702.3	65.5	2.34	6.4
30373-5218	5509.5	3159.0	5525.0	65.5	2.33	6.8
30373-5223	6407.6	3713.4	6413.1	65.5	2.38	5.0
30373-5224	6412.0	3719.9	6419.0	65.6	2.38	4.9
30373-5226	5936.3	3424.5	5943.2	65.6	2.36	5.6
Average					2.35	5.8
CV (%)					1	11

Table G.17 Specific gravity and air voids of cores obtained from M-37 SB – section 6 test site1

Core Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
30373-6101	6271.8	3713.6	6274.3	61.0	2.45	1.9
30373-6104	5774.8	3417.9	5777.0	61.3	2.45	2.0
30373-6107	5337.4	3148.0	5339.6	61.0	2.44	2.5
30373-6108	5273.5	3114.3	5275.1	61.0	2.44	2.2
30373-6110	5471.4	3232.8	5473.4	61.4	2.45	2.2
30373-6113	5920.9	3507.5	5922.3	61.0	2.46	1.8
30373-6115	6142.3	3645.9	6145.1	61.8	2.46	1.6
30373-6116	5639.4	3337.4	5642.4	61.6	2.45	2.0
30373-6117	5440.9	3221.0	5443.4	61.6	2.45	1.9
30373-6118	5883.6	3476.0	5885.9	61.0	2.44	2.2
30373-6123	5939.4	3520.9	5943.4	61.0	2.46	1.8
30373-6124	5448.4	3223.4	5450.2	61.5	2.45	2.0
30373-6125	5468.4	3242.3	5470.0	61.4	2.46	1.7
30373-6126	5421.5	3206.1	5423.2	61.7	2.45	2.1
30373-6141	5048.2	2979.7	5050.5	61.5	2.44	2.4
30373-6142	5094.6	3008.4	5096.8	61.3	2.44	2.3
30373-6143	5365.1	3173.7	5367.5	61.8	2.45	2.0
30373-6144	5524.7	3265.1	5526.2	61.6	2.45	2.1
Average					2.45	2.0
CV (%)					0	12

Table G.18 Specific gravity and air voids of cores obtained from M-53 NB – section 1 test site1

Core Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
30531-1101	5591.6	3212.5	5668.1	69.0	2.28	8.8
30531-1104	5822.8	3347.3	5826.9	69.0	2.35	6.0
30531-1105	5151.8	2931.1	5167.9	69.0	2.30	7.8
30531-1108	5826.0	3347.1	5834.1	69.0	2.34	6.2
30531-1109	5656.1	3194.6	5600.7	69.0	2.35	5.9
30531-1111	5830.4	3361.0	5834.4	69.0	2.36	5.6
30531-1112	4968.3	2854.8	4972.9	69.0	2.35	6.1
30531-1113	3634.2	2085.3	3639.9	69.0	2.34	6.4
30531-1115	5343.7	3063.3	5347.7	69.0	2.34	6.4
30531-1116	4125.1	2357.6	4135.8	69.0	2.32	7.1
30531-1118	4873.6	2791.4	4879.0	69.0	2.34	6.5
30531-1119	3952.1	2262.7	3964.5	69.0	2.32	7.0
30531-1121	5219.4	2990.0	5223.6	69.0	2.34	6.5
Average					2.33	6.7
CV (%)					1	13

Table G.19 Specific gravity and air voids of specimens obtained from I-69 EB – section 1 test site 1

Specimen Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air void (%)
	Dry	Submerged	Saturated surface dry			
10692-1104-20	3955.6	2301.6	3958.0	73.2	2.39	4.4
10692-1104-43	3124.1	1775.3	3126.8	71.5	2.31	7.5
10692-1107-32	4579.4	2628.2	4582.0	71.5	2.35	6.2
10692-1107-43	3188.1	1813.4	3191.2	71.5	2.32	7.4
10692-1110-32	4988.0	2896.6	4991.8	73.0	2.38	4.7
10692-1110-43	3215.5	1836.4	3218.2	71.5	2.33	6.9
10692-1115-32	4621.4	2663.7	4624.5	73.1	2.36	5.7
10692-1115-43	3166.7	1769.2	3176.2	71.5	2.25	9.9
10692-1116-20	3113.8	1810.6	3115.7	71.6	2.39	4.5
10692-1116-30	2314.2	1296.7	2317.6	71.6	2.27	9.3
10692-1118-32	5298.3	3057.8	5305.1	73.2	2.36	5.7
10692-1118-43	3109.0	1750.1	3115.1	71.5	2.28	8.8
10692-1123-20	2972.2	1708.7	2974.7	71.6	2.35	6.0
10692-1123-30	2444.3	1372.8	2447.4	71.6	2.28	9.0
10692-1124-20	2433.6	1390.0	2436.1	71.6	2.33	6.9
10692-1124-30	2708.1	1524.2	2711.0	71.6	2.28	8.7
10692-1125-20	2793.7	1579.9	2797.4	71.8	2.30	8.2
10692-1125-30	2531.7	1431.8	2536.6	71.8	2.29	8.3
10692-1126-20	3036.1	1737.1	3038.4	71.8	2.33	6.6
10692-1126-30	2387.9	1337.8	2405.1	71.8	2.24	10.5
Average					2.32	7.3
CV (%)					2	25

Table G.20 Specific gravity and air voids of specimens obtained from I-69 EB – section 1 test site 2

Specimen Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
10692-1201-20	3226.8	1928.6	3228.9	68.9	2.48	0.7
10692-1201-30	2237.5	1277.7	2239.6	68.9	2.33	6.9
10692-1201-40	1588.9	893.0	1590.6	68.9	2.28	8.8
10692-1204-32	4358.9	2535.7	4362.4	69.1	2.39	4.5
10692-1204-43	3107.5	1765.7	3111.2	69.0	2.31	7.5
10692-1207-32	4573.8	2642.9	4577.4	69.1	2.37	5.4
10692-1207-43	3341.6	1902.5	3344.9	69.1	2.32	7.3
10692-1210-20	3104.7	1810.1	3107.1	69.0	2.40	4.2
10692-1210-30	2439.0	1387.6	2441.4	69.0	2.32	7.3
10692-1210-40	1626.8	926.5	1628.6	69.0	2.32	7.2
10692-1218-32	5119.8	2947.4	5123.9	69.0	2.35	5.8
10692-1218-43	3245.3	1825.3	3248.8	69.0	2.28	8.7
10692-1223-20	3333.3	1911.5	3336.7	69.0	2.34	6.4
10692-1223-30	2283.1	1292.5	2285.4	69.0	2.30	8.0
10692-1223-40	1576.1	883.2	1579.4	69.0	2.27	9.4
10692-1224-20	2942.5	1640.7	2949.1	68.9	2.25	10.0
10692-1224-30	2537.6	1438.9	2539.0	68.9	2.31	7.7
10692-1224-40	1594.8	902.3	1596.3	68.9	2.30	8.0
10692-1225-20	3389.6	1959.2	3392.1	69.0	2.37	5.3
10692-1225-30	2383.3	1354.8	2385.3	69.0	2.31	7.4
10692-1225-40	1726.1	978.1	1728.5	69.0	2.30	7.9
10692-1226-32	5155.4	2907.2	5162.8	69.0	2.29	8.5
10692-1226-43	3178.4	1794.0	3182.3	69.0	2.29	8.4
Average					2.32	7.0
CV (%)					2	29

Table G.21 Specific gravity and air voids of specimens obtained from I-75 SB – section 1 test site 1

Specimen Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
10753-1126-432	3000.9	1747.8	3002.3	71.6	2.39	4.3
10753-1126-20	749.4	431.8	750.6	71.6	2.35	5.9
10753-1110-432	2934.4	1717.7	2935.5	71.6	2.41	3.6
10753-1110-20	483.0	281.5	484.0	71.6	2.39	4.5
10753-1125-43	2927.5	1704.5	2928.7	71.6	2.39	4.3
10753-1125-20	991.1	572.7	992.1	71.6	2.36	5.4
10753-1101-43	2841.2	1660.3	2842.8	71.6	2.40	3.8
10753-1101-20	590.3	342.0	591.3	71.6	2.37	5.2
Average					2.38	4.6
CV (%)					1	18

Table G.22 Specific gravity and air voids of specimens obtained from I-75 SB – section 1 test site 2

Specimen Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
10753-1210-43	2898.6	1688.8	2900.2	73.6	2.39	4.3
10753-1210-20	304.1	175.5	305.1	73.6	2.35	6.1
10753-1226-43	2820.4	1656.0	2821.6	73.6	2.42	3.2
10753-1226-20	528.6	306.2	529.5	73.6	2.37	5.3
10753-1218-43	2990.0	1727.4	2992.9	73.6	2.36	5.5
10753-1218-20	921.4	518.2	929.8	73.6	2.24	10.4
10753-1224-43	2914.3	1700.4	2915.7	73.6	2.40	4.0
10753-1224-20	932.0	537.7	933.2	73.6	2.36	5.7
Average					2.36	5.6
CV (%)					2	40

Table G.23 Specific gravity and air voids of specimens obtained from I-194 NB – section 2 test site 1

Specimen Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
11941-2101-20	1204.5	713.3	1205.3	67.2	2.45	2.0
11941-2101-32	3131.0	1831.6	3133.9	67.2	2.41	3.7
11941-2101-54	3409.0	2015.6	3410.2	67.2	2.45	2.1
11941-2110-20	656.3	386.0	657.1	67.3	2.42	3.1
11941-2110-32	3189.1	1859.8	3210.0	67.3	2.36	5.4
11941-2110-54	3296.6	1947.8	3295.5	67.3	2.45	2.1
11941-2118-32	2626.8	1537.7	2644.4	67.2	2.38	5.0
11941-2118-43	3282.4	1924.0	3305.4	67.2	2.38	4.9
11941-2118-50	1555.5	902.8	1557.2	67.2	2.38	4.8
11941-2123-20	662.0	387.6	662.9	67.1	2.41	3.7
11941-2123-32	3306.2	1935.5	3313.5	67.1	2.40	3.9
11941-2123-54	3593.1	2116.3	3595.0	67.1	2.43	2.7
11941-2124-20	1377.5	802.4	1382.9	67.2	2.38	5.0
11941-2124-43	3169.4	1856.6	3177.7	67.2	2.40	3.9
11941-2124-54	2246.7	1317.4	2248.1	67.2	2.42	3.4
11941-2126-20	2059.9	1205.4	2060.9	67.0	2.41	3.6
11941-2126-43	3248.4	1908.8	3253.1	67.0	2.42	3.3
11941-2126-54	2245.7	1307.8	2249.5	67.0	2.39	4.5
Average					2.41	3.7
CV (%)					1	29

Table G.24 Specific gravity and air voids of specimens obtained from I-194 NB – section 2 test site 2

Specimen Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
11941-2201-21	1009.4	587.6	1011.6	67.4	2.38	4.7
11941-2201-32	3310.3	1937.0	3312.1	67.4	2.41	3.6
11941-2201-54	3237.6	1916.4	3238.3	67.5	2.45	1.9
11941-2204-21	2173.3	1260.8	2175.9	67.2	2.38	4.9
11941-2204-43	3350.7	1970.6	3352.5	67.2	2.43	2.9
11941-2204-51	1612.3	951.4	1613.1	67.2	2.44	2.4
11941-2207-21	2149.6	1255.2	2152.0	67.2	2.40	4.0
11941-2207-43	3620.8	2131.4	3625.6	67.2	2.43	3.0
11941-2207-51	1688.7	999.9	1689.6	67.2	2.45	2.0
11941-2210-21	1839.4	1079.8	1840.6	67.2	2.42	3.2
11941-2210-43	3377.8	1995.7	3379.2	67.2	2.44	2.2
11941-2210-51	1594.9	944.3	1595.4	67.2	2.45	1.9
11941-2215-21	1058.2	616.8	1060.0	67.3	2.39	4.4
11941-2215-32	3305.5	1930.3	3309.0	67.3	2.40	4.0
11941-2215-54	3210.0	1887.5	3212.3	67.4	2.43	3.0
11941-2224-21	715.4	417.2	718.0	67.3	2.38	4.8
11941-2224-32	3245.7	1882.4	3266.4	67.3	2.35	6.1
11941-2224-54	3126.3	1836.9	3128.8	67.4	2.42	3.1
Average					2.41	3.5
CV (%)					1	34

Table G.25 Specific gravity and air voids of specimens obtained from US-10 EB – section 1 test site 1

Specimen Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
20102-1125-20	2856.5	1665.7	2858.2	65.7	2.40	4.1
20102-1125-43	2920.4	1655.2	2921.6	65.7	2.31	7.7
20102-1101-32	3226.3	1842.8	3232.2	65.7	2.32	7.0
20102-1101-40	1339.0	759.3	1340.3	65.7	2.31	7.7
20102-1126-20	2677.1	1571.7	2679.0	65.7	2.42	3.2
20102-1126-43	2902.6	1639.9	2905.0	65.7	2.30	8.1
20102-1104-20	1048.4	600.8	1050.5	65.7	2.33	6.6
20102-1104-32	2606.9	1482.8	2610.7	65.7	2.31	7.5
20102-1117-20	2737.7	1566.4	2724.8	65.7	2.37	5.4
20102-1117-43	3003.9	1709.8	3004.9	65.7	2.32	7.1
20102-1107-20	1552.2	907.1	1553.6	65.7	2.40	3.9
20102-1107-32	2719.2	1551	2725.3	65.7	2.32	7.3
20102-1107-40	1292.9	731	1294.1	65.7	2.30	8.1
Average					2.34	6.4
CV (%)					2	27

Table G.26 Specific gravity and air voids of specimens obtained from US-10 EB – section 1 test site 2

Specimen Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
20102-1223-43	2876.5	1609.3	2879.9	65.8	2.27	9.4
20102-1225-32	3049.8	1759.8	3053.3	65.8	2.36	5.6
20102-1225-43	2759.7	1536.2	2766.8	65.8	2.24	10.2
20102-1204-32	3047.2	1756.7	3049.3	65.8	2.36	5.6
20102-1204-40	1453.5	824.5	1454.4	65.7	2.31	7.6
20102-1204-43	2507.4	1415.3	2509.0	65.8	2.29	8.2
20102-1226-20	2703.9	1579.9	2706.5	65.8	2.40	3.9
20102-1126-43	2483.5	1396.4	2486.3	65.8	2.28	8.8
Average					2.31	7.4
CV (%)					2	29

Table G.27 Specific gravity and air voids of specimens obtained from US-23 SB – section 1 test site 1

Specimen Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
20233-1106-40	1382.2	808.3	1384.0	65.9	2.40	3.9
20233-1106-30	2620.6	1525.6	2623.5	65.9	2.39	4.4
20233-1106-20	1665.7	979.4	1666.8	65.9	2.43	3.0
20233-1125-43	3047.5	1765.9	3050.8	65.9	2.37	5.0
20233-1125-20	3231.8	1884.1	3234.1	65.9	2.40	4.1
20233-1127-43	3074.6	1795.7	3076.5	65.9	2.40	3.9
20233-1127-32	3065.2	1796.1	3066.6	65.9	2.42	3.4
20233-1117-43	2855.8	1669.7	2857.5	65.9	2.41	3.7
20233-1117-32	2779.5	1617.4	2781.5	65.9	2.39	4.4
20233-1116-20	748.5	436.6	749.6	65.9	2.39	4.2
20233-1116-32	2931.3	1708.5	2933.9	65.9	2.39	4.2
20233-1116-40	1494.0	862.5	1496.3	65.9	2.36	5.6
20233-1110-20	877.8	518.1	878.7	65.9	2.44	2.5
20233-1110-32	3018.4	1761.5	3020.5	65.9	2.40	4.0
20233-1110-40	1654.9	967.1	1656.6	65.9	2.40	3.9
20233-1120-20	765.8	449.0	767.0	65.9	2.41	3.6
20233-1120-32	2974.1	1744.1	2976.0	65.9	2.42	3.3
20233-1120-40	1731.9	1007.3	1733.9	65.9	2.39	4.6
Average					2.40	4.0
CV (%)					1	18

Table G.28 Specific gravity and air voids of specimens obtained from US-23 SB – section 1 test site 2

Specimen Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
20233-1227-32	3088.4	1805.4	3090.1	66.0	2.41	3.7
20233-1227-43	2664.8	1548.0	2668.3	66.0	2.38	4.8
20233-1210-32	3182.1	1842.8	3184.8	66.0	2.37	5.1
20233-1210-43	3017.4	1738.6	3021.1	66.0	2.36	5.8
20233-1217-20	1529.4	896.7	1530.6	66.0	2.42	3.4
20233-1217-43	2393.4	1382.1	2397.5	66.0	2.36	5.6
20233-1217-30	938.7	543.1	941.4	66.0	2.36	5.6
20233-1220-32	2940.9	1715.3	2942.5	66.0	2.40	4.0
20233-1220-43	2918.2	1689.3	2920.7	66.0	2.37	5.1
20233-1230-30	1524.4	883.2	1526.2	66.0	2.37	5.1
20233-1230-43	2542.4	1482.3	2544.4	66.0	2.40	4.2
20233-1230-20	2059.9	1211.9	2061.9	66.0	2.43	3.0
Average					2.38	4.6
CV (%)					1	20

Table G.29 Specific gravity and air voids of specimens obtained from US-27 SB – section 2 test site 1

Specimen Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
20273-2115-43	2499.7	1480.3	2500.3	67.1	2.45	1.9
20273-2116-43	2376.5	1408.2	2377.5	67.0	2.45	1.8
20273-2123-43	2614.7	1538.9	2615.7	67.0	2.43	2.8
20273-2125-43	2520.6	1493.7	2521.3	67.0	2.46	1.8
Average					2.45	2.1
CV (%)					0	23

Table G.30 Specific gravity and air voids of specimens obtained from US-27 SB – section 3 test site 1

Specimen Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
20273-3104-40	1842.9	1080.0	1844.3	68.3	2.41	3.5
20273-3116-40	1974.5	1147.2	1976.2	68.4	2.38	4.6
20273-3124-40	1909.2	1112.2	1910.5	68.2	2.39	4.3
20273-3101-34	3021.5	1771.5	3022.9	66.7	2.42	3.3
20273-3104-30	2713.3	1612.3	2714.7	68.3	2.46	1.5
20273-3107-34	3370.6	1961.2	3372.4	66.6	2.39	4.4
20273-3110-34	3464.7	2031.8	3466.2	66.6	2.42	3.3
20273-3110-34	3371.3	1963.0	3373.6	68.4	2.39	4.3
20273-3117-34	2984.4	1736.3	2986.3	68.2	2.39	4.4
20273-3118-34	3366.9	1973.4	3368.6	66.6	2.42	3.4
20273-3126-34	2993.0	1745.8	2994.6	66.6	2.40	4.0
20273-3116-30	2738.0	1626.1	2739.3	68.4	2.46	1.5
20273-3124-30	2905.2	1729.1	2906.5	68.3	2.47	1.2
20273-3101-23	3566.3	2127.7	3567.7	68.5	2.48	0.9
20273-3107-32	2978.0	1772.8	2979.3	66.6	2.47	1.2
20273-3110-32	2894.1	1733.7	2895.3	66.6	2.49	0.2
20273-3117-32	3606.4	2152.7	3607.9	68.2	2.48	0.8
20273-3118-23	3520.7	2014.4	3536.8	66.6	2.31	7.4
20273-3126-23	3452.4	2058.9	3453.4	66.6	2.48	0.9
20273-3104-20	1798.3	1081.6	1799.3	68.3	2.51	Negative
20273-3116-20	1995.9	1194.7	1997.0	68.3	2.49	0.4
20273-3118-20	2988.1	1790.0	2989.1	68.5	2.49	0.2
20273-3124-20	2375.4	1417.1	2376.7	68.2	2.48	0.9
Average					2.44	2.5
CV (%)					2	81

Negative = negative percent air voids because the specific gravity of the specimen is higher than the assumed maximum theoretical specific gravity of 2.50

Table G.31 Specific gravity and air voids of specimens obtained from US-27 SB–section 4 test site 1

Specimen Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
20273-4116-20	2488.8	1494.6	2489.9	67.4	2.50	Negative
20273-4116-34	3786.9	2236.8	3788.5	67.4	2.44	2.3
20273-4117-30	3534.6	2101.9	3535.7	67.5	2.47	1.3
20273-4126-30	3331.9	1991.2	3333.1	67.5	2.49	0.6
20273-4126-40	1652.5	989.6	1653.6	67.6	2.49	0.4
20273-4124-30	3446.4	2063.4	3447.6	67.6	2.49	0.3
20273-4115-30	3432.2	2053.7	3433.3	67.6	2.49	0.4
20273-4115-40	1150.9	689.6	1151.6	67.6	2.49	0.3
20273-4124-40	1406.1	847.1	1407.2	67.6	2.51	Negative
20273-4125-20	3377.9	2028.9	3378.9	67.7	2.50	Negative
20273-4107-20	2457.1	1464.7	2458.0	67.7	2.48	1.0
20273-4107-30	3145.0	1834.5	3146.2	67.7	2.40	4.0
20273-4123-20	2823.1	1698.8	2824.1	67.8	2.51	Negative
20273-4123-34	3450.6	2034.0	3451.7	67.8	2.44	2.6
20273-4118-34	3149.9	1858.9	3150.9	67.8	2.44	2.4
20273-4110-40	1214.0	728.3	1214.9	67.8	2.50	0.1
20273-4117-40	1383.0	829.2	1383.8	67.9	2.50	0.2
20273-4125-34	3301.7	1950.6	3302.9	67.9	2.44	2.3
20273-4110-30	3234.6	1900.2	3236.4	67.9	2.42	3.1
Average					2.47	1.0
CV (%)					1	127

Negative = negative percent air voids because the specific gravity of the specimen is higher than the assumed maximum theoretical specific gravity of 2.50

Table G.32 Specific gravity and air voids of specimens obtained from US-31 NB–section 1 test site 1

Specimen Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
20311-1101-20	2344.2	1399.4	2345.7	67.2	2.48	0.8
20311-1101-32	3316.0	1976.7	3316.5	67.0	2.48	0.9
20311-1101-40	1288.0	766.6	1288.4	67.2	2.47	1.2
20311-1104-20	3387.3	2014.9	3388.9	65.6	2.47	1.3
20311-1104-43	3101.3	1841.8	3102.4	65.6	2.46	1.5
20311-1107-20	3809.3	2274.0	3811.0	65.6	2.48	0.8
20311-1107-43	3306.9	1967.1	3307.7	65.6	2.47	1.2
20311-1115-20	3269.4	1931.3	3272.7	67.0	2.44	2.4
20311-1115-32	2982.4	1783.7	2983.5	67.1	2.49	0.5
20311-1115-40	1259.1	745.7	1259.5	67.1	2.45	1.9
20311-1116-20	3147.8	1856.4	3151.4	67.1	2.43	2.7
20311-1116-32	3428.0	2045.8	3429.3	67.0	2.48	0.8
20311-1116-40	1358.7	804.8	1359.5	67.2	2.45	1.9
20311-1118-20	2036.7	1214.1	2037.9	67.2	2.47	1.0
20311-1118-32	3061.0	1816.5	3062.3	67.1	2.46	1.6
20311-1118-40	1338.0	792.6	1338.7	67.2	2.45	1.9
20311-1123-20	3255.0	1934.9	3256.4	65.7	2.47	1.4
20311-1123-32	2748.4	1635.6	2749.4	65.7	2.47	1.2
20311-1123-40	1550.8	918.7	1551.3	65.7	2.45	1.8
20311-1124-20	3162.6	1873.5	3164.8	65.5	2.45	1.9
20311-1124-43	3278.1	1943.7	3279.4	65.5	2.46	1.7
20311-1125-20	3039.2	1807.0	3040.9	65.5	2.47	1.4
20311-1125-43	3586.7	2132.1	3588.2	65.5	2.47	1.4
20311-1126-20	3197.9	1914.1	3199.3	65.5	2.49	0.4
20311-1126-43	3329.3	1972.9	3330.4	65.5	2.46	1.8
Average					2.46	1.4
CV (%)					1	40

Table G.33 Specific gravity and air voids of specimens obtained from M-15 SB–section 1 test site 1

Specimen Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
30153-1124-43	2772.9	1602.6	2775.4	67.0	2.37	5.3
30153-1117-43	3406.9	1946.0	3411.0	67.2	2.33	6.9
30153-1104-43	3462.8	2019.2	3464.8	67.3	2.40	4.1
30153-1125-43	2898.4	1672.3	2900.8	67.3	2.36	5.5
30153-1101-32	2992.1	1734.8	2994.6	67.4	2.38	4.9
30153-1123-32	3047.5	1750.1	3050.2	67.4	2.35	6.2
30153-1110-43	3056.4	1776.2	3058.2	67.5	2.39	4.6
30153-1126-43	3008.3	1728.4	3012.3	67.6	2.35	6.2
30153-1107-32	2998.2	1724.9	3001.2	67.6	2.35	6.0
30153-1116-32	2938.7	1683.8	2941.7	67.6	2.34	6.5
30153-1115-32	2945.7	1682.0	2949.0	67.6	2.33	6.9
30153-1118-32	2943.8	1676.2	2947.8	67.6	2.32	7.3
Average					2.35	5.9
CV (%)					1	17

Table G.34 Specific gravity and air voids of specimens obtained from M-37 SB–section 5 test site 1

Specimen Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
30373-5123-20	3302.8	1916.9	3304.4	66.1	2.38	4.7
30373-5123-43	3266.6	1894.5	3269.0	66.1	2.38	4.8
30373-5117-20	1521.3	878.9	1523.0	66.1	2.36	5.4
30373-5117-32	2755.6	1588.2	2761.5	66.1	2.35	6.0
30373-5117-40	1627.7	936.6	1630.2	66.1	2.35	6.0
30373-5124-20	3253.2	1885.0	3255.3	66.1	2.38	4.9
30373-5124-43	3445.5	2001.8	3448.5	66.1	2.38	4.6
30373-5104-20	1422.2	823.3	1423.8	66.1	2.37	5.2
30373-5104-32	2879.7	1666.8	2883.1	66.1	2.37	5.2
30373-5104-40	1620.9	940.9	1622.4	66.1	2.38	4.8
30373-5125-20	2972.6	1721.9	2974.6	66.1	2.38	5.0
30373-5125-43	2755.5	1597.1	2758.5	66.1	2.37	5.0
Average					2.37	5.1
CV (%)					0	9

Table G.35 Specific gravity and air voids of specimens obtained from M-37 SB–section 5 test site 2

Specimen Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
30373-5201.20	1598.9	927.7	1599.9	65.8	2.38	4.8
30373-5201.32	2545.6	1468.7	2548.4	65.8	2.36	5.6
30373-5201.40	1476.3	856.2	1477.8	65.8	2.38	4.9
30373-5223-32	3183.7	1847.2	3185.6	65.8	2.38	4.8
30373-5223-43	3088.7	1792.2	3090.8	65.8	2.38	4.8
30373-5207-20	1009.6	582.8	1010.9	65.8	2.36	5.6
30373-5207-32	2702.0	1555.9	2708.2	65.8	2.35	6.1
30373-5207-40	1549.9	898.7	1550.9	65.8	2.38	4.8
30373-5225-32	3049.6	1758.9	3053.2	65.8	2.36	5.7
30373-5225-43	3072.2	1777.7	3075.9	65.8	2.37	5.2
30373-5215-20	1379.4	792.9	1380.9	65.8	2.35	6.1
30373-5215-32	2709.6	1558.0	2716.6	65.8	2.34	6.4
30373-5215-40	1381.7	797.2	1382.9	65.8	2.36	5.5
Average					2.37	5.4
CV (%)					1	10

Table G.36 Specific gravity and air voids of specimens obtained from M-37 SB–section 6 test site 1

Specimen Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
30373-6107-32	3165.5	1873.2	3167.1	66.9	2.45	2.0
30373-6107-43	2025.9	1192.6	2026.9	66.9	2.43	2.8
30373-6110-32	2107.5	1245.9	2108.3	67.0	2.45	2.2
30373-6110-43	3215.1	1898.9	3216.3	66.7	2.44	2.3
30373-6117-32	2091.3	1247.3	2092.5	67.0	2.48	0.9
30373-6117-43	3203.2	1889.4	3205.4	66.9	2.44	2.5
30373-6118-32	2759.1	1644.7	2760.7	66.8	2.47	1.0
30373-6118-43	2978.2	1754.7	2979.7	66.8	2.43	2.7
30373-6123-32	3112.0	1855.0	3115.1	67.0	2.47	1.1
30373-6123-43	2680.5	1581.9	2682.1	66.9	2.44	2.5
30373-6124-32	2163.6	1287.7	2164.8	67.0	2.47	1.2
30373-6124-43	3140.7	1852.6	3142.2	67.0	2.44	2.5
30373-6125-32	3194.0	1904.1	3195.4	66.7	2.48	1.0
30373-6125-43	2127.4	1253.5	2128.5	67.0	2.43	2.7
30373-6144-32	2375.5	1394.0	2376.5	67.0	2.42	3.2
30373-6144-32	3001.7	1785.8	3003.6	67.0	2.47	1.3
Average					2.45	2.0
CV (%)					1	38

Table G.37 Specific gravity and air voids of specimens obtained from M-53 NB–section 1 test site 1

Specimen Designation	Weight (g)			Water temperature (°F)	Bulk specific gravity	Air voids (%)
	Dry	Submerged	Saturated surface dry			
30531-1101-20	994.8	565.4	996.1	64.6	2.31	7.5
30531-1101-23	2927.1	1654.0	2931.2	64.6	2.29	8.2
30531-1101-40	1393.9	812.1	1394.8	64.7	2.39	4.2
30531-1102-20	758.7	430.6	760.3	64.9	2.30	7.9
30531-1102-32	2963.7	1664.1	2971.0	64.9	2.27	9.2
30531-1102-40	1392.7	801.7	1394.4	64.8	2.35	5.9
30531-1104-32	2671.1	1522.5	2674.2	64.9	2.32	7.1
30531-1107-20	2036.1	1174.3	2037.8	64.6	2.36	5.6
30531-1107-43	2443.2	1413.7	2444.6	64.6	2.37	5.1
30531-1108-20	2661.2	1532.8	2665.3	64.6	2.35	5.9
30531-1108-43	3030.1	1738.1	3032.8	64.6	2.34	6.3
30531-1109-20	2729.8	1551.8	2733.6	64.6	2.31	7.5
30531-1109-43	2793.0	1576.5	2795.7	64.6	2.29	8.3
30531-1109-43	2791.8	1576.5	2793.9	64.4	2.30	8.2
30531-1111-20	2573.6	1484.0	2575.5	64.6	2.36	5.6
30531-1111-43	3121.6	1798.7	3124.9	64.7	2.36	5.7
30531-1112-32	2991.7	1701.6	2994.1	64.7	2.32	7.3
30531-1112-40	1351.8	793.8	1352.6	64.7	2.42	3.1
30531-1113-43	3125.2	1797.5	3127.9	64.9	2.35	5.9
30531-1115-20	859.0	490.3	860.6	64.8	2.32	7.1
30531-1115-32	2976.2	1692.7	2978.5	64.8	2.32	7.3
30531-1115-40	1231.3	718.2	1232.1	64.8	2.40	4.1
30531-1116-32	1003.4	559.8	1006.4	64.8	2.25	10.0
30531-1116-43	2992.6	1721.9	2996.2	64.8	2.35	6.0
30531-1118-32	1689.4	949.6	1694.2	64.9	2.27	9.1
30531-1118-43	3050.5	1767.1	3052.7	64.8	2.38	5.0
30531-1119-20	901.8	502.9	904.3	64.8	2.25	10.0
30531-1119-43	2917.3	1676.9	2920.5	64.8	2.35	6.1
30531-1121-20	632.5	361.6	633.7	64.8	2.33	6.9
30531-1121-32	2945.1	1674.6	2947.3	64.8	2.32	7.3
30531-1121-40	1370.9	796.5	1372.0	64.8	2.38	4.6
Average					2.33	6.7
CV (%)					2	25

APPENDIX H

INDIRECT TENSILE CYCLIC LOAD TEST RESULTS

APPENDIX H
INDIRECT TENSILE CYCLIC LOAD TEST RESULTS

This appendix presents the results of the indirect tensile cyclic load tests carried out on the specimens from various rubblized pavement projects. A project may be divided into one or more test sections and each section may be divided into one or more test sites.

Table H.1 ITCLT parameters of specimens of I-69 EB – section 1 test site 1

Specimen designation	Specimen thickness (in)	Peak cyclic load (lb)	Average deformation from 3 consecutive cycles (in)			Modulus (ksi)	
			Vertical	Horizontal	Longitudinal	Vertical	3-D
10692-1107-43	3.2	211	0.00181	0.00017	0.00023	149	144
10692-1110-43	3.1	210	0.00367	0.00020	0.00016	101	97
10692-1115-43	3.2	205	0.00173	0.00019	0.00019	151	145
10692-1116-20	2.9	212	0.00167	0.00018	0.00017	178	171
10692-1116-30	2.3	206	0.00159	0.00019	0.00015	227	218
10692-1118-43	3.1	205	0.00195	0.00019	0.00019	138	133
10692-1123-20	2.9	214	0.00180	0.00016	0.00018	167	161
10692-1123-30	2.4	209	0.00175	0.00017	0.00021	202	195
10692-1124-20	2.4	209	0.00167	0.00017	0.00016	214	206
10692-1124-30	2.6	211	0.00162	0.00018	0.00020	202	195
10692-1125-20	2.8	209	0.00168	0.00018	0.00024	184	177
10692-1125-30	2.5	209	0.00181	0.00018	0.00021	190	184
10692-1126-20	3.0	209	0.00151	0.00015	0.00018	192	185
10692-1126-30	2.5	207	0.00183	0.00018	0.00019	189	182
Average	2.8	209				177	171
CV (%)	12	1				19	19

Table H.2 ITCLT parameters of specimens of I-69 EB – section 1 test site 2

Specimen designation	Specimen thickness (in)	Peak cyclic load (lb)	Average deformation from 3 consecutive cycles (in)			Modulus (ksi)	
			Vertical	Horizontal	Longitudinal	Vertical	3-D
10692-1207-43	3.3	208	0.00175	0.00014	0.00025	147	142
10692-1225-20	3.2	209	0.00175	0.00016	0.00025	150	145
10692-1218-43	3.2	216	0.00180	0.00017	0.00015	152	147
10692-1223-20	3.2	210	0.00163	0.00014	0.00018	163	157
10692-1210-20	2.9	209	0.00173	0.00016	0.00015	165	160
10692-1226-43	3.1	209	0.00164	0.00016	0.00014	166	160
10692-1204-43	3.0	214	0.00165	0.00019	0.00014	173	167
10692-1224-20	2.9	206	0.00167	0.00015	0.00015	173	167
10692-1201-20	3.0	212	0.00148	0.00015	0.00021	192	186
10692-1224-30	2.5	210	0.00168	0.00016	0.00018	202	195
10692-1210-30	2.4	209	0.00170	0.00018	0.00018	211	204
10692-1223-30	2.3	210	0.00175	0.00019	0.00018	216	209
10692-1225-30	2.4	203	0.00158	0.00015	0.00017	221	214
Average	2.9	209				179	173
CV (%)	13	2				15	15

Table H.3 ITCLT parameters of specimens of I-75 SB – section 1 test site 1

Specimen designation	Specimen thickness (in)	Peak cyclic load (lb)	Average deformation from 3 consecutive cycles (in)			Modulus (ksi)	
			Vertical	Horizontal	Longitudinal	Vertical	3-D
10753-1110-432	3.0	211	0.00137	0.00008	0.00012	209	202
10753-1125-43	3.0	210	0.00146	0.00010	0.00015	195	189
10753-1126-432	2.9	211	0.00134	0.00008	0.00015	222	215
Average	3.0	210				209	202
CV (%)	2	0				6	6

Table H.4 ITCLT parameters of specimens of I-75 SB – section 1 test site 2

Specimen designation	Specimen thickness (in)	Peak cyclic load (lb)	Average deformation from 3 consecutive cycles (in)			Modulus (ksi)	
			Vertical	Horizontal	Longitudinal	Vertical	3-D
10753-1210-43	2.9	211	0.00154	0.00010	0.00010	193	187
10753-1218-43	2.9	210	0.00156	0.00010	0.00014	190	183
10753-1224-43	2.9	211	0.00149	0.00011	0.00018	199	192
10753-1226-43	2.8	206	0.00148	0.00010	0.00012	203	196
Average	2.9	209				196	189
CV (%)	2	1				3	3

Table H.5 ITCLT parameters of specimens of I-194 NB – section 2 test site 1

Specimen designation	Specimen thickness (in)	Peak cyclic load (lb)	Average deformation from 3 consecutive cycles (in)			Modulus (ksi)	
			Vertical	Horizontal	Longitudinal	Vertical	3-D
11941-2101-32	2.9	211	0.00130	0.00014	0.00013	229	221
11941-2101-54	3.1	207	0.00145	0.00011	0.00016	189	183
11941-2110-32	3.0	216	0.00145	0.00013	0.00015	203	196
11941-2110-54	3.0	215	0.00140	0.00013	0.00016	208	201
11941-2118-43	3.1	211	0.00142	0.00014	0.00011	197	190
11941-2123-32	3.1	210	0.00138	0.00011	0.00017	200	193
11941-2123-54	3.3	211	0.00139	0.00012	0.00014	190	183
11941-2124-43	3.0	211	0.00147	0.00013	0.00012	195	188
11941-2126-43	3.0	218	0.00137	0.00012	0.00015	216	208
Average	3.1	212				203	196
CV (%)	4	2				6	6

Table H.6 ITCLT parameters of specimens of I-194 NB – section 2 test site 2

Specimen designation	Specimen thickness (in)	Peak cyclic load (lb)	Average deformation from 3 consecutive cycles (in)			Modulus (ksi)	
			Vertical	Horizontal	Longitudinal	Vertical	3-D
11941-2201-32	3.1	212	0.00132	0.00010	0.00014	212	205
11941-2201-54	3.0	213	0.00132	0.00012	0.00013	221	214
11941-2204-43	3.1	215	0.00137	0.00014	0.00011	208	200
11941-2207-43	3.3	216	0.00118	0.00012	0.00015	227	219
11941-2210-43	3.1	213	0.00145	0.00013	0.00014	194	188
11941-2215-32	3.1	209	0.00143	0.00014	0.00014	193	186
11941-2215-54	3.0	208	0.00129	0.00013	0.00013	219	211
11941-2224-32	3.1	212	0.00116	0.00012	0.00014	241	232
Average	3.1	212				214	207
CV (%)	3	1				8	7

Table H.7 ITCLT parameters of specimens of US-10 EB – section 1 test site 1

Specimen designation	Specimen thickness (in)	Peak cyclic load (lb)	Average deformation from 3 consecutive cycles (in)			Modulus (ksi)	
			Vertical	Horizontal	Longitudinal	Vertical	3-D
20102-1101-32	3.2	199	0.00173	0.00015	0.00017	146	141
20102-1107-32	2.8	208	0.00153	0.00023	0.00014	197	190
20102-1117-20	2.8	212	0.00190	0.00018	0.00016	169	163
20102-1117-43	3.0	215	0.00143	0.00019	0.00015	197	190
20102-1125-20	2.8	210	0.00176	0.00018	0.00016	180	174
20102-1126-20	2.5	211	0.00143	0.00014	0.00028	230	222
20102-1126-43	2.9	213	0.00166	0.00016	0.00019	197	190
Average	2.9	209				188	181
CV (%)	8	3				14	14

Table H.8 ITCLT parameters of specimens of US-10 EB – section 1 test site 2

Specimen designation	Specimen thickness (in)	Peak cyclic load (lb)	Average deformation from 3 consecutive cycles (in)			Modulus (ksi)	
			Vertical	Horizontal	Longitudinal	Vertical	3-D
20102-1204-32	3.0	208	0.00146	0.00020	0.00017	196	189
20102-1223-20	2.5	204	0.00129	0.00017	0.00019	245	236
20102-1223-43	3.0	206	0.00133	0.00019	0.00017	203	195
20102-1225-32	3.0	210	0.00153	0.00016	0.00016	176	170
20102-1225-43	2.8	207	0.00163	0.00020	0.00022	185	178
20102-1226-20	2.6	215	0.00160	0.00019	0.00016	209	201
20102-1226-43	2.4	212	0.00160	0.00013	0.00014	238	230
Average	2.8	208				207	200
CV (%)	9	2				12	12

Table H.9 ITCLT parameters of specimens of US-23 SB – section 1 test site 1

Specimen designation	Specimen thickness (in)	Peak cyclic load (lb)	Average deformation from 3 consecutive cycles (in)			Modulus (ksi)	
			Vertical	Horizontal	Longitudinal	Vertical	3-D
20233-1106-30	2.5	207	0.00146	0.00025	0.00015	238	229
20233-1110-32	2.9	214	0.00153	0.00019	0.00018	202	195
20233-1116-32	2.8	199	0.00139	0.00015	0.00014	212	205
20233-1117-43	2.7	210	0.00163	0.00022	0.00016	196	189
20233-1120-32	2.8	212	0.00173	0.00021	0.00015	191	185
20233-1125-20	3.0	216	0.00146	0.00023	0.00016	199	192
20233-1125-43	2.9	209	0.00159	0.00017	0.00010	183	176
20233-1127-32	2.9	208	0.00146	0.00022	0.00014	206	199
20233-1127-43	2.9	218	0.00163	0.00020	0.00020	189	182
Average	2.8	210				201	194
CV (%)	5	3				8	8

Table H.10 ITCLT parameters of specimens of US-23 SB – section 1 test site 2

Specimen designation	Specimen thickness (in)	Peak cyclic load (lb)	Average deformation from 3 consecutive cycles (in)			Modulus (ksi)	
			Vertical	Horizontal	Longitudinal	Vertical	3-D
20233-1210-32	3.0	205	0.00139	0.00020	0.00021	192	185
20233-1210-43	2.9	206	0.00149	0.00020	0.00015	204	196
20233-1217-30	2.3	210	0.00163	0.00022	0.00016	239	230
20233-1220-32	2.8	213	0.00166	0.00019	0.00028	210	202
20233-1220-43	2.8	216	0.00153	0.00029	0.00019	200	193
20233-1227-32	2.9	210	0.00149	0.00016	0.00015	194	187
20233-1227-43	2.5	214	0.00163	0.00023	0.00016	214	207
20233-1230-30	2.4	214	0.00133	0.00019	0.00017	247	238
Average	2.7	210				213	205
CV (%)	10	2				10	10

Table H.11 ITCLT parameters of specimens of US-27 SB – section 2 test site 1

Specimen designation	Specimen thickness (in)	Peak cyclic load (lb)	Average deformation from 3 consecutive cycles (in)			Modulus (ksi)	
			Vertical	Horizontal	Longitudinal	Vertical	3-D
20273-2115-43	2.2	212	0.00138	0.00017	0.00012	285	275
20273-2123-43	2.5	215	0.00130	0.00015	0.00011	309	298
20273-2125-43	2.3	210	0.00139	0.00015	0.00012	279	269
Average	2.3	212				291	281
CV (%)	7	1				5	5

Table H.12 ITCLT parameters of specimens of US-27 SB – section 3 test site 1

Specimen designation	Specimen thickness (in)	Peak cyclic load (lb)	Average deformation from 3 consecutive cycles (in)			Modulus (ksi)	
			Vertical	Horizontal	Longitudinal	Vertical	3-D
20273-3101-32	3.2	208	0.00126	0.00015	0.00016	203	196
20273-3104-30	2.4	208	0.00129	0.00019	0.00015	270	260
20273-3107-43	3.2	209	0.00145	0.00019	0.00017	187	180
20273-3110-43	3.2	210	0.00128	0.00017	0.00017	209	202
20273-3116-30	2.5	211	0.00135	0.00018	0.00019	257	248
20273-3117-43	2.8	205	0.00153	0.00020	0.00017	193	186
20273-3124-30	2.6	208	0.00152	0.00014	0.00015	210	203
20273-3126-32	3.1	210	0.00135	0.00017	0.00018	204	197
Average	2.9	209				217	209
CV (%)	12	1				14	14

Table H.13 ITCLT parameters of specimens of US-27 SB – section 4 test site 1

Specimen designation	Specimen thickness (in)	Peak cyclic load (lb)	Average deformation from 3 consecutive cycles (in)			Modulus (ksi)	
			Vertical	Horizontal	Longitudinal	Vertical	3-D
20273-4107-43	3.0	210	0.00112	0.00018	0.00011	254	245
20273-4110-32	3.0	211	0.00135	0.00008	0.00008	213	206
20273-4115-32	3.1	214	0.00111	0.00007	0.00011	254	245
20273-4117-32	3.2	214	0.00106	0.00009	0.00009	259	250
20273-4118-20	2.7	213	0.00108	0.00009	0.00009	298	288
20273-4118-43	2.9	208	0.00117	0.00010	0.00009	250	241
20273-4123-20	2.5	211	0.00111	0.00009	0.00009	310	299
20273-4123-43	3.2	208	0.00107	0.00011	0.00008	249	241
20273-4124-32	3.1	210	0.00120	0.00009	0.00009	230	222
20273-4125-20	3.0	213	0.00115	0.00009	0.00010	252	244
20273-4126-32	3.0	212	0.00110	0.00013	0.00009	265	256
Average	3.0	211				258	249
CV (%)	7	1				11	11

Table H.14 ITCLT parameters of specimens of US-31 NB – section 1 test site 1

Specimen designation	Specimen thickness (in)	Peak cyclic load (lb)	Average deformation from 3 consecutive cycles (in)			Modulus (ksi)	
			Vertical	Horizontal	Longitudinal	Vertical	3-D
20311-1101-32	3.0	212	0.00109	0.00016	0.00014	206	198
20311-1104-20	3.1	210	0.00129	0.00020	0.00014	206	198
20311-1107-43	3.0	209	0.00126	0.00016	0.00013	224	216
20311-1116-32	3.1	210	0.00112	0.00018	0.00014	264	254
20311-1118-32	2.8	218	0.00123	0.00013	0.00012	251	242
20311-1104-43	2.7	207	0.00136	0.00013	0.00010	227	219
20311-1123-32	2.5	210	0.00119	0.00018	0.00013	275	266
20311-1124-20	2.9	209	0.00142	0.00015	0.00013	208	200
20311-1124-43	3.0	213	0.00127	0.00018	0.00016	230	222
20311-1125-20	2.8	213	0.00118	0.00016	0.00011	265	255
20311-1125-43	3.3	209	0.00116	0.00015	0.00012	224	216
20311-1126-20	2.9	214	0.00132	0.00015	0.00015	226	218
Average	2.9	211				234	226
CV (%)	7	1				10	10

Table H.15 ITCLT parameters of specimens of US-15 SB – section 1 test site 1

Specimen designation	Specimen thickness (in)	Peak cyclic load (lb)	Average deformation from 3 consecutive cycles (in)			Modulus (ksi)	
			Vertical	Horizontal	Longitudinal	Vertical	3-D
30153-1101-32	2.9	212	0.00142	0.00014	0.00015	209	202
30153-1107-32	2.9	216	0.00149	0.00012	0.00017	201	194
30153-1110-43	2.9	210	0.00137	0.00014	0.00015	215	207
30153-1115-32	2.9	210	0.00138	0.00011	0.00017	213	205
30153-1116-32	2.9	214	0.00132	0.00015	0.00014	230	222
30153-1117-43	2.6	213	0.00134	0.00012	0.00015	250	241
30153-1118-32	2.9	208	0.00137	0.00012	0.00018	213	206
30153-1123-32	2.9	213	0.00137	0.00012	0.00013	213	205
30153-1124-43	2.7	213	0.00137	0.00014	0.00014	234	226
30153-1125-43	2.8	214	0.00140	0.00013	0.00013	220	213
30153-1126-43	2.9	211	0.00130	0.00012	0.00014	222	215
Average	2.9	212				220	212
CV (%)	4	1				6	6

Table H.16 ITCLT parameters of specimens of M-37 SB – section 5 test site 1

Specimen designation	Specimen thickness (in)	Peak cyclic load (lb)	Average deformation from 3 consecutive cycles (in)			Modulus (ksi)	
			Vertical	Horizontal	Longitudinal	Vertical	3-D
30373-5104-32	2.8	207	0.00156	0.00017	0.00014	199	192
30373-5117-32	2.6	212	0.00170	0.00017	0.00014	207	200
30373-5123-20	3.2	207	0.00176	0.00018	0.00014	154	148
30373-5123-43	3.1	200	0.00153	0.00012	0.00015	175	169
30373-5124-20	3.1	205	0.00143	0.00016	0.00013	185	179
30373-5124-43	3.3	218	0.00170	0.00017	0.00017	162	156
30373-5125-20	2.8	210	0.00156	0.00017	0.00015	200	193
30373-5125-43	2.6	208	0.00170	0.00010	0.00020	202	195
Average	2.9	208				186	179
CV (%)	9	3				11	11

Table H.17 ITCLT parameters of specimens of M-37 SB – section 5 test site 2

Specimen designation	Specimen thickness (in)	Peak cyclic load (lb)	Average deformation from 3 consecutive cycles (in)			Modulus (ksi)	
			Vertical	Horizontal	Longitudinal	Vertical	3-D
30373-5201-32	2.4	204	0.00166	0.00017	0.00022	198	191
30373-5207-32	2.6	205	0.00153	0.00017	0.00018	209	201
30373-5215-32	2.6	214	0.00156	0.00015	0.00016	214	206
30373-5223-20	3.1	206	0.00143	0.00014	0.00013	189	182
30373-5223-43	2.9	215	0.00180	0.00018	0.00016	176	170
30373-5225-20	2.9	206	0.00153	0.00017	0.00013	197	190
30373-5225-43	3.0	199	0.00129	0.00016	0.00013	189	182
Average	2.8	206				196	189
CV (%)	9	3				7	7

Table H.18 ITCLT parameters of specimens of M-37 SB – section 6 test site 1

Specimen designation	Specimen thickness (in)	Peak cyclic load (lb)	Average deformation from 3 consecutive cycles (in)			Modulus (ksi)	
			Vertical	Horizontal	Longitudinal	Vertical	3-D
30373-6107-32	2.3	214	0.00116	0.00015	0.00012	328	316
30373-6110-43	3.0	213	0.00120	0.00020	0.00012	242	233
30373-6117-43	3.0	209	0.00116	0.00015	0.00012	250	241
30373-6118-43	2.8	209	0.00117	0.00018	0.00012	261	251
30373-6123-32	2.8	216	0.00130	0.00013	0.00014	242	233
30373-6124-43	2.9	209	0.00118	0.00015	0.00012	249	240
30373-6125-32	2.9	211	0.00133	0.00015	0.00013	224	216
30373-6144-32	2.8	214	0.00140	0.00018	0.00011	222	214
Average	2.8	212				252	243
CV (%)	8	1				13	13

Table H.19 ITCLT parameters of specimens of M-53 NB – section 1 test site 1

Specimen designation	Specimen thickness (in)	Peak cyclic load (lb)	Average deformation from 3 consecutive cycles (in)			Modulus (ksi)	
			Vertical	Horizontal	Longitudinal	Vertical	3-D
30531-1101-32	2.8	162	0.00142	0.00010	0.00013	167	161
30531-1102-32	2.9	203	0.00162	0.00013	0.00016	178	172
30531-1104-43	2.8	212	0.00187	0.00011	0.00018	165	159
30531-1108-20	2.5	210	0.00176	0.00011	0.00017	195	188
30531-1109-20	2.6	208	0.00198	0.00012	0.00016	165	159
30531-1111-20	2.5	205	0.00179	0.00014	0.00017	187	181
30531-1112-32	2.9	209	0.00177	0.00013	0.00019	166	160
30531-1113-43	2.9	213	0.00190	0.00011	0.00021	158	153
30531-1115-32	2.8	209	0.00167	0.00012	0.00022	182	176
30531-1116-43	2.8	209	0.00176	0.00010	0.00016	173	167
30531-1118-43	2.8	213	0.00184	0.00012	0.00018	169	163
30531-1121-32	2.8	205	0.00180	0.00013	0.00003	166	160
Average	2.8	205				172	167
CV (%)	5	7				6	6

APPENDIX I

INDIRECT TENSILE STRENGTH TEST RESULTS

APPENDIX I
INDIRECT TENSILE STRENGTH TEST RESULTS

This appendix presents the results of the indirect tensile strength tests carried out on the specimens from various rubblized pavement projects. A project may be divided into one or more test sections and each section may be divided into one or more test sites.

Table I.1 ITST parameters of specimens of I-69 EB – section 1 test site 1

Specimen designation	Specimen thickness (in)	Specimen diameter (in)	Peak		Approximately half of the peak load		Indirect tensile strength (psi)	Equivalent modulus (psi)
			Load (lb)	Deformation (in)	Load (lb)	Deformation (in)		
10692-1115-43	3.2	5.9	3500	0.15	1750	0.050	119	44693
10692-1107-43	3.2	5.9	3625	0.15	1800	0.050	123	45970
10692-1118-43	3.1	5.9	3525	0.13	1800	0.050	123	47152
10692-1110-43	3.1	5.9	3850	0.11	1900	0.040	134	62215
10692-1125-30	2.5	5.9	2400	0.13	1200	0.030	105	65966
10692-1124-30	2.6	5.9	2500	0.14	1000	0.020	103	77148
10692-1123-20	2.9	5.9	2000	0.18	1000	0.030	75	46821
10692-1123-30	2.4	5.9	2125	0.17	1000	0.030	96	56341
10692-1125-20	2.8	5.9	2000	0.13	1000	0.035	79	42321
10692-1124-20	2.4	5.9	1750	0.15	800	0.030	79	45450
10692-1126-20	3.0	5.9	2025	0.16	900	0.030	73	40734
10692-1126-30	2.5	5.9	2050	0.11	1000	0.030	89	54312
10692-1116-20	2.9	5.9	1925	0.14	1000	0.030	72	46821
10692-1116-30	2.3	5.9	2000	0.18	800	0.030	94	47228
Average	2.8	5.9	2520	0.15	1211	0.035	97	51655
CV (%)	12	0	30	15	34	27	22	20

Table I.2 ITST parameters of specimens of I-69 EB – section 1 test site 2

Specimen designation	Specimen thickness (in)	Specimen diameter (in)	Peak		Approximately half of the peak load		Indirect tensile strength (psi)	Equivalent modulus (psi)
			Load (lb)	Deformation (in)	Load (lb)	Deformation (in)		
10692-1201-20	3.0	5.8	2400	0.150	1100	0.030	87	49293
10692-1204-43	3.1	5.8	3575	0.140	1600	0.040	129	53422
10692-1207-43	3.3	5.9	4000	0.135	2000	0.035	131	70536
10692-1210-20	3.0	5.8	2150	0.150	700	0.020	79	47842
10692-1210-30	2.4	5.8	2550	0.110	1200	0.020	117	102262
10692-1218-43	3.2	5.9	3950	0.135	2000	0.040	132	63252
10692-1223-20	3.2	5.9	2325	0.180	1250	0.050	78	31528
10692-1223-30	2.3	5.9	2400	0.130	1100	0.020	114	98695
10692-1224-20	2.9	5.9	2200	0.160	900	0.030	82	42139
10692-1224-30	2.5	5.9	2500	0.030	1300	0.030	107	70046
10692-1225-20	3.2	5.8	2450	0.150	1200	0.030	83	50445
10692-1225-30	2.4	5.8	2425	0.125	1100	0.020	113	94932
10692-1226-43	3.1	5.9	4050	0.115	2000	0.035	140	74367
Average	2.9	5.9	2844	0.132	1342	0.031	107	65289
CV (%)	13	1	26	27	32	30	21	35

Table I.3 ITST parameters of specimens of I-75 SB – section 1 test site 1

Specimen designation	Specimen thickness (in)	Specimen diameter (in)	Peak		Approximately half of the peak load		Indirect tensile strength (psi)	Equivalent modulus (psi)
			Load (lb)	Deformation (in)	Load (lb)	Deformation (in)		
10753-1125-43	3.0	5.7	3750	0.14	2100	0.055	140	51844
10753-1101-43	2.9	5.7	3950	0.145	1750	0.040	152	61453
10753-1126-432	3.0	5.6	3700	0.155	1700	0.030	139	76943
10753-1110-432	2.9	5.7	3975	0.14	2000	0.050	153	56185
Average	3.0	5.7	3844	0.145	1888	0.044	146	61606
CV (%)	2	1	4	5	10	25	5	18

Table I.4 ITST parameters of specimens of I-75 SB – section 1 test site 2

Specimen designation	Specimen thickness (in)	Specimen diameter (in)	Peak		Approximately half of the peak load		Indirect tensile strength (psi)	Equivalent modulus (psi)
			Load (lb)	Deformation (in)	Load (lb)	Deformation (in)		
10753-1210-43	2.9	5.7	4300	0.140	2200	0.050	152	59744
10753-1218-43	2.9	5.7	5100	0.140	2600	0.040	197	91301
10753-1224-43	2.9	5.7	4650	0.130	2300	0.040	179	80766
10753-1226-43	3.0	5.6	4100	0.115	1750	0.040	155	59404
Average	2.9	5.7	4538	0.134	2213	0.040	171	72804
CV (%)	2	1	10	9	16	12	12	22

Table I.5 ITST parameters of specimens of I-194 NB – section 2 test site 1

Specimen designation	Specimen thickness (in)	Specimen diameter (in)	Peak		Approximately half of the peak load		Indirect tensile strength (psi)	Equivalent modulus (psi)
			Load (lb)	Deformation (in)	Load (lb)	Deformation (in)		
11941-2101-54	3.1	5.9	4950	0.140	2400	0.040	172	78841
11941-2110-54	3.0	5.9	4750	0.135	2100	0.030	171	95047
11941-2126-43	3.0	5.9	7100	0.160	3600	0.060	255	81469
11941-2124-43	3.0	5.9	7100	0.155	N.A.	N.A.	255	Error
11941-2123-54	3.1	5.9	5800	0.145	2600	0.040	202	85411
Average	3.0	5.9	5940	0.147	2800	0.040	211	85192
CV (%)	2	0	19	7	22	31	20	8

Table I.6 ITST parameters of specimens of I-194 NB – section 2 test site 2

Specimen designation	Specimen thickness (in)	Specimen diameter (in)	Peak		Approximately half of the peak load		Indirect tensile strength (psi)	Equivalent modulus (psi)
			Load (lb)	Deformation (in)	Load (lb)	Deformation (in)		
11941-2201-32	3.1	5.9	8800	0.170	4200	0.060	306	91981
11941-2201-54	3.0	5.9	4800	0.270	2500	0.110	173	30859
11941-2204-43	3.1	5.9	6700	0.150	3300	0.050	233	86725
11941-2207-43	3.3	5.9	6900	0.120	3400	0.040	226	104922
11941-2210-43	3.1	5.9	7600	0.205	4000	0.065	265	80862
11941-2215-32	3.1	5.9	9100	0.175	4000	0.060	317	87601
11941-2215-54	3.0	5.9	4500	0.175	2200	0.050	162	59744
11941-2224-32	3.0	5.9	6800	0.095	3600	0.035	245	139660
Average	3.1	5.9	6900	0.170	3400	0.059	241	85294
CV (%)	3	0	24	31	21	39	23	37

Table I.7 ITST parameters of specimens of US-10 EB – section 1 test site 1

Specimen designation	Specimen thickness (in)	Specimen diameter (in)	Peak		Approximately half of the peak load		Indirect tensile strength (psi)	Equivalent modulus (psi)
			Load (lb)	Deformation (in)	Load (lb)	Deformation (in)		
20102-1101-32	3.2	5.8	4500	0.120	2100	0.035	156	76377
20102-1104-43	2.6	5.8	2600	0.130	1200	0.030	111	62668
20102-1107-32	2.8	5.8	3100	0.115	1400	0.035	124	59250
20102-1117-20	2.8	5.8	3500	0.100	1800	0.040	137	65466
20102-1117-43	3.0	5.8	3700	0.140	1800	0.040	137	61101
20102-1125-20	3.1	5.8	3450	0.125	1650	0.040	125	55091
20102-1125-43	3.1	5.8	3525	0.130	900	0.040	126	29565
20102-1126-20	2.5	5.8	3100	0.110	1700	0.040	137	69248
20102-1126-43	2.9	5.8	3400	0.150	1900	0.040	130	66951
Average	2.9	5.8	3431	0.124	1606	0.038	131	60635
CV (%)	8	0	15	12	23	10	9	22

Table I.8 ITST parameters of specimens of US-10 EB – section 1 test site 2

Specimen designation	Specimen thickness (in)	Specimen diameter (in)	Peak		Approximately half of the peak load		Indirect tensile strength (psi)	Equivalent modulus (psi)
			Load (lb)	Deformation (in)	Load (lb)	Deformation (in)		
20102-1204-32	3.0	5.8	3675	0.110	1800	0.035	136	69830
20102-1223-43	3.0	5.8	2275	0.130	1200	0.030	84	54861
20102-1225-32	3.0	5.8	3400	0.135	1800	0.045	125	54312
20102-1225-43	2.8	5.8	3025	0.130	1500	0.040	118	53786
20102-1226-20	2.6	5.8	3100	0.155	1600	0.035	133	72176
20102-1226-43	2.4	5.8	3000	0.130	1600	0.040	139	68175
Average	2.8	5.8	3079	0.132	1583	0.038	122	62190
CV (%)	9	0	15	11	14	14	17	14

Table I.9 ITST parameters of specimens of US-23 SB – section 1 test site 1

Specimen designation	Specimen thickness (in)	Specimen diameter (in)	Peak		Approximately half of the peak load		Indirect tensile strength (psi)	Equivalent modulus (psi)
			Load (lb)	Deformation (in)	Load (lb)	Deformation (in)		
20233-1116-32	2.8	5.9	3625	0.140	1800	0.040	141	66656
20233-1117-43	2.7	5.9	3525	0.140	1700	0.050	141	51295
20233-1125-20	3.0	5.9	4175	0.135	2000	0.035	152	78373
20233-1125-43	2.9	5.9	3600	0.145	2000	0.045	135	62862
20233-1127-32	2.9	5.9	3400	0.120	1700	0.040	129	60532
20233-1127-43	2.9	5.9	3475	0.090	1700	0.020	131	120223
Average	2.8	5.9	3633	0.128	1817	0.038	138	73323
CV (%)	3	0	8	16	8	27	6	34

Table I.10 ITST parameters of specimens of US-23 SB – section 1 test site 2

Specimen designation	Specimen thickness (in)	Specimen diameter (in)	Peak		Approximately half of the peak load		Indirect tensile strength (psi)	Equivalent modulus (psi)
			Load (lb)	Deformation (in)	Load (lb)	Deformation (in)		
20233-1210-32	3.0	5.9	3300	0.175	1700	0.055	117	41691
20233-1210-43	2.9	5.9	3250	0.195	1600	0.055	120	40722
20233-1217-30	2.3	5.9	2275	0.165	1100	0.025	106	77589
20233-1220-32	2.8	5.9	3200	0.140	1600	0.040	125	58822
20233-1220-43	2.8	5.9	3300	0.170	1650	0.050	126	47499
20233-1227-32	2.9	5.9	3000	0.130	1600	0.040	112	56575
20233-1227-43	2.5	5.9	3050	0.185	1600	0.065	131	40108
20233-1230-30	2.4	5.9	2750	0.170	1200	0.050	123	40905
Average	2.7	5.9	3016	0.166	1506	0.048	120	50489
CV (%)	10	0	12	13	15	26	7	26

Table I.11 ITST parameters of specimens of US-27 SB – section 2 test site 1

Specimen designation	Specimen thickness (in)	Specimen diameter (in)	Peak		Approximately half of the peak load		Indirect tensile strength (psi)	Equivalent modulus (psi)
			Load (lb)	Deformation (in)	Load (lb)	Deformation (in)		
20273-2125-43	2.3	5.8	4250	0.105	2200	0.035	200	109890
20273-2115-43	2.2	5.9	4600	0.130	2300	0.040	226	106465
Average	2.3	5.9	4425	0.122	2250	0.038	213	108177
CV (%)	4	1	6	15	3	9	9	2

Table I.12 ITST parameters of specimens of US-27 SB – section 3 test site 1

Specimen designation	Specimen thickness (in)	Specimen diameter (in)	Peak		Approximately half of the peak load		Indirect tensile strength (psi)	Equivalent modulus (psi)
			Load (lb)	Deformation (in)	Load (lb)	Deformation (in)		
20273-3101-32	3.2	5.9	2350	0.175	1200	0.050	79	30267
20273-3104-30	2.4	5.9	2400	0.200	1250	0.050	106	41736
20273-3107-43	3.2	5.9	3150	0.135	1500	0.040	107	47885
20273-3110-43	3.2	5.9	3275	0.180	1700	0.060	111	36180
20273-3116-30	2.5	5.9	2600	0.160	1250	0.040	114	51329
20273-3117-43	2.8	5.9	2475	0.185	1200	0.040	94	43029
20273-3126-32	3.1	5.9	2750	0.140	1350	0.030	95	58564
Average	2.9	5.9	2714	0.168	1350	0.044	101	44141
CV (%)	12	0	14	14	14	22	12	21

Table I.13 ITST parameters of specimens of US-27 SB – section 4 test site 1

Specimen designation	Specimen thickness (in)	Specimen diameter (in)	Peak		Approximately half of the peak load		Indirect tensile strength (psi)	Equivalent modulus (psi)
			Load (lb)	Deformation (in)	Load (lb)	Deformation (in)		
20273-4107-43	3.0	5.9	2800	0.200	1350	0.050	102	37031
20273-4110-32	3.0	5.8	2950	0.180	1300	0.035	108	50433
20273-4115-32	3.1	5.9	2700	0.210	1300	0.050	95	34386
20273-4117-32	3.2	5.9	3075	0.210	1500	0.050	104	38188
20273-4118-43	2.9	5.9	2700	0.150	1350	0.040	102	47736
20273-4123-20	2.6	5.9	2400	0.140	1300	0.040	102	51916
20273-4123-43	3.2	5.9	2975	0.185	1600	0.060	101	34052
20273-4124-32	3.1	5.9	2850	0.170	1300	0.050	100	34275
20273-4125-20	3.0	5.9	2500	0.155	1300	0.045	89	38837
20273-4126-32	3.0	5.9	2775	0.175	1400	0.045	100	42243
Average	3.0	5.9	2773	0.178	1370	0.047	100	40910
CV (%)	6	0	8	14	8	15	5	17

Table I.14 ITST parameters of specimens of US-31 NB – section 1 test site 1

Specimen designation	Specimen thickness (in)	Specimen diameter (in)	Peak		Approximately half of the peak load		Indirect tensile strength (psi)	Equivalent modulus (psi)
			Load (lb)	Deformation (in)	Load (lb)	Deformation (in)		
20311-1101-32	3.0	5.9	3200	0.150	1600	0.040	116	54677
20311-1104-20	3.1	5.9	4000	0.140	2000	0.040	140	65913
20311-1104-43	2.8	5.9	2700	0.155	1300	0.050	105	38097
20311-1107-43	3.0	5.9	3200	0.135	1550	0.035	115	60132
20311-1116-32	3.1	5.9	3450	0.150	1600	0.040	122	53247
20311-1118-32	2.8	5.9	3800	0.125	1900	0.035	146	78694
20311-1123-32	2.5	5.9	2650	0.140	1250	0.040	115	50918
20311-1124-20	2.9	5.9	3800	0.110	1900	0.030	141	88654
20311-1124-43	3.0	5.9	3000	0.150	1650	0.055	108	40734
20311-1125-20	2.8	5.9	3550	0.125	1700	0.035	137	70662
20311-1125-43	3.3	5.9	3100	0.145	1600	0.045	102	44156
20311-1126-20	2.9	5.9	3300	0.090	1800	0.030	124	84863
Average	2.9	5.9	3313	0.135	1654	0.040	123	60896
CV (%)	7	0	13	14	14	19	12	28

Table I.15 ITST parameters of specimens of M-15 NB – section 1 test site 1

Specimen designation	Specimen thickness (in)	Specimen diameter (in)	Peak		Approximately half of the peak load		Indirect tensile strength (psi)	Equivalent modulus (psi)
			Load (lb)	Deformation (in)	Load (lb)	Deformation (in)		
30153-1101-32	2.9	5.9	4775	0.140	2400	0.045	178	74656
30153-1107-32	2.9	5.9	4750	0.090	2500	0.030	176	115854
30153-1110-43	2.9	5.9	4850	0.130	2500	0.040	180	87188
30153-1115-32	2.9	5.9	4400	0.140	2200	0.050	163	61380
30153-1116-32	2.9	5.9	4200	0.120	2100	0.030	157	98664
30153-1118-32	2.9	5.9	4250	0.130	2100	0.040	158	73490
30153-1123-32	3.0	5.9	4700	0.130	2100	0.040	171	71763
30153-1124-43	2.7	5.9	4350	0.135	2200	0.045	174	73485
30153-1125-43	2.8	5.9	4825	0.155	2400	0.050	185	69090
30153-1126-43	3.0	5.9	4825	0.120	2400	0.030	176	110093
Average	2.9	5.9	4593	0.129	2290	0.040	172	83566
CV (%)	3	0	6	13	7	20	5	22

Table I.16 ITST parameters of specimens of M-37 SB – section 5 test site 1

Specimen designation	Specimen thickness (in)	Specimen diameter (in)	Peak		Approximately half of the peak load		Indirect tensile strength (psi)	Equivalent modulus (psi)
			Load (lb)	Deformation (in)	Load (lb)	Deformation (in)		
30373-5104-32	2.8	5.9	4725	0.150	2100	0.050	182	61101
30373-5117-32	2.6	5.9	3550	0.150	1800	0.040	147	70502
30373-5123-20	3.2	5.9	5125	0.155	2500	0.050	173	63647
30373-5123-43	3.1	5.9	4750	0.170	2400	0.050	165	63072
30373-5124-20	3.1	5.9	4900	0.145	2600	0.050	171	68329
30373-5124-43	3.3	5.9	4825	0.150	2825	0.055	158	63402
30373-5125-20	2.8	5.9	4700	0.140	2200	0.040	181	80014
30373-5125-43	2.6	5.9	3800	0.160	1900	0.050	158	59535
Average	2.9	5.9	4547	0.153	2291	0.048	167	66200
CV (%)	9	0	12	6	15	11	7	10

Table I.17 ITST parameters of specimens of M-37 SB – section 5 test site 2

Specimen designation	Specimen thickness (in)	Specimen diameter (in)	Peak		Approximately half of the peak load		Indirect tensile strength (psi)	Equivalent modulus (psi)
			Load (lb)	Deformation (in)	Load (lb)	Deformation (in)		
30373-5201-32	2.4	5.9	3350	0.155	1750	0.035	151	84863
30373-5207-32	2.6	5.9	3200	0.140	2100	0.040	133	82252
30373-5215-32	2.6	5.9	3025	0.165	1500	0.040	126	58751
30373-5223-32	3.1	5.9	5100	0.155	2500	0.050	178	65700
30373-5223-43	2.9	5.9	4425	0.155	2300	0.045	165	71792
30373-5225-43	3.0	5.9	4775	0.160	2100	0.050	172	57028
Average	2.8	5.9	3979	0.155	2042	0.043	154	70065
CV (%)	10	0	22	5	18	14	14	17

Table I.18 ITST parameters of specimens of M-37 SB – section 6 test site 1

Specimen designation	Specimen thickness (in)	Specimen diameter (in)	Peak		Approximately half of the peak load		Indirect tensile strength (psi)	Equivalent modulus (psi)
			Load (lb)	Deformation (in)	Load (lb)	Deformation (in)		
30373-6107-32	2.8	5.9	3650	0.160	1700	0.035	141	70662
30373-6110-43	3.0	5.9	3900	0.130	1900	0.030	140	85995
30373-6117-43	3.0	5.9	3750	0.215	1900	0.045	135	57330
30373-6118-43	2.8	5.9	3175	0.190	1500	0.040	122	54555
30373-6123-32	2.8	5.9	4950	0.130	2400	0.040	191	87288
30373-6124-43	2.9	5.9	3625	0.180	2000	0.050	135	56185
30373-6125-32	2.9	5.9	3550	0.160	1800	0.030	132	84278
30373-6144-32	2.8	5.9	3875	0.140	2000	0.040	149	72740
Average	2.9	5.9	3809	0.163	1900	0.039	143	71129
CV (%)	3	0	13	19	14	18	14	19

Table I.19 ITST parameters of specimens of M-53 SB – section 1 test site 1

Specimen designation	Specimen thickness (in)	Specimen diameter (in)	Peak		Approximately half of the peak load		Indirect tensile strength (psi)	Equivalent modulus (psi)
			Load (lb)	Deformation (in)	Load (lb)	Deformation (in)		
30531-1101-32	2.8	5.9	5500	0.110	2600	0.040	212	94562
30531-1102-32	2.9	5.9	6200	0.090	3300	0.035	231	132437
30531-1104-43	2.8	5.9	6050	0.125	3000	0.050	233	87288
30531-1108-20	2.5	5.9	5150	0.100	3000	0.040	222	122203
30531-1109-20	2.6	5.9	6650	0.105	3000	0.040	276	117503
30531-1111-20	2.5	5.9	5400	0.095	2600	0.030	233	141212
30531-1112-32	2.9	5.9	6100	0.100	3200	0.040	227	112370
30531-1113-43	2.9	5.9	6500	0.110	3700	0.030	242	173238
30531-1115-32	2.8	5.9	6300	0.100	3700	0.020	243	269137
30531-1116-43	2.8	5.9	6000	0.090	2800	0.030	231	135781
30531-1118-43	2.8	5.9	6150	0.110	3000	0.040	237	109110
30531-1121-32	2.8	5.9	6100	0.095	3000	0.030	235	145480
Average	2.8	5.9	6008	0.103	3075	0.035	235.17	136693
CV (%)	5	0	7	10	12	22	7	35

APPENDIX J

BACKCALCULATED LAYER MODULI

APPENDIX J
BACKCALCULATED LAYER MODULI

This appendix presents the results of the backcalculation of the layer moduli of various rubblized pavement projects. A project may be divided into one or more test sections and each section may be divided into one or more test sites.

Table J1. Measured pavement deflections and backcalculated layer moduli for I-69 EB - section 1 test site 1

Route	I-69 EB		C.S.	76023		J.N.	36020		BMP	0.040		EMP	5.932			
FWD station	Deflection (mils)							MDT (°C)	Backcalculated modulus (ksi)					RMS (%)	Converged	Accepted
	0	8	12	16	24	36	60		AC	TC AC	RCS	Base	RB			
	D1	D2	D3	D4	D5	D6	D7									
1	10.76	8.20	7.03	5.67	4.57	2.82	1.23	28.7	327	555	37	23	15	1.25	Y	Y
3	11.41	8.74	7.49	6.10	4.87	2.97	1.16	28.8	317	551	49	19	16	0.59	Y	Y
4	10.45	8.04	6.90	5.57	4.50	2.86	1.21	28.9	0	582	46	19	15	0.92	Y	Y
5	10.62	8.24	7.11	5.79	4.72	2.98	1.28	28.8	0	433	98	16	15	0.69	Y	Y
6	10.19	7.63	6.57	5.44	4.54	3.01	1.34	28.8	0	495	61	31	13	0.58	Y	Y
7	9.96	7.55	6.42	5.24	4.36	2.95	1.44	28.6	0	487	86	24	12	0.35	Y	Y
8	9.88	7.52	6.55	5.44	4.56	3.17	1.55	28.8	0	716	72	36	12	0.50	Y	Y
9	8.58	6.80	5.97	4.98	4.24	3.00	1.57	29.0	0	544	102	25	12	0.51	Y	Y
10	9.30	7.14	6.30	5.27	4.48	3.16	1.58	29.2	0	429	170	25	14	0.34	Y	Y
11	8.70	6.36	5.53	4.67	4.00	2.85	1.41	28.8	0	408	98	19	16	0.38	Y	Y
12	9.77	7.14	6.06	4.97	4.08	2.72	1.20	29.2	0	433	90	20	15	1.00	Y	Y
13	10.09	7.40	6.38	5.28	4.36	2.88	1.32	29.6	0	458	100	26	12	0.41	Y	Y
14	9.84	7.32	6.39	5.30	4.47	3.14	1.56	29.8	0	413	218	26	14	0.31	Y	Y
15	8.42	6.10	5.28	4.50	3.90	2.84	1.43	30.0	0	502	111	23	16	0.50	Y	Y
16	8.89	6.59	5.66	4.69	3.91	2.66	1.24	30.1	0	518	90	21	15	0.91	Y	Y
17	9.65	7.22	6.31	5.18	4.33	2.89	1.34	30.4	0	488	152	29	12	0.41	Y	Y
18	8.92	6.65	5.85	4.97	4.28	3.11	1.62	30.5	0	420	275	33	13	0.74	Y	Y
19	7.94	5.71	4.91	4.22	3.71	2.79	1.44	30.6	0	554	118	24	15	0.18	Y	Y
20	8.58	6.44	5.56	4.60	3.86	2.69	1.27	30.5	0	588	84	21	15	0.71	Y	Y
21	9.40	7.16	6.24	5.12	4.29	2.87	1.33	30.5	0	485	172	25	12	0.21	Y	Y
22	8.84	6.64	5.80	4.97	4.28	3.13	1.60	30.5	0	449	261	40	13	0.41	Y	Y
23	7.68	5.52	4.81	4.12	3.62	2.75	1.47	30.5	0	487	138	24	15	0.20	Y	Y
24	8.66	6.38	5.49	4.55	3.84	2.69	1.27	30.7	0	548	96	23	14	0.52	Y	Y
25	9.29	6.99	6.07	4.98	4.19	2.86	1.35	30.8	0	547	139	28	11	0.17	Y	Y
26	8.90	6.79	5.96	5.05	4.33	3.20	1.66	30.9	0	551	213	36	13	0.90	Y	Y
27	7.55	5.71	4.89	4.19	3.68	2.77	1.45	31.3	0	481	131	21	16	0.33	Y	Y
28	9.01	6.61	5.69	4.67	3.92	2.74	1.25	31.1	0	598	85	18	14	0.84	Y	Y
29	9.70	7.44	6.46	5.34	4.48	2.97	1.36	30.8	0	525	170	19	12	0.21	Y	Y
30	9.07	6.94	6.11	5.23	4.51	3.28	1.64	30.8	0	532	222	27	14	0.56	Y	Y
31	7.82	5.87	5.12	4.36	3.82	2.81	1.43	30.9	0	593	98	24	15	0.16	Y	Y
32	8.83	6.70	5.79	4.75	3.96	2.72	1.26	30.6	0	587	70	18	17	0.83	Y	Y
33	9.70	7.39	6.33	5.13	4.23	2.70	1.15	30.4	0	601	90	21	16	0.40	Y	Y
34	9.05	6.92	6.00	4.91	4.10	2.76	1.25	30.1	0	650	70	20	14	0.78	Y	Y
35	9.62	7.46	6.59	5.39	4.51	3.01	1.38	29.9	0	614	95	25	13	0.41	Y	Y
36	8.92	6.88	6.01	5.02	4.22	2.93	1.43	30.7	0	611	83	33	12	0.72	Y	Y
37	9.22	7.04	6.18	5.15	4.36	3.06	1.58	30.9	0	538	168	19	12	0.37	Y	Y
38	9.02	6.94	6.09	5.20	4.52	3.27	1.64	31.0	0	653	150	29	11	0.30	Y	Y
39	8.36	6.51	5.78	4.95	4.30	3.17	1.69	31.1	0	573	113	40	11	0.36	Y	Y
40	8.66	6.58	5.72	4.78	4.11	3.06	1.63	31.3	0	650	144	29	13	0.54	Y	Y
2	8.07	6.26	5.43	4.59	3.98	2.89	1.48	28.6	0	510	46	13	17	1.04	Y	N
Average	9.21	6.96	6.03	5.02	4.23	2.93	1.41	30.1	16.5	534	122	25	14	0.52		
CV (%)	9	10	10	9	7	6	11	3	436	14	47	24	11	50		

MDT = Mid-depth temperature, TCAC = Temperature corrected asphalt concrete, RCS = Rubblized concrete slab, RB = Roadbed, RMS = Root mean square error

Table J2. Measured pavement deflections and backcalculated layer moduli for I-69 EB - section 1 test site 2

Route	I-69 EB		C.S.	76023		J.N.	36020		BMP	0.040		EMP	5.932			
FWD station	Deflection (mils)							MDT (°C)	Backcalculated modulus (ksi)					RMS (%)	Converged	Accepted
	0	8	12	16	24	36	60		AC	TC AC	RCS	Base	RB			
	D1	D2	D3	D4	D5	D6	D7									
1	9.00	6.58	5.63	4.60	3.71	2.33	0.99	31.7	323	591	86	20	20	1.31	Y	Y
2	8.91	6.45	5.45	4.41	3.64	2.35	1.03	31.7	284	520	102	22	19	0.87	Y	Y
3	9.59	7.16	6.03	4.85	3.96	2.57	1.10	31.5	304	551	77	21	17	0.43	Y	Y
4	9.72	7.19	6.18	5.07	4.18	2.81	1.31	31.4	291	524	87	24	15	0.57	Y	Y
5	9.19	6.72	5.76	4.67	3.87	2.60	1.25	31.4	300	541	83	31	15	0.74	Y	Y
6	8.72	6.34	5.46	4.55	3.85	2.62	1.28	31.5	280	506	132	27	15	0.90	Y	Y
7	9.61	7.14	6.16	5.03	4.11	2.71	1.25	31.5	318	576	76	24	15	0.86	Y	Y
8	9.51	7.08	6.00	4.83	3.98	2.64	1.17	31.7	297	544	83	23	16	0.35	Y	Y
9	8.26	6.06	5.21	4.25	3.53	2.32	1.01	32.1	318	594	125	21	19	0.58	Y	Y
10	8.81	6.29	5.28	4.22	3.41	2.17	0.91	32.3	282	532	93	23	21	0.58	Y	Y
11	8.63	5.99	5.09	4.14	3.43	2.23	1.02	32.5	254	483	121	27	19	1.23	Y	Y
12	9.25	6.66	5.75	4.73	3.95	2.69	1.30	32.8	267	517	110	27	15	0.74	Y	Y
13	9.16	6.44	5.56	4.63	3.88	2.70	1.33	33.1	236	464	138	29	14	0.68	Y	Y
14	8.30	5.73	4.83	3.90	3.22	2.15	0.95	33.1	246	483	140	27	20	0.27	Y	Y
15	7.85	5.30	4.47	3.76	3.16	2.20	1.02	33.0	220	430	237	28	19	0.25	Y	Y
16	8.73	6.24	5.36	4.47	3.82	2.70	1.28	32.8	239	464	184	24	15	0.34	Y	Y
17	8.50	6.03	5.17	4.36	3.76	2.71	1.35	32.8	236	455	200	30	14	0.33	Y	Y
18	7.63	5.21	4.35	3.61	3.04	2.08	0.95	32.7	239	460	202	30	21	0.47	Y	Y
19	7.47	4.99	4.24	3.51	3.01	2.15	1.02	32.7	223	430	259	35	19	0.49	Y	Y
20	8.53	6.04	5.19	4.35	3.74	2.64	1.29	32.8	237	459	195	27	15	0.42	Y	Y
21	8.31	5.80	4.94	4.19	3.65	2.65	1.38	32.9	226	440	206	40	14	0.52	Y	Y
22	7.38	5.03	4.19	3.50	2.97	2.10	1.00	33.3	240	478	213	38	19	0.48	Y	Y
23	7.35	5.07	4.27	3.54	3.00	2.17	1.05	33.4	254	507	200	40	18	0.54	Y	Y
24	8.39	6.13	5.21	4.36	3.72	2.65	1.27	33.7	268	543	166	27	15	0.47	Y	Y
25	7.99	5.66	4.94	4.18	3.59	2.65	1.40	33.8	261	533	192	42	13	0.29	Y	Y
26	7.12	5.14	4.43	3.71	3.15	2.18	1.06	34.1	321	664	187	32	18	0.58	Y	Y
27	7.58	5.22	4.33	3.65	3.11	2.22	1.03	34.1	229	475	253	30	19	0.90	Y	Y
28	8.72	6.33	5.46	4.60	3.90	2.75	1.26	34.0	251	516	198	18	16	0.16	Y	Y
29	7.73	5.78	5.03	4.27	3.69	2.75	1.41	33.7	316	642	195	34	13	0.39	Y	Y
30	7.34	5.37	4.65	3.92	3.31	2.29	1.09	33.5	327	655	190	26	18	0.57	Y	Y
31	7.10	5.21	4.50	3.75	3.16	2.22	1.04	33.6	339	684	189	28	19	0.11	Y	Y
32	7.14	5.20	4.54	3.76	3.17	2.23	1.08	33.5	347	694	166	33	18	0.40	Y	Y
33	7.66	5.88	5.12	4.27	3.64	2.55	1.22	33.1	387	763	149	24	16	0.33	Y	Y
34	8.40	6.31	5.55	4.62	3.90	2.73	1.28	32.8	327	633	151	20	16	0.31	Y	Y
35	8.16	6.03	5.32	4.58	3.93	2.86	1.51	32.9	299	580	191	32	13	0.64	Y	Y
36	7.48	5.81	5.17	4.43	3.86	2.88	1.55	33.0	401	782	187	34	12	0.20	Y	Y
37	7.70	5.99	5.27	4.49	3.87	2.80	1.51	33.0	425	833	130	39	12	0.57	Y	Y
38	7.84	5.94	5.16	4.47	3.84	2.82	1.44	33.0	324	635	210	27	14	0.36	Y	Y
39	7.70	5.97	5.25	4.37	3.72	2.59	1.33	33.0	462	903	98	37	14	0.83	Y	Y
40	7.44	5.60	4.92	4.16	3.50	2.41	1.17	33.1	391	769	152	26	17	0.88	Y	Y
Average	8.25	5.98	5.14	4.27	3.60	2.50	1.20	32.8	295	571	159	29	17	0.55		
CV (%)	9	10	11	10	10	10	15	2	20	20	32	21	15	49		

MDT = Mid-depth temperature, TCAC = Temperature corrected asphalt concrete, RCS = Rubblized concrete slab, RB = Roadbed, RMS = Root mean square error

Table J3. Measured pavement deflections and backcalculated layer moduli for I-75 SB -section 1 test site 1

Route	I-75 SB		C.S.	16092		J.N.	25559		BMP	13.816		EMP	15.218			
FWD station	Deflection (mils)							MDT (°C)	Backcalculated modulus (ksi)					RMS (%)	Converged	Accepted
	0	8	12	16	24	36	60		AC	TC AC	RCS	Base	RB			
	D1	D2	D3	D4	D5	D6	D7									
1	9.46	8.29	7.45	6.22	5.30	3.67	2.03	13.1	2040	1472	106	-	16	1.13	Y	Y
2	10.02	8.59	7.69	6.47	5.48	3.82	2.12	13.2	1511	1097	118	-	15	1.01	Y	Y
4	9.52	8.17	7.22	5.93	4.96	3.51	1.92	13.3	1312	958	126	-	17	1.00	Y	Y
5	9.73	8.44	7.53	6.25	5.22	3.59	1.85	13.4	2358	1733	69	-	17	0.28	Y	Y
6	9.56	8.07	7.13	5.92	4.98	3.50	1.90	13.7	1192	889	133	-	17	0.67	Y	Y
7	9.88	8.25	7.35	6.14	5.17	3.67	1.97	13.7	1116	832	134	-	16	0.33	Y	Y
8	9.32	8.18	7.36	6.18	5.31	3.82	2.02	13.7	2411	1797	102	-	16	0.56	Y	Y
9	9.01	7.81	7.09	6.03	5.11	3.70	2.02	14.0	2072	1572	132	-	16	0.37	Y	Y
10	9.07	7.78	6.94	5.86	4.78	3.31	1.79	14.2	1916	1464	103	-	18	1.08	Y	Y
11	9.67	8.39	7.50	6.24	5.20	3.50	1.92	14.4	1986	1540	87	-	17	1.41	Y	Y
12	9.24	7.73	6.89	5.80	4.93	3.58	1.92	14.4	1032	800	168	-	17	0.24	Y	Y
13	9.00	7.76	6.95	5.82	4.89	3.17	1.72	14.6	2533	1985	73	-	18	1.93	Y	Y
14	10.30	8.47	7.26	5.96	5.02	3.52	1.90	14.8	678	537	142	-	17	1.02	Y	Y
16	8.22	6.97	6.27	5.34	4.60	3.38	1.87	15.2	1197	969	215	-	17	0.16	Y	Y
18	7.77	6.70	6.04	5.16	4.50	3.40	1.81	15.2	1809	1464	204	-	18	1.24	Y	Y
19	7.68	6.63	6.03	5.16	4.44	3.34	1.95	15.3	1378	1119	265	-	17	1.07	Y	Y
20	7.22	6.21	5.60	4.87	4.26	3.29	1.87	15.4	1090	892	351	-	18	0.55	Y	Y
21	8.57	7.55	6.81	5.67	4.74	3.21	1.73	15.4	2826	2313	80	-	18	1.15	Y	Y
22	7.43	6.47	5.89	5.12	4.48	3.46	1.84	15.8	2543	2126	207	-	17	1.71	Y	Y
23	7.49	6.53	5.90	5.11	4.45	3.39	1.99	15.6	1347	1118	304	-	17	0.80	Y	Y
24	6.87	5.93	5.40	4.78	4.21	3.32	1.91	15.6	962	799	467	-	17	0.58	Y	Y
25	8.50	7.46	6.69	5.57	4.62	3.20	1.74	15.4	2352	1931	102	-	18	1.09	Y	Y
27	6.65	5.96	5.53	4.91	4.33	3.35	2.01	15.5	3147	2593	304	-	17	0.29	Y	Y
28	6.49	5.69	5.25	4.72	4.19	3.33	1.94	15.1	1039	841	561	-	17	0.76	Y	Y
29	8.30	7.30	6.58	5.52	4.62	3.26	1.75	15.0	2675	2150	104	-	18	0.50	Y	Y
30	7.07	6.20	5.65	4.92	4.34	3.40	1.94	14.8	1552	1239	334	-	17	0.71	Y	Y
31	6.05	5.48	5.14	4.68	4.22	3.50	2.12	14.6	2966	2341	510	-	15	1.19	Y	Y
32	9.70	8.16	7.24	6.18	5.26	3.87	1.99	14.6	1255	991	143	-	16	1.40	Y	Y
35	8.29	6.89	6.21	5.24	4.45	3.26	1.82	14.6	941	740	225	-	18	0.79	Y	Y
36	7.06	6.11	5.57	4.90	4.28	3.30	1.94	14.8	1271	1011	370	-	17	0.47	Y	Y
37	6.36	5.66	5.28	4.80	4.32	3.44	1.99	14.8	1632	1303	491	-	16	1.78	Y	Y
38	6.76	5.96	5.55	5.02	4.49	3.62	2.12	14.9	844	677	664	-	16	1.10	Y	Y
39	8.47	7.33	6.55	5.54	4.67	3.27	1.77	15.1	2235	1808	118	-	18	0.55	Y	Y
40	8.76	7.85	6.77	5.62	4.73	3.34	1.86	15.2	1663	1351	131	-	17	1.82	Y	Y
3	9.62	8.48	7.78	6.47	5.17	3.64	2.03	12.2	2114	1457	91	-	16	2.32	Y	N
15	8.12	7.22	6.44	5.42	4.58	3.27	1.85	16.0	2137	1800	147	-	18	1.28	Y	N
17	8.90	7.78	6.98	5.84	4.90	3.15	1.73	16.0	2719	2289	69	-	18	2.21	Y	N
34	7.89	7.09	6.42	5.70	4.53	3.27	1.90	14.8	2957	2351	132	-	17	2.65	Y	N
42	7.76	6.30	5.68	4.88	4.27	3.28	1.89	14.3	533	412	454	-	18	1.76	Y	N
26	6.92	6.10	5.64	4.98	4.45	3.51	1.89	13.7	-	-	-	-	-	2.32	N	N
33	7.26	6.29	5.66	4.89	4.25	3.31	1.98	15.3	-	-	-	-	-	1.74	N	N
41	10.06	8.69	7.41	5.79	4.91	3.61	2.04	13.2	-	-	-	-	-	3.85	N	N
Average	8.34	7.21	6.48	5.52	4.72	3.45	1.91	14.7	1732	1366	225	-	17	0.90		
CV (%)	15	14	12	10	8	5	6	5	39	40	70	-	5	53		

MDT = Mid-depth temperature, TCAC = Temperature corrected asphalt concrete, RCS = Rubblized concrete slab, RB = Roadbed, RMS = Root mean square error

Table J4. Measured pavement deflections and backcalculated layer moduli for I-75 SB -section 1 test site 2

Route	I-75 SB		C.S.	16092		J.N.	25559		BMP	13.816		EMP	15.218			
FWD station	Deflection (mils)							MDT (°C)	Backcalculated modulus (ksi)					RMS (%)	Converged	Accepted
	0	8	12	16	24	36	60		AC	TC AC	RCS	Base	RB			
	D1	D2	D3	D4	D5	D6	D7									
2	9.30	7.84	6.92	5.74	4.80	3.46	1.83	15.0	1193	957	170	-	17	0.67	Y	Y
3	9.98	8.42	7.38	6.08	5.07	3.51	1.78	14.8	1596	1269	114	-	16	0.24	Y	Y
4	8.38	7.15	6.41	5.45	4.68	3.34	1.66	15.1	3241	2622	123	-	18	1.55	Y	Y
6	9.12	7.68	6.74	5.53	4.56	3.14	1.60	15.2	1743	1412	119	-	18	0.27	Y	Y
9	9.33	7.49	6.49	4.89	4.07	2.81	1.41	15.4	853	702	132	-	21	1.98	Y	Y
10	7.85	6.66	5.85	4.82	3.95	2.72	1.42	15.4	2060	1694	141	-	21	0.71	Y	Y
12	8.37	7.50	6.54	5.39	4.57	3.23	1.70	15.7	2463	2054	136	-	18	1.20	Y	Y
13	9.40	7.23	6.22	4.91	4.03	2.74	1.36	16.2	597	510	150	-	21	0.62	Y	Y
14	6.86	6.05	5.37	4.50	3.80	2.70	1.45	16.2	3050	2606	181	-	21	0.75	Y	Y
16	8.17	7.05	6.29	5.34	4.55	3.24	1.72	16.5	2328	2027	167	-	17	0.36	Y	Y
22	6.79	5.96	5.25	4.32	3.63	2.62	1.41	16.5	2275	1981	208	-	22	1.30	Y	Y
30	7.52	6.46	5.70	4.67	3.88	2.68	1.37	16.6	2602	2277	133	-	21	0.31	Y	Y
32	6.53	5.77	5.34	4.72	4.11	3.18	1.82	16.5	3088	2688	341	-	17	0.41	Y	Y
33	7.26	6.38	5.78	4.94	4.24	3.20	1.80	16.4	2134	1849	273	-	17	0.84	Y	Y
35	5.93	5.27	4.84	4.28	3.77	2.97	1.67	16.3	3220	2777	395	-	18	0.83	Y	Y
36	6.65	5.84	5.28	4.53	3.92	2.97	1.65	16.3	2325	2005	303	-	19	0.50	Y	Y
38	7.20	6.21	5.63	4.89	4.30	3.17	1.69	16.1	2659	2271	238	-	18	1.17	Y	Y
40	8.40	6.82	5.99	4.92	4.05	2.81	1.42	15.9	1210	1023	159	-	21	0.39	Y	Y
41	8.98	7.39	6.44	5.24	4.31	2.90	1.46	16.0	1527	1292	118	-	20	0.51	Y	Y
42	10.30	8.34	7.11	5.58	4.45	2.82	1.29	15.9	1921	1617	50	-	21	1.28	Y	Y
43	6.79	5.80	5.12	4.37	3.77	2.80	1.50	15.9	1419	1195	307	-	20	0.55	Y	Y
7	10.01	8.00	6.85	5.43	4.33	2.85	1.32	14.8	1574	1252	71	-	21	1.41	Y	N
17	9.03	6.76	5.78	4.66	3.88	2.68	1.35	15.9	404	341	214	-	22	1.38	Y	N
5	10.55	8.38	7.07	5.61	4.60	3.26	1.68	15.4	563	460	148	-	18	2.11	Y	N
8	10.83	8.70	7.35	5.82	4.61	2.93	1.25	14.8	2333	1855	33	-	21	2.58	Y	N
19	7.68	5.99	5.27	4.52	3.93	3.09	1.81	14.2	168	130	1309	-	18	3.77	Y	N
21	8.63	6.41	5.51	4.48	3.72	2.60	1.36	16.4	431	374	240	-	23	2.32	Y	N
23	7.22	5.82	5.19	4.50	3.95	3.14	1.87	14.2	207	160	1465	-	18	3.36	Y	N
24	7.89	6.82	6.23	5.51	4.89	3.35	1.79	17.5	562	516	385	-	17	3.19	Y	N
26	7.16	6.22	5.48	4.49	3.74	2.18	1.34	18.6	2637	2563	127	-	23	6.06	Y	N
39	10.54	7.66	6.54	5.28	4.47	3.26	1.80	16.9	111	99	571	-	18	4.82	Y	N
1	10.45	8.53	7.37	5.95	4.87	3.45	1.89	13.7	-	-	-	-	16	2.98	N	N
11	9.31	7.62	6.68	5.51	4.63	3.40	1.83	14.8	-	-	-	-	17	2.05	N	N
15	8.09	6.57	5.81	4.97	4.25	3.22	1.84	14.8	-	-	-	-	17	2.64	N	N
18	6.16	5.40	4.90	4.24	3.64	2.69	1.42	17.0	-	-	-	-	21	0.80	N	N
20	8.03	6.93	6.29	5.50	4.85	3.26	1.76	18.1	-	-	-	-	17	2.27	N	N
25	7.52	6.08	5.20	4.26	3.59	2.58	1.40	17.0	-	-	-	-	22	2.48	N	N
27	6.47	5.72	5.18	4.58	4.08	3.24	1.92	14.7	-	-	-	-	17	1.23	N	N
28	8.08	7.05	6.37	5.60	4.96	3.37	1.80	16.9	-	-	-	-	17	2.23	N	N
29	7.53	6.22	5.32	4.41	3.76	2.79	1.54	16.9	-	-	-	-	21	2.84	N	N
31	6.57	5.69	5.14	4.47	3.91	3.13	1.89	15.3	-	-	-	-	17	2.48	N	N
34	8.73	7.58	6.82	5.88	5.11	3.42	1.74	16.4	-	-	-	-	17	1.91	N	N
37	7.65	6.31	5.51	4.58	3.90	2.89	1.57	16.9	-	-	-	-	20	1.99	N	N
Average	8.05	6.83	6.03	5.01	4.21	3.00	1.57	15.9	2072	1754	188	-	19	0.78		
CV (%)	16	13	12	10	9	9	11	3	37	38	47	-	9	60		

MDT = Mid-depth temperature, TCAC = Temperature corrected asphalt concrete, RCS = Rubblized concrete slab, RB = Roadbed, RMS = Root mean square error

Table J5. Measured pavement deflections and backcalculated layer moduli for I-194 NB -section 2 test site 1

Route	I-194 NB		C.S.	13033		J.N.	29670		BMP	0.492		EMP	1.679			
FWD station	Deflection (mils)							MDT (°C)	Backcalculated modulus (ksi)					RMS (%)	Converged	Accepted
	0	8	12	16	24	36	60		AC	TC AC	RCS	Base	RB			
	D1	D2	D3	D4	D5	D6	D7									
1	4.38	3.99	3.71	3.35	3.03	2.48	1.69	15.9	2580	2087	171	50	25	0.21	Y	Y
2	4.85	4.40	4.10	3.66	3.28	2.73	1.80	16.1	1988	1623	230	28	24	0.80	Y	Y
3	5.19	4.69	4.39	3.93	3.55	2.91	1.96	16.2	1952	1604	188	33	22	0.27	Y	Y
4	4.94	4.42	4.10	3.67	3.24	2.73	1.79	16.3	1620	1341	260	29	24	1.05	Y	Y
5	5.11	4.48	4.11	3.65	3.29	2.70	1.80	16.4	1268	1052	252	39	24	0.47	Y	Y
6	5.13	4.58	4.22	3.72	3.35	2.79	1.87	16.9	1499	1275	201	45	23	0.96	Y	Y
7	5.28	4.75	4.39	3.91	3.50	2.78	1.83	16.9	1963	1676	108	41	23	0.21	Y	Y
9	5.31	4.68	4.33	3.85	3.43	2.81	1.85	17.3	1376	1199	216	33	23	0.49	Y	Y
10	4.42	3.98	3.69	3.30	3.01	2.46	1.67	17.3	2013	1753	253	41	26	0.45	Y	Y
11	4.99	4.42	4.10	3.66	3.31	2.75	1.87	18.0	1461	1317	261	42	23	0.49	Y	Y
13	4.86	4.11	3.76	3.31	2.98	2.45	1.68	18.5	1022	944	250	66	25	0.41	Y	Y
14	4.81	4.20	3.92	3.54	3.23	2.71	1.87	18.5	1239	1148	424	35	23	0.37	Y	Y
17	4.69	4.04	3.73	3.32	3.02	2.50	1.72	19.3	1173	1132	323	54	25	0.38	Y	Y
19	4.74	4.29	3.99	3.63	3.29	2.72	1.83	19.6	1962	1918	299	26	24	0.28	Y	Y
21	4.87	4.32	3.95	3.57	3.27	2.68	1.89	19.8	1473	1459	244	59	22	0.52	Y	Y
23	4.63	4.14	3.87	3.48	3.15	2.61	1.79	19.5	1844	1792	267	42	24	0.33	Y	Y
24	5.01	4.45	4.09	3.65	3.28	2.73	1.86	19.6	1499	1466	204	54	22	0.59	Y	Y
25	5.20	4.62	4.29	3.87	3.49	2.87	1.95	19.2	1517	1452	249	35	22	0.23	Y	Y
26	4.78	4.22	3.91	3.53	3.18	2.59	1.79	19.1	1642	1565	228	50	24	0.11	Y	Y
27	4.82	4.28	3.97	3.56	3.20	2.62	1.80	19.5	1758	1712	184	55	23	0.07	Y	Y
28	5.24	4.68	4.29	3.86	3.47	2.80	1.90	19.2	1640	1574	168	43	22	0.29	Y	Y
29	5.02	4.45	3.95	3.54	3.17	2.61	1.80	19.0	1319	1256	163	74	23	0.97	Y	Y
30	5.67	4.71	4.19	3.69	3.28	2.66	1.78	19.5	738	718	207	56	24	0.54	Y	Y
31	6.11	5.01	4.46	3.86	3.40	2.73	1.79	19.8	658	650	172	52	23	0.58	Y	Y
32	5.53	4.93	4.53	4.03	3.59	2.86	1.90	20.1	1677	1685	106	46	22	0.17	Y	Y
33	4.90	4.42	4.12	3.75	3.38	2.77	1.86	20.3	1918	1950	276	24	24	0.14	Y	Y
34	5.28	4.65	4.30	3.85	3.43	2.78	1.87	20.4	1509	1540	172	44	23	0.11	Y	Y
12	4.96	4.36	4.05	3.64	3.27	2.69	1.77	19.7	1315	1292	364	20	25	0.42	Y	N
18	4.64	4.17	3.87	3.54	3.24	2.74	1.87	20.1	1568	1578	489	20	24	0.54	Y	N
20	4.54	4.07	3.80	3.42	3.15	2.60	1.76	17.9	1716	1538	402	22	25	0.48	Y	N
22	4.94	4.42	4.12	3.71	3.39	2.82	1.89	22.9	1535	1780	379	19	24	0.49	Y	N
8	5.03	4.51	4.20	3.78	3.40	2.75	1.78	16.9	1770	1511	265	17	25	0.20	Y	N
15	4.74	4.22	3.94	3.58	3.24	2.67	1.81	20.7	1627	1690	364	24	24	0.14	Y	N
16	5.94	5.06	4.53	3.95	3.54	2.84	1.86	16.3	839	692	187	41	23	0.73	Y	N
35	9.27	6.97	6.17	5.12	4.45	3.34	1.99	16.4	288	240	148	20	22	0.62	Y	N
36	6.10	5.11	4.58	3.97	3.55	2.77	1.86	19.4	820	797	140	52	23	0.52	Y	N
Average	5.03	4.44	4.09	3.66	3.29	2.70	1.82	18.5	1567	1440	225	44	23	0.43		
CV (%)	7	6	6	5	5	5	4	8	26	25	29	28	4	63		

MDT = Mid-depth temperature, TCAC = Temperature corrected asphalt concrete, RCS = Rubblized concrete slab, RB = Roadbed, RMS = Root mean square error

Table J6. Measured pavement deflections and backcalculated layer moduli for I-194 NB -section 2 test site 2

Route	I-194 NB		C.S.	13033		J.N.	29670		BMP	0.479		EMP	1.679			
FWD station	Deflection (mils)							MDT (°C)	Backcalculated modulus (ksi)					RMS (%)	Converged	Accepted
	0	8	12	16	24	36	60		AC	TC AC	RCS	Base	RB			
	D1	D2	D3	D4	D5	D6	D7									
4	5.93	5.35	4.94	4.41	3.91	3.13	2.02	22.5	1835	2275	138	26	21	0.27	Y	Y
8	6.71	5.92	5.39	4.82	4.30	3.45	2.25	23.3	1095	1417	193	23	19	0.42	Y	Y
12	5.75	5.09	4.69	4.17	3.73	3.00	1.96	23.6	1395	1832	216	26	22	0.24	Y	Y
16	5.65	4.97	4.56	4.04	3.58	2.86	1.90	24.1	1491	2014	145	44	22	0.12	Y	Y
20	5.58	4.96	4.56	4.03	3.59	2.90	1.95	24.5	1645	2271	125	53	21	0.23	Y	Y
21	5.92	5.18	4.78	4.34	3.92	3.23	2.20	25.2	1070	1531	317	29	20	0.17	Y	Y
24	5.69	5.01	4.57	4.09	3.66	2.95	1.96	24.8	1293	1810	216	34	22	0.31	Y	Y
27	5.62	5.05	4.65	4.21	3.78	3.06	2.05	25.2	1668	2387	215	29	21	0.29	Y	Y
28	5.71	5.04	4.64	4.17	3.69	2.98	1.97	25.8	1428	2102	200	31	22	0.30	Y	Y
29	6.73	5.72	5.15	4.55	4.02	3.26	2.20	25.5	811	1178	155	49	19	0.34	Y	Y
30	6.29	5.65	5.21	4.68	4.20	3.38	2.22	25.6	1518	2219	186	22	20	0.25	Y	Y
31	6.41	5.37	4.82	4.25	3.76	3.03	2.00	24.6	732	1017	200	42	21	0.38	Y	Y
32	5.62	4.94	4.47	3.98	3.53	2.87	1.95	23.7	1323	1749	151	58	21	0.45	Y	Y
33	5.77	5.01	4.58	4.11	3.62	2.88	1.93	23.2	1285	1664	166	42	22	0.43	Y	Y
34	5.95	5.19	4.73	4.20	3.71	2.97	1.94	23.2	1186	1534	183	33	22	0.26	Y	Y
36	5.75	5.04	4.63	4.20	3.78	3.14	2.16	23.4	1115	1454	286	40	20	0.30	Y	Y
37	6.73	5.73	5.16	4.56	3.99	3.18	2.18	23.4	942	1228	105	61	19	0.35	Y	Y
38	6.68	5.76	5.19	4.58	4.00	3.20	2.11	23.1	989	1270	125	43	20	0.37	Y	Y
39	6.61	5.88	5.39	4.79	4.22	3.39	2.21	23.2	1375	1779	122	32	19	0.38	Y	Y
40	6.91	5.87	5.28	4.67	4.15	3.32	2.18	23.2	740	958	193	32	20	0.39	Y	Y
1	5.81	5.30	4.91	4.48	4.05	3.32	2.17	21.2	1780	2054	294	11	22	0.38	Y	N
2	5.52	5.06	4.76	4.36	3.94	3.29	2.21	21.2	2122	2448	313	13	21	0.36	Y	N
3	5.68	5.12	4.75	4.28	3.89	3.19	2.10	21.7	1508	1791	317	15	21	0.42	Y	N
6	5.85	5.34	4.93	4.48	4.02	3.32	2.19	21.7	1766	2097	243	18	20	0.55	Y	N
7	5.47	5.01	4.67	4.27	3.92	3.25	2.19	22.2	1862	2276	376	12	21	0.43	Y	N
9	6.17	5.64	5.23	4.78	4.32	3.48	2.28	22.8	1944	2445	212	13	20	0.33	Y	N
11	5.59	5.02	4.70	4.26	3.84	3.17	2.10	22.2	1555	1900	338	14	22	0.32	Y	N
15	5.46	4.88	4.52	4.13	3.76	3.08	2.08	22.2	1416	1730	378	17	22	0.24	Y	N
17	5.59	5.01	4.62	4.22	3.85	3.21	2.17	25.0	1289	1817	404	18	20	0.50	Y	N
19	5.38	4.86	4.52	4.14	3.75	3.12	2.10	22.7	1652	2077	363	17	21	0.33	Y	N
26	6.09	5.53	5.14	4.64	4.19	3.42	2.23	26.0	1662	2482	252	13	21	0.29	Y	N
23	5.55	4.99	4.62	4.20	3.80	3.14	2.11	22.7	1530	1924	313	21	21	0.34	Y	N
25	6.53	5.54	5.02	4.49	3.98	3.27	2.21	23.8	765	1019	221	42	19	0.39	Y	N
41	9.09	6.89	5.99	5.02	4.33	3.28	2.04	21.1	317	365	124	31	21	0.21	Y	N
42	6.46	5.40	4.80	4.19	3.71	2.96	1.96	22.1	726	887	168	47	21	0.43	Y	N
43	7.24	6.13	5.32	4.69	4.17	3.31	2.15	23.8	628	836	162	37	20	1.12	Y	N
5	6.53	6.04	5.59	5.05	4.48	3.48	2.05	21.7	-	-	-	-	-	4.43	N	N
10	6.28	5.80	5.40	4.95	4.46	3.60	2.31	22.8	-	-	-	-	-	2.79	N	N
13	5.47	4.96	4.59	4.22	3.86	3.26	2.18	24.4	-	-	-	-	-	1.19	N	N
14	6.08	5.51	5.12	4.67	4.24	3.43	2.24	25.0	-	-	-	-	-	1.95	N	N
22	6.00	5.42	5.03	4.58	4.15	3.41	2.21	24.4	-	-	-	-	-	1.65	N	N
35	7.07	6.33	5.81	5.08	4.37	3.26	1.97	23.8	-	-	-	-	-	2.57	N	N
18	5.98	5.40	5.03	4.56	4.15	3.39	2.21	25.5	-	-	-	-	-	1.04	N	N
Average	6.10	5.34	4.87	4.34	3.86	3.11	2.07	24.1	1247	1684	182	37	21	0.31		
CV (%)	8	7	6	6	6	6	6	4	25	26	29	30	6	28		

MDT = Mid-depth temperature, TCAC = Temperature corrected asphalt concrete, RCS = Rubblized concrete slab, RB = Roadbed, RMS = Root mean square error

Table J7. Measured pavement deflections and backcalculated layer moduli for US-10 EB -section 1 test site 1

Route	US-10 SB		C.S.	53022		J.N.	37974		BMP	3.495		EMP	9.395			
FWD station	Deflection (mils)							MDT (°C)	Backcalculated modulus (ksi)					RMS (%)	Converged	Accepted
	0	8	12	16	24	36	60		AC	TC AC	RCS	Base	RB			
	D1	D2⁻	D3	D4	D5	D6	D7									
1	9.93	8.52	7.51	6.23	5.28	3.84	2.21	31.7	863	1580	47	28	15	0.49	Y	Y
2	10.24	8.70	7.62	6.32	5.35	3.85	2.16	32.0	736	1363	59	21	16	0.51	Y	Y
3	9.89	8.40	7.40	6.18	5.26	3.84	2.17	32.0	736	1370	74	20	16	0.47	Y	Y
4	9.47	8.09	7.07	5.87	5.00	3.65	2.13	32.1	818	1527	57	30	16	0.64	Y	Y
6	10.51	9.03	8.02	6.71	5.62	3.95	2.25	32.4	1016	1930	24	33	15	0.29	Y	Y
7	9.73	8.23	7.34	6.24	5.37	3.98	2.29	32.7	694	1336	102	18	15	0.22	Y	Y
8	10.90	9.16	8.01	6.61	5.52	3.96	2.23	33.4	667	1330	51	22	15	0.34	Y	Y
9	10.48	8.92	7.91	6.67	5.74	4.31	2.43	33.9	623	1273	99	16	15	0.70	Y	Y
10	11.66	9.66	8.43	6.92	5.86	4.21	2.34	34.2	515	1071	64	18	15	0.52	Y	Y
11	9.54	8.10	7.08	5.85	4.94	3.62	2.12	34.2	801	1665	50	33	16	0.53	Y	Y
12	9.53	8.11	7.09	5.77	4.78	3.50	2.03	35.0	853	1849	35	42	16	0.77	Y	Y
13	9.62	8.08	7.09	5.90	5.05	3.75	2.20	35.7	680	1527	74	28	16	0.56	Y	Y
14	11.29	9.43	8.21	6.76	5.75	4.15	2.29	36.2	531	1222	72	17	15	0.72	Y	Y
15	9.36	7.98	6.99	5.83	4.87	3.55	2.07	36.2	891	2055	45	34	16	0.36	Y	Y
16	9.26	7.82	6.88	5.72	4.81	3.52	2.00	36.7	796	1881	65	26	17	0.43	Y	Y
17	9.39	7.81	6.85	5.74	4.89	3.65	2.15	36.9	644	1539	83	29	16	0.39	Y	Y
18	10.87	9.09	7.95	6.54	5.48	3.98	2.24	37.2	613	1489	58	22	15	0.52	Y	Y
19	9.39	7.99	7.06	5.87	4.92	3.51	2.03	37.3	982	2394	36	35	17	0.19	Y	Y
20	9.21	7.76	6.80	5.72	4.84	3.56	2.02	37.4	713	1751	88	22	17	0.45	Y	Y
21	9.15	7.60	6.57	5.57	4.86	3.69	2.17	37.6	523	1297	127	26	16	0.97	Y	Y
22	10.44	8.80	7.65	6.35	5.34	3.91	2.20	37.9	628	1584	68	21	16	0.68	Y	Y
23	9.58	8.04	6.98	5.79	4.85	3.45	1.96	38.1	746	1902	57	26	17	0.39	Y	Y
24	9.06	7.69	6.76	5.65	4.78	3.51	1.95	38.2	762	1949	89	20	18	0.63	Y	Y
25	9.00	7.45	6.56	5.54	4.78	3.55	2.13	38.6	644	1682	97	30	16	0.35	Y	Y
26	10.30	8.69	7.59	6.30	5.33	3.86	2.21	38.9	691	1829	59	24	16	0.49	Y	Y
27	9.76	8.26	7.22	5.91	4.87	3.44	1.91	39.1	848	2268	38	29	18	0.35	Y	Y
28	9.42	7.94	6.92	5.72	4.80	3.48	1.93	38.4	721	1865	72	22	18	0.64	Y	Y
29	9.13	7.62	6.65	5.55	4.76	3.53	2.09	37.9	672	1694	82	30	16	0.51	Y	Y
30	10.52	8.84	7.79	6.42	5.43	3.91	2.24	37.7	702	1744	53	25	15	0.36	Y	Y
31	10.20	8.55	7.37	6.01	4.94	3.41	1.91	37.8	768	1928	33	31	18	0.40	Y	Y
32	10.34	8.65	7.54	6.13	5.07	3.60	1.97	37.4	689	1686	49	23	17	0.51	Y	Y
33	10.04	8.43	7.29	5.95	4.90	3.44	1.97	37.0	792	1902	30	39	17	0.33	Y	Y
34	9.90	8.16	7.04	5.77	4.78	3.40	1.88	36.6	612	1445	63	23	18	0.41	Y	Y
35	10.90	8.87	7.65	6.21	5.09	3.58	2.02	36.9	563	1346	45	27	17	0.15	Y	Y
36	10.64	8.88	7.72	6.24	5.13	3.52	1.96	37.4	752	1844	29	31	17	0.29	Y	Y
37	9.63	7.95	6.90	5.67	4.71	3.42	2.05	37.7	722	1793	41	45	16	0.15	Y	Y
38	10.95	8.89	7.68	6.21	5.16	3.66	2.07	37.6	525	1303	52	26	16	0.31	Y	Y
39	10.97	9.11	7.92	6.60	5.57	4.06	2.29	37.8	541	1356	72	20	15	0.44	Y	Y
40	11.05	9.23	8.04	6.64	5.53	3.96	2.24	38.1	633	1608	49	23	15	0.29	Y	Y
5	10.66	9.14	8.17	6.88	5.81	4.21	2.28	32.6	787	1505	72	13	16	0.27	Y	N
Average	10.03	8.42	7.36	6.09	5.13	3.71	2.12	36.3	710	1646	61	27	16	0.45		
CV (%)	7	7	7	6	6	7	6	6	17	18	37	25	6	39		

MDT = Mid-depth temperature, TCAC = Temperature corrected asphalt cement, RCS = Rubblized concrete slab, RB = Roadbed, RMS = Root mean square error

Table J8. Measured pavement deflections and backcalculated layer moduli for US-10 EB -section 1 test site 2

Route	US-10 SB		C.S.	53022		J.N.	37974		BMP	3.495		EMP	9.395			
FWD station	Deflection (mils)							MDT (°C)	Backcalculated modulus (ksi)					RMS (%)	Converged	Accepted
	0	8	12	16	24	36	60		AC	TC AC	RCS	Base	RB			
	D1	D2	D3	D4	D5	D6	D7									
2	11.91	10.22	8.93	7.33	6.07	4.18	2.21	40.4	784	2246	33	17	15	0.45	Y	Y
4	11.39	9.37	8.19	6.65	5.55	3.97	2.17	40.5	529	1522	63	18	16	0.58	Y	Y
6	11.39	9.56	8.38	6.85	5.73	4.03	2.17	40.8	638	1861	56	16	16	0.45	Y	Y
8	12.25	10.23	8.87	7.20	5.95	4.23	2.31	41.1	563	1670	45	19	15	0.63	Y	Y
9	11.08	9.02	7.80	6.40	5.34	3.87	2.18	41.8	493	1516	67	22	16	0.41	Y	Y
10	13.26	11.06	9.49	7.36	5.88	3.94	2.16	41.8	602	1850	14	43	15	0.73	Y	Y
12	11.29	9.36	8.13	6.59	5.47	3.94	2.16	42.2	561	1767	57	20	16	0.71	Y	Y
13	12.78	10.58	9.12	7.43	6.16	4.33	2.28	42.6	471	1515	57	14	15	0.60	Y	Y
14	12.72	10.57	8.99	7.00	5.65	3.91	2.19	43.0	562	1839	20	38	15	0.91	Y	Y
15	13.29	11.05	9.50	7.67	6.24	4.28	2.23	43.0	523	1716	38	15	15	0.50	Y	Y
16	10.83	8.81	7.61	6.17	5.12	3.76	2.14	43.2	512	1697	60	27	16	0.72	Y	Y
17	12.80	10.40	8.88	7.22	5.98	4.19	2.26	43.3	415	1380	57	16	15	0.51	Y	Y
18	11.61	9.53	8.09	6.40	5.31	3.81	2.18	43.3	508	1695	39	31	15	1.02	Y	Y
19	13.53	11.07	9.44	7.54	6.13	4.17	2.16	43.6	443	1497	42	15	16	0.55	Y	Y
20	10.68	8.84	7.48	6.06	5.08	3.70	2.08	43.7	525	1787	59	26	16	1.14	Y	Y
21	12.35	10.16	8.74	7.03	5.77	4.03	2.21	43.8	525	1791	41	21	15	0.43	Y	Y
22	11.36	9.21	7.84	6.22	5.17	3.79	2.12	43.9	449	1539	54	27	16	1.24	Y	Y
23	13.72	11.17	9.47	7.54	6.15	4.16	2.17	44.0	423	1458	41	15	16	0.57	Y	Y
24	11.01	8.93	7.63	6.17	5.10	3.73	2.10	44.1	477	1656	59	27	16	0.85	Y	Y
25	12.37	9.90	8.57	6.97	5.68	3.98	2.20	44.3	449	1575	51	20	16	0.19	Y	Y
26	11.41	9.40	8.03	6.36	5.28	3.78	2.12	44.4	529	1866	43	27	16	1.00	Y	Y
27	13.66	11.37	9.79	7.77	6.21	4.11	2.12	44.4	582	2053	22	19	16	0.33	Y	Y
28	11.07	8.93	7.67	6.27	5.23	3.80	2.08	44.1	431	1497	79	20	17	0.71	Y	Y
29	12.28	9.85	8.49	6.84	5.63	3.88	2.14	43.9	458	1567	49	20	16	0.22	Y	Y
30	11.41	9.38	8.10	6.56	5.40	3.80	2.14	43.7	581	1974	42	25	16	0.27	Y	Y
31	13.80	11.52	9.86	7.72	6.21	4.08	2.16	43.9	587	2016	16	26	15	0.60	Y	Y
32	12.66	10.35	8.93	7.22	5.89	4.03	2.14	43.7	504	1712	44	17	16	0.17	Y	Y
33	11.59	9.24	7.90	6.32	5.23	3.64	2.02	43.5	442	1487	55	22	17	0.39	Y	Y
34	12.34	9.86	8.47	6.75	5.52	3.80	2.12	43.3	466	1552	40	24	16	0.23	Y	Y
35	11.68	9.43	8.12	6.56	5.32	3.64	2.06	43.5	569	1915	34	28	16	0.35	Y	Y
36	13.21	10.59	9.06	7.26	5.83	3.88	2.04	43.8	455	1553	39	17	17	0.24	Y	Y
37	12.44	10.01	8.60	6.92	5.65	3.90	2.19	43.5	491	1645	38	24	15	0.23	Y	Y
38	12.21	10.00	8.63	6.97	5.84	4.11	2.28	42.9	484	1577	53	20	15	0.55	Y	Y
39	11.20	9.02	7.80	6.33	5.25	3.69	2.15	42.4	540	1715	45	30	16	0.33	Y	Y
40	11.62	9.45	8.12	6.56	5.41	3.81	2.13	42.0	507	1581	49	23	16	0.32	Y	Y
1	13.49	11.22	9.85	8.03	6.64	4.50	2.27	39.8	532	1480	50	10	15	0.23	Y	N
3	10.57	8.72	7.66	6.37	5.35	3.83	2.06	39.3	552	1490	90	15	17	0.20	Y	N
5	10.94	9.16	8.06	6.70	5.63	4.07	2.15	40.4	571	1632	89	13	17	0.57	Y	N
7	13.04	10.71	9.30	7.66	6.41	4.52	2.32	40.9	404	1186	78	10	15	0.54	Y	N
11	13.32	11.06	9.54	7.79	6.40	4.34	2.24	40.6	517	1495	45	13	15	0.37	Y	N
Average	12.12	9.93	8.54	6.86	5.64	3.94	2.16	43.1	517	1694	46	23	16	0.55		
CV (%)	7	8	8	7	7	5	3	3	14	11	31	29	3	51		

MDT = Mid-depth temperature, TCAC = Temperature corrected asphalt concrete, RCS = Rubblized concrete slab, RB = Roadbed, RMS = Root mean square error

Table J9. Measured pavement deflections and backcalculated layer moduli for US-23 SB -section 1 test site 1

Route	US-23 SB		C.S.	04031		J.N.	44350		BMP	4.218		EMP	7.893			
FWD station	Deflection (mils)							MDT (°C)	Backcalculated modulus (ksi)					RMS (%)	Converged	Accepted
	0	8	12	16	24	36	60		AC	TC AC	RCS	Base	RB			
	D1	D2	D3	D4	D5	D6	D7									
1	12.05	9.61	8.37	6.87	5.68	3.98	2.19	40.2	597	1694	55	33	11	0.81	Y	Y
2	11.58	8.98	7.69	6.25	5.26	3.78	2.15	39.9	446	1245	66	42	11	0.54	Y	Y
3	11.80	8.82	7.52	6.22	5.18	3.75	2.12	39.7	319	880	82	40	11	0.72	Y	Y
4	11.55	9.06	7.63	6.21	5.17	3.70	2.14	39.5	518	1415	50	51	11	0.65	Y	Y
5	11.51	9.02	7.89	6.36	5.22	3.73	2.19	39.3	673	1821	37	62	10	1.01	Y	Y
7	11.03	8.69	7.48	6.40	5.35	3.72	2.14	38.9	515	1363	82	35	11	1.79	Y	Y
8	11.03	8.69	7.59	6.21	5.24	3.76	2.12	38.6	531	1383	73	38	11	0.63	Y	Y
9	11.05	8.66	7.42	6.22	5.19	3.77	2.13	38.6	455	1186	83	38	11	0.63	Y	Y
10	11.22	8.90	7.56	6.18	5.20	3.75	2.17	39.0	547	1457	57	49	11	0.57	Y	Y
11	11.53	8.80	7.66	6.27	5.23	3.74	2.19	39.5	464	1268	63	46	11	1.23	Y	Y
12	11.62	8.81	7.50	6.22	5.17	3.71	2.16	40.2	394	1116	68	46	11	1.14	Y	Y
13	12.12	9.22	7.96	6.61	5.56	3.98	2.20	40.8	325	950	91	32	11	0.70	Y	Y
14	11.48	9.29	7.93	6.38	5.29	3.78	2.08	41.5	626	1894	49	40	11	0.24	Y	Y
15	12.46	9.46	8.22	6.80	5.66	4.00	2.17	42.2	328	1030	88	28	11	0.86	Y	Y
16	12.31	9.71	8.39	6.86	5.73	4.07	2.27	42.9	493	1609	60	34	10	0.61	Y	Y
17	12.70	10.00	8.69	7.18	5.93	4.17	2.25	43.7	457	1549	68	26	11	0.73	Y	Y
18	12.39	9.63	8.36	7.02	5.91	4.17	2.30	44.0	363	1256	92	27	11	0.97	Y	Y
19	13.97	11.23	9.62	7.68	6.29	4.29	2.28	43.8	564	1927	36	29	10	0.48	Y	Y
20	13.60	10.61	9.06	7.30	6.01	4.30	2.39	43.7	428	1454	47	35	10	0.32	Y	Y
21	15.14	11.94	10.18	8.11	6.55	4.40	2.38	43.3	518	1726	27	33	10	0.92	Y	Y
24	15.26	11.63	9.73	7.67	6.18	4.22	2.28	43.8	368	1255	35	28	10	0.69	Y	Y
25	15.14	11.80	9.74	7.63	6.08	4.12	2.26	44.2	453	1575	24	33	10	0.66	Y	Y
26	14.55	11.53	9.69	7.51	6.07	4.11	2.26	44.7	534	1905	22	45	10	0.51	Y	Y
27	15.24	11.86	9.85	7.71	6.30	4.30	2.34	45.1	399	1460	32	49	10	0.60	Y	Y
28	12.92	10.16	8.75	7.00	5.78	3.95	2.16	45.5	544	2023	42	35	11	0.93	Y	Y
29	14.28	11.26	9.40	7.46	6.15	4.33	2.33	46.2	407	1568	42	34	10	0.42	Y	Y
30	14.23	11.20	9.51	7.72	6.34	4.47	2.45	46.9	430	1721	45	32	10	0.44	Y	Y
31	15.51	12.05	10.35	8.44	6.72	4.46	2.36	47.4	471	1938	34	31	10	1.51	Y	Y
32	14.87	11.33	9.73	7.93	6.54	4.56	2.54	47.6	344	1426	51	25	9	1.11	Y	Y
33	14.98	11.43	9.57	7.69	6.24	4.33	2.37	47.3	350	1433	41	29	10	0.76	Y	Y
34	15.61	11.97	10.09	7.90	6.40	4.37	2.31	46.9	360	1445	37	32	10	0.47	Y	Y
35	16.13	12.50	10.68	8.31	6.59	4.37	2.39	46.5	505	1984	18	28	10	1.03	Y	Y
36	15.60	12.11	10.22	8.16	6.56	4.35	2.35	46.0	453	1726	29	47	10	1.23	Y	Y
37	15.19	11.79	10.02	8.04	6.49	4.33	2.31	45.4	440	1629	35	31	10	1.15	Y	Y
38	15.22	11.58	9.87	7.92	6.44	4.35	2.34	44.8	362	1299	43	27	10	1.21	Y	Y
39	14.66	11.31	9.56	7.67	6.31	4.31	2.30	44.0	369	1274	47	26	10	0.79	Y	Y
40	14.90	11.37	9.53	7.60	6.22	4.31	2.31	43.5	330	1112	47	27	10	0.46	Y	Y
41	14.82	11.23	9.44	7.62	6.18	4.29	2.32	43.2	327	1082	48	29	10	0.75	Y	Y
42	14.49	11.31	9.40	7.44	6.14	4.32	2.33	43.3	373	1241	42	29	10	0.43	Y	Y
43	14.48	11.30	9.56	7.45	6.04	4.28	2.35	43.5	444	1489	31	33	10	0.26	Y	Y
44	13.95	10.92	9.42	7.65	6.10	4.24	2.35	44.0	553	1904	32	41	10	1.13	Y	Y
45	14.19	10.69	9.28	7.49	6.17	4.21	2.36	44.6	380	1351	49	39	10	1.64	Y	Y

MDT = Mid-depth temperature, TCAC = Temperature corrected asphalt concrete, RCS = Rubblized concrete slab, RB = Roadbed, RMS = Root mean square error

Table J9.(continued) Measured pavement deflections and backcalculated layer moduli for US-23 SB-section 1 test site 1

Route	US-23 SB		C.S.	04031		J.N.	44350		BMP	4.218		EMP	7.893			
FWD station	Deflection (mils)							MDT (°C)	Backcalculated modulus (ksi)					RMS (%)	Converged	Accepted
	0	8	12	16	24	36	60		AC	TC AC	RCS	Base	RB			
	D1	D2	D3	D4	D5	D6	D7									
46	14.20	10.83	9.24	7.50	6.12	4.29	2.39	45.3	376	1390	47	32	10	0.96	Y	Y
47	16.57	12.61	10.55	8.33	6.74	4.60	2.44	46.2	315	1215	37	33	10	0.57	Y	Y
48	15.73	12.10	10.47	8.40	6.88	4.70	2.43	47.0	336	1351	52	26	10	0.76	Y	Y
49	13.98	11.06	9.62	7.54	6.08	4.15	2.21	47.0	584	2350	29	20	10	0.70	Y	Y
50	14.30	11.02	9.53	7.77	6.35	4.43	2.36	46.6	366	1445	58	35	10	0.79	Y	Y
51	15.57	11.20	9.66	7.90	6.52	4.52	2.43	46.4	195	761	74	25	10	1.25	Y	Y
52	14.83	11.49	10.10	8.20	6.76	4.71	2.60	46.4	418	1634	48	24	9	1.21	Y	Y
6	11.25	8.67	7.69	6.53	5.31	3.72	2.14	39.0	250	965	170	-	11	2.13	Y	N
22	14.42	11.58	9.94	7.91	6.32	4.21	error	46.2	-	-	-	-	100	-	N	N
Avg	13.75	10.65	9.09	7.33	6.01	4.17	2.29	43.6	436	1474	50	34	10	0.82		
CV(%)	12	11	11	10	8	7	5	6	22	22	38	24	5	43		

MDT = Mid-depth temperature, TCAC = Temperature corrected asphalt concrete, RCS = Rubblized concrete slab, RB = Roadbed, RMS = Root mean square error

Table J10. Measured pavement deflections and backcalculated layer moduli for US-23 SB-section 1 test site 2

Route	US-23 SB	C.S.	04031	J.N.	44350	BMP	4.218	EMP	7.893	Converged	Accepted
FWD station	Deflection (mils)					MDT (°C)	Backcalculated modulus (ksi)			RMS (%)	
	0	8	12	16	24	36	60		AC	TC AC	RCS	Base	RB			
	D1	D2	D3	D4	D5	D6	D7									
1	14.53	9.95	8.34	7.22	6.25	4.65	2.52	49.3	111	505	155	35	10	0.84	Y	Y
2	14.64	9.88	8.29	7.24	6.27	4.64	2.52	49.4	102	464	174	34	10	0.87	Y	Y
3	14.47	9.55	8.24	7.38	6.29	4.61	2.42	49.5	88	403	310	24	10	0.80	Y	Y
4	13.57	9.45	8.01	6.97	6.03	4.44	2.43	49.8	126	585	172	35	10	0.70	Y	Y
5	16.05	11.39	10.34	9.03	7.87	5.92	3.30	50.5	105	508	241	23	7	0.54	Y	Y
6	14.64	10.14	9.22	8.03	6.78	5.08	2.87	50.4	118	568	200	29	9	1.34	Y	Y
7	15.00	9.96	8.62	7.42	6.41	4.65	2.54	51.0	98	483	181	31	10	0.57	Y	Y
8	15.26	11.52	9.99	8.39	7.14	5.23	2.95	50.6	223	1081	84	28	8	0.54	Y	Y
9	15.38	10.69	8.88	7.38	6.30	4.61	2.56	50.7	141	685	84	37	9	0.40	Y	Y
10	16.89	12.27	10.37	8.34	7.08	5.18	2.90	50.9	189	933	56	33	8	0.38	Y	Y
11	14.13	10.55	9.23	7.62	6.42	4.57	2.50	51.0	246	1221	87	26	10	0.86	Y	Y
12	16.94	11.69	9.69	8.10	6.66	4.70	2.55	51.4	132	669	74	28	9	1.04	Y	Y
13	15.49	10.48	8.93	7.42	6.26	4.47	2.46	51.2	126	632	97	33	10	0.89	Y	Y
14	14.92	10.75	9.36	7.82	6.60	4.73	2.55	51.4	165	835	108	25	10	0.66	Y	Y
16	18.11	11.85	10.68	8.91	7.42	5.30	2.90	51.8	90	465	120	24	8	1.84	Y	Y
17	17.43	12.13	10.50	8.81	7.41	5.33	2.92	51.3	121	608	95	25	8	0.84	Y	Y
18	16.14	11.60	9.43	7.49	6.24	4.38	2.43	51.2	204	1018	47	36	10	0.77	Y	Y
19	15.80	11.48	9.30	7.52	6.21	4.36	2.42	51.2	214	1069	49	35	10	0.96	Y	Y
20	16.21	11.28	9.42	7.94	6.68	4.61	2.44	51.2	126	629	99	24	10	1.08	Y	Y
21	16.43	11.32	9.26	7.62	6.15	4.19	2.28	51.7	155	798	61	29	11	1.65	Y	Y
22	15.50	11.48	9.44	7.50	6.21	4.38	2.43	51.6	260	1329	44	36	10	0.61	Y	Y
23	15.58	10.87	9.04	7.51	6.38	4.59	2.45	51.9	135	701	92	30	10	0.45	Y	Y
24	16.94	12.09	9.95	7.98	6.66	4.60	2.50	52.1	177	925	54	29	10	0.94	Y	Y
25	17.89	12.96	10.95	9.04	7.56	5.37	2.90	51.9	158	819	67	23	8	0.55	Y	Y
26	17.19	12.29	10.49	8.87	7.47	5.32	2.83	51.8	130	674	99	22	9	0.57	Y	Y
15	17.08	13.47	11.55	9.59	8.16	6.01	3.30	52.7	265	1433	63	22	7	0.30	Y	N
Average	15.80	11.10	9.44	7.90	6.67	4.80	2.62	51.0	150	744	114	29	9	0.83		
CV (%)	8	8	9	8	8	9	9	2	33	34	58	16	8	44		

MDT = Mid-depth temperature, TCAC = Temperature corrected asphalt concrete, RCS = Rubblized concrete slab, RB = Roadbed, RMS = Root mean square error

Table J11. Measured pavement deflections and backcalculated layer moduli for US-27 SB-section 2 test site 1

Route	US-27 SB		C.S.	37013		J.N.	21186		BMP	8.952		EMP	11.719			
FWD station	Deflection (mils)							MDT (°C)	Backcalculated modulus (ksi)					RMS (%)	Converged	Accepted
	0	8	12	16	24	36	60		AC	TC AC	RCS	Base	RB			
	D1	D2	D3	D4	D5	D6	D7									
1	8.41	7.10	6.16	4.97	4.07	2.83	1.46	22.8	1638	1893	86	27	20	0.36	Y	Y
2	8.35	7.03	6.12	4.84	3.98	2.71	1.41	23.1	1764	2069	70	31	21	0.55	Y	Y
3	7.74	6.63	5.80	4.68	3.87	2.70	1.42	23.3	2101	2488	81	32	21	0.44	Y	Y
4	7.92	6.73	5.83	4.64	3.83	2.68	1.42	23.2	1833	2160	77	36	20	0.65	Y	Y
5	8.39	6.93	5.96	4.68	3.86	2.65	1.40	23.1	1383	1623	80	33	21	0.60	Y	Y
6	8.09	6.74	5.86	4.68	3.90	2.73	1.45	23.2	1484	1749	96	32	20	0.52	Y	Y
8	8.20	6.72	5.74	4.55	3.75	2.66	1.41	23.2	1176	1388	97	36	21	0.67	Y	Y
9	8.70	7.05	6.01	4.63	3.75	2.53	1.39	23.4	1429	1701	48	52	21	0.57	Y	Y
10	8.03	6.72	5.84	4.63	3.81	2.60	1.39	23.4	1875	2232	63	40	21	0.42	Y	Y
11	7.49	6.42	5.66	4.59	3.86	2.71	1.47	23.5	2208	2641	88	35	20	0.50	Y	Y
12	7.23	6.23	5.48	4.44	3.69	2.61	1.42	23.6	2489	2990	75	41	21	0.46	Y	Y
13	8.63	7.42	6.24	4.94	4.07	2.56	1.29	23.9	2120	2590	40	32	22	1.36	Y	Y
14	7.43	6.36	5.59	4.53	3.73	2.61	1.39	24.1	2365	2926	74	37	21	0.28	Y	Y
15	7.00	5.98	5.30	4.40	3.70	2.71	1.49	24.1	1944	2406	140	34	20	0.41	Y	Y
16	6.84	5.86	5.12	4.17	3.52	2.58	1.43	24.2	2012	2500	114	44	21	0.72	Y	Y
18	6.85	5.80	5.06	4.16	3.53	2.57	1.42	24.4	1704	2137	141	39	21	0.47	Y	Y
19	6.63	5.60	4.96	4.15	3.55	2.65	1.46	24.2	1419	1758	211	33	21	0.56	Y	Y
20	6.60	5.59	4.83	3.99	3.37	2.53	1.41	24.3	1592	1988	151	46	21	0.86	Y	Y
22	6.52	5.51	4.82	3.96	3.35	2.53	1.41	24.3	1619	2024	159	45	21	0.99	Y	Y
23	6.47	5.49	4.84	4.07	3.49	2.69	1.44	24.1	1226	1515	266	29	21	1.29	Y	Y
24	6.39	5.43	4.82	3.98	3.38	2.55	1.41	24.3	1808	2253	173	41	21	0.87	Y	Y
26	6.49	5.49	4.83	3.95	3.36	2.50	1.42	24.1	1864	2304	137	50	21	0.65	Y	Y
27	6.72	5.74	5.11	4.31	3.66	2.72	1.48	23.6	1674	2020	207	27	21	0.47	Y	Y
28	6.40	5.52	4.90	4.07	3.43	2.55	1.42	23.6	2299	2764	145	40	21	0.63	Y	Y
30	6.98	5.79	5.05	4.09	3.47	2.51	1.38	23.4	1412	1684	142	40	21	0.59	Y	Y
31	7.15	6.18	5.54	4.70	3.97	2.87	1.53	23.4	2158	2565	172	20	20	0.10	Y	Y
32	7.52	6.35	5.64	4.63	3.93	2.83	1.56	23.3	1724	2042	127	33	19	0.41	Y	Y
33	6.79	5.93	5.28	4.35	3.69	2.70	1.49	23.1	2685	3154	110	38	20	0.63	Y	Y
34	7.13	6.08	5.30	4.32	3.64	2.64	1.42	23.1	1706	1997	134	33	21	0.74	Y	Y
35	7.95	6.83	5.88	4.71	3.92	2.71	1.40	23.2	1839	2171	86	29	21	0.79	Y	Y
36	7.26	6.16	5.44	4.47	3.74	2.63	1.45	23.3	2250	2669	91	39	20	0.31	Y	Y
37	7.94	7.09	6.19	5.03	4.15	2.80	1.40	23.5	3216	3849	38	32	21	0.75	Y	Y
38	6.73	5.82	5.20	4.27	3.60	2.66	1.48	23.2	2536	2987	109	43	20	0.65	Y	Y
39	6.65	5.68	5.04	4.14	3.51	2.60	1.42	23.2	1938	2283	153	36	21	0.73	Y	Y
40	6.92	5.84	5.09	4.15	3.52	2.55	1.41	23.2	1703	2006	129	41	21	0.52	Y	Y
7	9.75	7.91	6.68	5.18	4.09	2.66	1.31	22.0	1175	1303	59	25	22	0.13	Y	N
41	11.70	9.15	7.42	5.20	4.13	2.62	1.30	22.6	709	809	39	30	22	1.67	Y	N
42	8.23	6.86	5.93	4.74	3.89	2.64	1.33	22.6	1484	1695	96	25	22	0.34	Y	N
43	9.27	7.37	6.14	4.69	3.74	2.49	1.36	22.6	1161	1326	46	49	21	0.45	Y	N
44	8.59	6.90	5.86	4.56	3.79	2.59	1.40	23.1	1075	1264	82	38	21	0.72	Y	N
45	10.87	9.30	7.40	5.14	4.02	2.64	1.34	23.3	1048	1244	24	54	21	3.05	Y	N
17	8.13	7.11	6.25	4.99	4.03	2.44	1.31	24.9	-	-	-	-	20	7.07	N	N
21	7.99	6.91	6.12	4.99	4.01	2.49	1.32	26.0	-	-	-	-	5	4.99	N	N
25	7.75	6.77	6.01	4.94	4.02	2.61	1.33	24.9	-	-	-	-	22	2.40	N	N
29	7.93	7.01	6.15	5.00	4.09	2.66	1.35	24.9	-	-	-	-	21	1.02	N	N
Average	7.33	6.22	5.44	4.43	3.70	2.65	1.43	23.6	1891	2272	117	36	21	0.61		
CV (%)	10	9	8	7	6	4	3	2	23	23	43	18	3	41		

MDT = Mid-depth temperature, TCAC = Temperature corrected asphalt concrete, RCS = Rubblized concrete slab, RB = Roadbed, RMS = Root mean square error

Table J12. Measured pavement deflections and backcalculated layer moduli for US-27 SB-section 3 test site 1

Route	US-27 SB		C.S.	37013		J.N.	38205		BMP	8.062		EMP	9.007			
FWD station	Deflection (mils)							MDT (°C)	Backcalculated modulus (ksi)					RMS (%)	Converged	Accepted
	0	8	12	16	24	36	60		AC	TC AC	RCS	Base	RB			
	D1	D2	D3	D4	D5	D6	D7									
1	12.70	10.38	9.00	7.34	6.11	4.21	2.04	33.0	403	785	57	14	13	0.46	Y	Y
3	12.20	10.04	8.69	7.06	5.81	3.94	1.90	33.1	466	916	46	16	14	0.35	Y	Y
4	11.80	9.97	8.75	7.26	5.94	3.98	1.93	33.1	686	1352	26	20	13	0.28	Y	Y
8	12.61	10.34	8.99	7.33	5.91	3.90	1.87	32.9	515	1003	30	18	14	0.26	Y	Y
9	12.05	9.90	8.57	7.03	5.83	4.05	2.02	33.2	447	884	53	17	13	0.36	Y	Y
10	11.70	9.69	8.50	7.20	6.04	4.18	2.11	33.5	499	1001	67	14	13	0.55	Y	Y
11	12.41	10.14	8.83	7.26	6.08	4.21	2.07	33.8	407	828	64	14	13	0.37	Y	Y
12	11.74	9.77	8.58	7.10	5.88	3.97	1.97	34.4	587	1231	39	18	13	0.40	Y	Y
14	11.27	9.21	8.04	6.78	5.74	4.03	2.07	34.6	436	925	82	16	13	0.48	Y	Y
15	12.05	9.86	8.67	7.25	6.06	4.24	2.10	34.2	428	891	73	13	13	0.09	Y	Y
16	12.86	10.17	8.73	7.10	5.78	3.90	1.88	33.8	347	706	53	16	14	0.16	Y	Y
17	10.95	8.83	7.76	6.48	5.42	3.86	2.02	33.3	439	870	75	20	13	0.11	Y	Y
18	11.48	9.39	8.28	6.95	5.79	3.89	1.90	33.4	506	1010	65	13	14	0.77	Y	Y
21	12.57	9.99	8.46	6.87	5.65	3.82	1.83	33.7	334	678	59	15	14	0.48	Y	Y
22	10.84	8.68	7.58	6.39	5.35	3.83	2.01	34.0	396	817	89	19	13	0.26	Y	Y
25	12.16	9.86	8.56	6.95	5.71	3.78	1.83	34.5	464	978	43	17	14	0.42	Y	Y
26	10.71	8.66	7.70	6.53	5.54	3.89	2.01	33.8	444	904	100	15	13	0.63	Y	Y
27	12.21	10.00	8.77	7.36	6.13	4.23	2.13	33.5	455	913	61	15	12	0.41	Y	Y
29	12.21	10.00	8.58	7.06	5.72	3.76	1.80	33.5	499	1004	36	17	14	0.57	Y	Y
30	10.91	8.89	7.87	6.65	5.56	3.83	2.00	32.5	538	1026	63	19	13	0.89	Y	Y
31	12.62	10.29	8.94	7.40	6.08	4.14	2.11	32.8	459	890	41	19	12	0.45	Y	Y
32	12.45	9.99	8.69	7.11	5.80	3.87	1.96	32.7	455	876	37	21	13	0.62	Y	Y
33	11.77	9.43	8.20	6.76	5.58	3.80	1.92	32.4	427	812	55	19	13	0.46	Y	Y
34	11.19	9.15	8.10	6.83	5.68	3.78	1.86	32.8	558	1078	60	14	14	1.05	Y	Y
35	11.88	9.58	8.32	6.80	5.55	3.67	1.79	32.7	475	916	43	18	14	0.50	Y	Y
36	11.54	9.37	8.16	6.66	5.41	3.51	1.74	32.7	581	1121	27	25	15	0.83	Y	Y
37	12.44	10.07	8.63	6.97	5.62	3.61	1.77	32.7	502	969	24	25	14	0.69	Y	Y
38	11.87	9.55	8.25	6.75	5.54	3.73	1.81	32.9	422	822	55	16	14	0.30	Y	Y
39	11.31	9.21	8.02	6.59	5.43	3.73	1.88	33.4	488	973	51	20	14	0.13	Y	Y
40	11.30	9.07	7.87	6.63	5.50	3.79	1.97	33.8	426	869	68	19	13	0.74	Y	Y
2	12.35	10.17	8.91	7.41	6.17	4.18	2.00	33.7	462	935	61	12	13	0.34	Y	N
5	12.87	10.58	9.27	7.65	6.25	4.08	1.88	33.2	506	998	40	12	14	0.54	Y	N
6	12.52	10.34	9.08	7.54	6.20	4.16	1.93	33.2	486	959	55	11	14	0.26	Y	N
7	13.53	10.89	9.41	7.70	6.37	4.19	1.90	33.2	352	695	60	10	14	0.47	Y	N
13	13.20	10.72	9.25	7.67	6.30	4.13	1.89	34.4	397	836	56	10	14	0.65	Y	N
19	12.03	9.65	8.47	7.13	6.01	4.23	2.09	32.9	343	667	100	11	13	0.15	Y	N
20	11.34	9.08	7.94	6.71	5.63	3.84	1.89	33.4	385	771	94	12	14	0.76	Y	N
23	12.21	9.84	8.70	7.39	6.21	4.29	2.14	32.9	380	740	89	11	13	0.68	Y	N
24	11.38	9.15	8.05	6.79	5.69	3.85	1.84	32.9	405	790	94	10	15	0.72	Y	N
28	11.04	9.25	8.18	6.94	5.74	3.83	1.83	33.0	689	1346	49	13	15	0.81	Y	N
Average	11.86	9.65	8.40	6.95	5.74	3.90	1.94	33.4	470	935	55	17	13	0.47		
CV (%)	5	5	5	4	4	5	6	2	15	15	34	18	5	50		

MDT = Mid-depth temperature, TCAC = Temperature corrected asphalt concrete, RCS = Rubblized concrete slab, RB = Roadbed, RMS = Root mean square error

Table J13. Measured pavement deflections and backcalculated layer moduli for US-27 SB-section 4 test site 1

Route	US-27 SB	C.S.	37014	J.N.	38205	BMP	0.000	EMP	1.533						Converged	Accepted
FWD station	Deflection (mils)							MDT (°C)	Backcalculated modulus (ksi)					RMS (%)		
	0	8	12	16	24	36	60		AC	TC AC	RCS	Base	RB			
	D1	D2	D3	D4	D5	D6	D7									
1	6.87	5.09	4.43	3.78	3.25	2.45	1.42	36.9	358	856	242	48	21	0.05	Y	Y
2	6.96	5.11	4.43	3.82	3.32	2.52	1.44	37.0	309	744	307	44	21	0.37	Y	Y
3	6.74	4.83	4.23	3.71	3.21	2.43	1.41	37.2	282	685	399	45	22	0.27	Y	Y
4	7.42	5.32	4.49	3.83	3.27	2.47	1.39	37.3	278	679	229	49	22	0.68	Y	Y
5	6.92	4.76	4.13	3.64	3.22	2.48	1.38	37.5	211	522	688	37	22	0.80	Y	Y
6	6.77	4.82	4.17	3.65	3.16	2.36	1.36	37.8	278	695	365	47	22	0.44	Y	Y
7	7.03	5.24	4.64	4.11	3.64	2.78	1.53	37.6	276	685	630	20	21	0.57	Y	Y
8	6.90	4.94	4.30	3.80	3.35	2.51	1.45	37.4	259	636	464	42	21	0.52	Y	Y
9	7.67	5.54	4.81	4.08	3.47	2.56	1.47	37.4	300	738	208	43	21	0.40	Y	Y
10	7.43	5.33	4.59	3.93	3.41	2.60	1.49	37.4	271	666	268	49	20	0.46	Y	Y
11	6.24	4.40	3.95	3.49	3.09	2.37	1.42	37.4	272	668	621	53	22	0.32	Y	Y
12	7.21	4.97	4.29	3.71	3.20	2.46	1.41	37.6	234	582	339	53	21	0.42	Y	Y
14	7.03	4.97	4.34	3.80	3.32	2.59	1.48	38.1	243	617	460	46	21	0.64	Y	Y
15	6.28	4.11	3.70	3.34	2.95	2.34	1.42	38.7	207	543	1061	63	21	0.40	Y	Y
16	5.94	4.09	3.66	3.30	2.93	2.36	1.44	38.7	249	653	908	71	21	0.41	Y	Y
18	6.38	4.24	3.79	3.39	3.04	2.44	1.49	38.9	211	559	897	75	20	0.35	Y	Y
19	5.90	3.98	3.52	3.19	2.86	2.29	1.38	39.0	228	608	1131	66	22	0.53	Y	Y
20	5.79	3.86	3.41	3.12	2.80	2.27	1.41	39.0	224	597	1233	82	21	0.51	Y	Y
22	6.32	4.03	3.54	3.24	2.91	2.41	1.48	39.0	182	486	1409	80	20	0.83	Y	Y
24	5.86	3.73	3.31	3.09	2.83	2.30	1.44	39.1	190	510	2783	40	22	0.42	Y	Y
26	6.02	3.81	3.42	3.16	2.89	2.39	1.49	39.0	183	487	2997	32	21	0.48	Y	Y
27	5.64	3.67	3.33	3.09	2.79	2.26	1.38	38.8	211	556	2854	23	24	0.24	Y	Y
28	5.87	3.78	3.42	3.18	2.87	2.31	1.42	38.4	199	514	2630	27	23	0.29	Y	Y
31	5.81	4.01	3.55	3.21	2.88	2.31	1.41	37.9	250	627	987	71	21	0.55	Y	Y
32	5.92	4.19	3.72	3.39	2.99	2.40	1.43	37.8	263	657	992	52	21	0.67	Y	Y
34	6.42	4.17	3.73	3.39	3.03	2.39	1.41	37.5	190	469	1505	37	22	0.12	Y	Y
35	6.70	4.39	3.72	3.31	2.95	2.36	1.38	37.8	194	486	596	78	22	1.27	Y	Y
36	6.35	4.07	3.55	3.25	2.89	2.28	1.34	37.9	185	464	1386	47	23	0.54	Y	Y
38	6.33	4.18	3.63	3.28	2.92	2.33	1.37	37.9	200	502	1028	59	22	0.84	Y	Y
39	6.26	4.20	3.74	3.41	3.00	2.44	1.43	37.8	209	525	1331	43	22	0.87	Y	Y
40	6.17	4.07	3.56	3.28	2.97	2.43	1.45	38.0	192	485	2043	36	22	1.05	Y	Y
13	6.62	4.86	4.37	3.98	3.55	2.75	1.57	39.7	261	722	1087	16	21	0.33	Y	N
17	6.47	4.57	4.12	3.82	3.44	2.75	1.56	38.6	220	575	2236	5	28	0.46	Y	N
21	6.21	4.05	3.79	3.54	3.23	2.62	1.56	39.1	195	524	3963	2	70	0.68	Y	N
25	6.21	4.25	3.88	3.56	3.21	2.59	1.52	39.1	215	577	2275	12	23	0.33	Y	N
30	6.01	3.82	3.44	3.21	2.90	2.38	1.44	39.7	185	510	3362	11	25	0.38	Y	N
33	5.83	3.74	3.34	3.10	2.81	2.29	1.38	36.9	194	463	2969	19	24	0.44	Y	N
37	6.83	4.53	3.95	3.68	3.30	2.64	1.43	38.5	172	446	2548	4	40	1.08	Y	N
23	5.69	3.68	3.36	3.10	2.79	2.30	1.38	37.5	205	505	3211	13	25	0.53	Y	N
29	6.19	4.12	3.74	3.51	3.23	2.60	1.49	38.5	-	-	-	-	100	8.14	N	N
Average	6.49	4.45	3.91	3.48	3.08	2.42	1.43	38.0	237	597	1064	50	22	0.53		
CV (%)	9	12	11	9	7	5	3	2	19	16	77	33	4	50		

MDT = Mid-depth temperature, TCAC = Temperature corrected asphalt concrete, RCS = Rubblized concrete slab, RB = Roadbed, RMS = Root mean square error

Table J14. Measured pavement deflections and backcalculated layer moduli for US-31 NB-section 1 test site 1

Route	US-31 NB		C.S.	70013		J.N.	38179		BMP	1.233		EMP	13.013			
FWD station	Deflection (mils)							MDT (°C)	Backcalculated modulus (ksi)					RMS (%)	Converged	Accepted
	0	8	12	16	24	36	60		AC	TC AC	RCS	Base	RB			
	D1	D2	D3	D4	D5	D6	D7									
1	6.27	5.14	4.64	3.94	3.35	2.46	1.50	34.8	1009	2166	105	46	23	0.80	Y	Y
2	6.58	5.42	4.82	4.11	3.56	2.68	1.57	35.0	734	1589	180	29	23	0.27	Y	Y
3	6.51	5.52	4.88	4.17	3.60	2.79	1.61	35.0	841	1827	177	27	22	0.96	Y	Y
4	6.90	5.64	4.97	4.27	3.70	2.89	1.71	35.1	598	1306	196	33	20	0.70	Y	Y
5	6.92	5.54	4.93	4.26	3.70	2.83	1.69	35.2	525	1151	229	29	21	0.08	Y	Y
6	5.97	4.86	4.36	3.87	3.44	2.79	1.73	35.4	567	1254	396	37	20	0.73	Y	Y
7	6.30	5.12	4.64	4.07	3.61	2.88	1.75	35.9	561	1275	373	27	21	0.60	Y	Y
8	6.14	5.06	4.50	3.99	3.51	2.75	1.70	36.4	668	1557	285	35	21	0.47	Y	Y
9	6.73	5.46	4.79	3.95	3.34	2.43	1.43	36.7	783	1857	95	43	24	0.21	Y	Y
10	7.11	5.69	4.96	4.11	3.49	2.48	1.36	36.8	602	1435	138	25	26	0.39	Y	Y
11	6.22	4.93	4.38	3.80	3.19	2.46	1.52	37.1	669	1617	168	51	23	0.75	Y	Y
12	6.64	5.36	4.76	4.17	3.65	2.87	1.79	37.5	561	1384	238	41	20	0.33	Y	Y
13	5.83	4.75	4.30	3.88	3.47	2.84	1.81	37.9	559	1405	509	38	20	0.50	Y	Y
14	6.47	5.24	4.61	3.89	3.29	2.47	1.39	38.0	663	1676	177	28	26	0.61	Y	Y
15	5.67	4.63	4.10	3.55	3.08	2.42	1.55	38.3	830	2128	169	69	22	0.18	Y	Y
16	5.68	4.62	4.19	3.83	3.43	2.83	1.79	38.6	518	1351	719	29	20	0.69	Y	Y
17	5.53	4.53	4.15	3.76	3.42	2.86	1.81	38.5	535	1387	881	25	20	0.89	Y	Y
18	6.19	5.02	4.47	3.77	3.24	2.44	1.41	38.6	713	1863	191	31	25	0.43	Y	Y
19	5.32	4.30	3.90	3.44	2.97	2.40	1.53	38.5	755	1962	288	59	23	0.69	Y	Y
20	5.33	4.29	3.95	3.64	3.32	2.74	1.79	38.8	498	1311	1096	31	20	0.26	Y	Y
22	6.23	4.96	4.28	3.64	3.18	2.46	1.43	38.7	525	1377	236	37	25	1.13	Y	Y
23	5.20	4.16	3.79	3.37	2.92	2.40	1.56	38.5	694	1799	336	69	22	0.85	Y	Y
26	5.63	4.59	4.02	3.47	3.10	2.44	1.47	38.3	636	1637	304	41	24	1.10	Y	Y
27	5.09	4.12	3.76	3.34	2.96	2.40	1.59	38.3	742	1909	363	69	22	0.30	Y	Y
30	5.39	4.48	3.98	3.44	3.03	2.40	1.43	38.3	792	2036	298	37	25	0.96	Y	Y
31	5.29	4.20	3.80	3.39	2.98	2.46	1.59	38.1	586	1493	418	65	22	0.67	Y	Y
32	5.56	4.43	4.00	3.62	3.24	2.64	1.63	38.2	471	1208	752	28	22	0.66	Y	Y
33	5.57	4.48	4.07	3.69	3.39	2.81	1.79	38.1	461	1175	937	33	20	0.84	Y	Y
34	5.54	4.45	4.12	3.77	3.46	2.89	1.88	38.2	455	1160	1288	25	19	0.50	Y	Y
35	6.10	4.97	4.54	4.04	3.61	2.91	1.85	38.0	577	1461	414	35	19	0.25	Y	Y
36	6.83	5.47	4.89	4.30	3.81	3.04	1.91	38.0	491	1241	278	42	18	0.35	Y	Y
37	5.65	4.55	4.16	3.83	3.49	2.92	1.87	38.1	449	1140	1178	23	20	0.65	Y	Y
38	5.59	4.49	4.08	3.70	3.35	2.76	1.77	38.1	488	1238	748	38	20	0.56	Y	Y
39	5.76	4.84	4.24	3.64	3.14	2.44	1.51	38.3	960	2462	143	57	23	0.65	Y	Y
40	5.71	4.66	4.09	3.46	2.99	2.35	1.42	38.2	768	1964	177	55	24	0.90	Y	Y
21	5.29	4.26	3.94	3.69	3.42	2.89	1.86	39.2	428	1154	2802	4	28	0.58	Y	N
24	4.90	4.18	3.83	3.58	3.32	2.84	1.85	38.6	643	1680	1953	7	23	1.04	Y	N
25	5.15	4.24	3.92	3.66	3.41	2.90	1.85	40.3	484	1379	2859	3	36	0.82	Y	N
28	5.03	4.14	3.85	3.60	3.33	2.80	1.85	39.2	529	1421	2173	9	22	0.40	Y	N
29	5.37	4.30	3.98	3.74	3.43	2.91	1.87	40.3	421	1197	2602	4	26	0.61	Y	N
Average	5.98	4.86	4.35	3.80	3.34	2.65	1.63	37.8	637	1566	414	40	22	0.60		
CV (%)	9	9	9	7	7	8	10	3	23	22	79	35	9	45		

MDT = Mid-depth temperature, TCAC = Temperature corrected asphalt concrete, RCS = Rubblized concrete slab, RB = Roadbed, RMS = Root mean square error

Table J15. Measured pavement deflections and backcalculated layer moduli for M-15 SB -section 1 test site 1

Route	M-15 SB		C.S.	25092		J.N.	45534		BMP	9.501		EMP	10.409			
FWD station	Deflection (mils)							MDT (°C)	Backcalculated modulus (ksi)					RMS (%)	Converged	Accepted
	0	8	12	16	24	36	60		AC	TC AC	RCS	Base	RB			
	D1	D2	D3	D4	D5	D6	D7									
1	8.63	7.61	6.82	5.73	4.76	3.31	1.75	17.6	2354	2075	40	24	20	0.10	Y	Y
2	7.95	7.02	6.37	5.34	4.51	3.20	1.78	17.6	2747	2433	32	42	19	0.22	Y	Y
4	8.06	7.02	6.34	5.33	4.57	3.39	2.03	17.7	2010	1784	60	52	17	0.26	Y	Y
5	7.99	7.03	6.34	5.38	4.58	3.33	1.85	17.9	2024	1817	106	22	19	0.16	Y	Y
6	7.49	6.48	5.86	5.00	4.29	3.20	1.84	17.9	1549	1391	166	27	19	0.13	Y	Y
10	8.06	7.18	6.52	5.57	4.75	3.36	1.84	18.2	2984	2714	43	26	19	0.32	Y	Y
11	8.64	7.65	6.79	5.64	4.67	3.27	1.75	18.4	2226	2051	32	33	19	0.39	Y	Y
12	7.54	6.59	5.95	5.08	4.37	3.30	1.99	18.7	2008	1876	94	47	17	0.06	Y	Y
13	7.32	6.46	5.80	4.86	4.06	2.85	1.56	18.6	2877	2675	30	49	22	0.08	Y	Y
14	7.59	6.70	6.10	5.24	4.47	3.21	1.77	18.7	2592	2421	97	21	20	0.28	Y	Y
15	8.31	7.31	6.54	5.42	4.55	3.19	1.75	18.9	2250	2131	41	33	20	0.32	Y	Y
16	7.35	6.43	5.80	4.91	4.20	3.15	1.92	18.6	2280	2119	61	65	18	0.12	Y	Y
17	7.17	6.27	5.69	4.75	3.99	2.79	1.53	18.6	2953	2743	32	48	22	0.37	Y	Y
19	8.25	7.25	6.46	5.37	4.51	3.23	1.80	18.4	2067	1900	51	35	19	0.39	Y	Y
20	7.34	6.37	5.74	4.86	4.17	3.12	1.85	18.6	1875	1749	108	43	19	0.19	Y	Y
21	7.35	6.38	5.73	4.78	3.99	2.76	1.51	18.4	2648	2434	35	45	23	0.34	Y	Y
22	7.87	6.89	6.24	5.25	4.43	3.13	1.69	18.7	2302	2156	78	22	21	0.23	Y	Y
23	8.31	7.30	6.54	5.48	4.55	3.21	1.78	19.3	2433	2344	27	49	19	0.06	Y	Y
24	7.33	6.37	5.77	4.88	4.15	3.14	1.91	18.9	2156	2038	69	63	18	0.34	Y	Y
25	7.45	6.51	5.81	4.86	4.04	2.79	1.51	19.2	2641	2531	34	42	23	0.22	Y	Y
27	8.18	7.24	6.52	5.46	4.60	3.25	1.77	19.4	2502	2421	43	30	19	0.22	Y	Y
28	7.26	6.38	5.76	4.87	4.18	3.15	1.86	19.3	2150	2069	93	45	19	0.36	Y	Y
29	7.44	6.56	5.85	4.89	4.08	2.81	1.48	18.6	2699	2512	43	29	23	0.24	Y	Y
31	7.87	7.03	6.34	5.34	4.55	3.26	1.79	18.2	2687	2452	54	28	19	0.35	Y	Y
32	7.53	6.65	6.07	5.17	4.40	3.16	1.72	18.7	2547	2381	101	19	21	0.19	Y	Y
33	6.30	5.54	5.04	4.38	3.86	2.99	1.77	18.4	1627	1499	311	27	20	0.45	Y	Y
34	7.13	6.20	5.61	4.78	4.14	3.11	1.87	18.1	1933	1756	123	44	19	0.21	Y	Y
35	7.53	6.66	5.98	5.02	4.30	3.14	1.83	18.4	2449	2256	53	49	19	0.38	Y	Y
36	7.26	6.37	5.80	4.95	4.22	3.10	1.79	18.5	2554	2364	80	37	19	0.21	Y	Y
37	7.47	6.51	5.87	4.87	4.06	2.82	1.51	18.6	2512	2342	49	31	23	0.22	Y	Y
38	8.12	7.18	6.44	5.29	4.32	2.93	1.45	18.3	2644	2423	23	28	23	0.40	Y	Y
3	7.07	6.27	5.74	5.03	4.46	3.51	2.03	16.8	1307	1109	393	200	19	0.74	Y	N
8	8.17	7.14	6.42	5.32	4.43	3.02	1.50	17.9	2118	1900	80	13	23	0.25	Y	N
9	8.68	7.53	6.73	5.67	4.74	3.27	1.56	17.9	1394	1250	154	14	24	0.10	Y	N
18	7.51	6.66	6.03	5.15	4.39	3.17	1.70	20.0	2274	2280	135	7	21	0.10	Y	N
26	8.21	7.17	6.39	5.34	4.49	3.14	1.64	20.0	1813	1814	100	15	21	0.23	Y	N
30	8.06	7.03	6.30	5.28	4.44	3.13	1.58	20.0	1633	1633	143	17	23	0.29	Y	N
39	8.48	7.31	6.57	5.43	4.49	3.03	1.54	18.3	1985	1819	63	12	22	0.30	Y	N
40	7.97	6.97	6.30	5.31	4.44	3.08	1.60	19.4	2327	2257	78	17	22	0.19	Y	N
41	9.51	8.12	7.19	5.91	4.90	3.36	1.69	16.8	1221	1034	99	17	21	0.24	Y	N
42	7.98	6.75	5.92	4.89	4.10	2.96	1.65	17.3	1226	1068	110	13	21	0.38	Y	N
43	7.87	6.79	6.10	5.18	4.47	3.23	1.66	19.0	1081	1026	257	31	23	0.44	Y	N
7	7.54	6.70	6.00	5.03	4.20	2.91	1.61	17.9	-	-	-	-	21	2.43	N	N
Average	7.68	6.75	6.08	5.12	4.33	3.12	1.75	19.0	2364	2189	71	37	20	0.25		
CV (%)	7	7	7	6	6	6	9	2	15	16	78	33	9	44		

MDT = Mid-depth temperature, TCAC = Temperature corrected asphalt concrete, RCS = Rubblized concrete slab, RB = Roadbed, RMS = Root mean square error

Table J16. Measured pavement deflections and backcalculated layer moduli for M-37 SB -section 5 test site 1

Route	M-37 SB		C.S.	41033		J.N.	38190		BMP	15.738		EMP	17.120			
FWD station	Deflection (mils)							MDT (°C)	Backcalculated modulus (ksi)					RMS (%)	Converged	Accepted
	0	8	12	16	24	36	60		AC	TC AC	RCS	Base	RB			
	D1	D2	D3	D4	D5	D6	D7									
2	7.95	6.55	5.83	5.08	4.47	3.53	2.07	38.5	492	1280	248	23	16	0.83	Y	Y
4	8.91	7.22	6.39	5.46	4.75	3.65	2.13	38.6	448	1166	166	25	16	0.54	Y	Y
5	8.70	7.07	6.26	5.41	4.81	3.83	2.25	38.7	395	1037	237	25	15	1.13	Y	Y
6	8.96	7.31	6.49	5.67	4.99	3.90	2.31	38.9	417	1104	215	23	15	0.55	Y	Y
7	8.50	6.92	6.19	5.47	4.83	3.84	2.30	39.0	406	1082	278	23	15	0.60	Y	Y
8	8.95	7.32	6.48	5.66	5.01	3.99	2.35	39.2	391	1051	243	22	14	1.04	Y	Y
9	9.25	7.50	6.65	5.70	4.99	3.90	2.32	39.5	422	1157	165	28	14	0.64	Y	Y
10	8.63	7.02	6.23	5.41	4.82	3.82	2.27	39.9	402	1120	245	25	15	0.94	Y	Y
11	8.74	7.17	6.37	5.47	4.75	3.66	2.07	39.9	468	1306	199	18	17	0.74	Y	Y
12	8.36	6.85	6.05	5.20	4.55	3.56	2.12	40.1	502	1420	171	31	16	0.69	Y	Y
13	8.15	6.56	5.87	5.14	4.58	3.63	2.22	40.4	404	1159	268	31	15	0.54	Y	Y
14	8.40	6.76	5.99	5.24	4.66	3.76	2.26	40.8	379	1105	262	31	15	1.06	Y	Y
15	8.71	6.97	6.19	5.30	4.63	3.59	2.03	40.8	387	1132	224	20	17	0.85	Y	Y
16	8.22	6.51	5.74	5.03	4.46	3.54	2.13	40.8	355	1040	273	32	16	0.80	Y	Y
17	8.10	6.44	5.75	5.06	4.49	3.57	2.17	40.9	370	1086	293	31	15	0.53	Y	Y
18	8.46	6.65	5.85	5.08	4.51	3.64	2.23	41.0	345	1019	221	43	15	0.95	Y	Y
19	8.16	6.68	5.96	5.19	4.58	3.51	2.00	41.4	460	1389	267	16	17	0.52	Y	Y
20	7.61	6.15	5.54	4.93	4.42	3.53	2.12	41.6	390	1191	440	21	16	0.68	Y	Y
21	7.84	6.23	5.59	4.92	4.38	3.48	2.15	41.5	386	1169	304	34	16	0.38	Y	Y
22	8.01	6.52	5.81	5.08	4.52	3.62	2.24	41.5	457	1383	233	37	15	0.66	Y	Y
24	7.42	6.02	5.43	4.86	4.37	3.49	2.12	41.8	405	1248	466	22	16	0.58	Y	Y
25	7.73	6.15	5.53	4.89	4.32	3.43	2.11	42.0	398	1240	309	33	16	0.31	Y	Y
26	7.98	6.51	5.83	5.09	4.53	3.63	2.24	41.9	466	1445	240	35	15	0.67	Y	Y
28	7.62	6.05	5.47	4.84	4.31	3.49	2.13	41.7	369	1131	396	31	16	0.69	Y	Y
29	7.71	6.10	5.49	4.77	4.21	3.35	2.09	41.7	420	1283	242	42	16	0.39	Y	Y
30	8.07	6.44	5.70	4.90	4.33	3.47	2.17	41.5	438	1330	179	48	15	0.66	Y	Y
32	7.14	5.65	5.07	4.47	3.98	3.18	1.93	41.6	395	1200	378	34	17	0.59	Y	Y
33	6.96	5.72	5.22	4.71	4.20	3.36	2.06	41.4	485	1465	496	20	17	0.24	Y	Y
34	7.36	5.82	5.28	4.71	4.22	3.48	2.14	41.4	349	1055	514	33	16	0.98	Y	Y
35	7.75	6.16	5.53	4.82	4.28	3.38	2.08	41.3	413	1239	267	36	16	0.39	Y	Y
36	7.47	5.86	5.28	4.59	4.05	3.24	2.01	41.4	404	1219	268	44	16	0.50	Y	Y
37	7.67	6.00	5.40	4.69	4.16	3.27	2.02	41.6	388	1181	269	40	16	0.29	Y	Y
38	8.26	6.58	5.87	5.12	4.54	3.61	2.20	41.6	387	1181	247	34	15	0.60	Y	Y
39	8.10	6.32	5.65	4.88	4.28	3.39	2.11	41.7	388	1186	205	45	16	0.36	Y	Y
40	8.04	6.33	5.66	4.85	4.29	3.44	2.12	41.7	400	1227	208	45	15	0.78	Y	Y
1	8.80	7.33	6.53	5.66	4.90	3.75	2.08	38.2	512	1311	206	13	17	0.66	Y	N
3	7.33	6.07	5.51	4.97	4.42	3.55	2.13	37.6	473	1174	476	15	17	0.59	Y	N
23	7.63	6.28	5.68	5.00	4.41	3.44	1.96	39.7	478	1323	362	12	19	0.49	Y	N
27	7.46	6.10	5.51	4.85	4.28	3.32	1.89	39.7	470	1300	372	13	19	0.44	Y	N
31	7.10	5.87	5.31	4.66	4.13	3.21	1.87	39.7	556	1535	341	17	19	0.39	Y	N
Average	8.11	6.52	5.82	5.08	4.49	3.56	2.15	40.8	411	1201	275	31	16	0.65		
CV (%)	7	7	7	6	6	5	5	3	10	10	33	28	5	35		

MDT = Mid-depth temperature, TCAC = Temperature corrected asphalt concrete, RCS = Rubblized concrete slab, RB = Roadbed, RMS = Root mean square error

Table J17. Measured pavement deflections and backcalculated layer moduli for M-37 SB -section 5 test site 2

Route	M-37 SB		C.S.	41033		J.N.	38190		BMP	15.738		EMP	17.120		Converged	Accepted
FWD station	Deflection (mils)							MDT (°C)	Backcalculated modulus (ksi)					RMS (%)		
	0	8	12	16	24	36	60		AC	TC AC	RCS	Base	RB			
	D1	D2	D3	D4	D5	D6	D7									
1	9.40	7.64	6.72	5.55	4.63	3.33	1.92	43.2	653	2157	68	31	17	0.27	Y	Y
2	9.22	7.29	6.49	5.58	4.88	3.76	2.17	43.1	343	1132	223	22	16	0.56	Y	Y
3	8.97	7.16	6.35	5.55	4.85	3.78	2.18	43.2	352	1163	258	21	16	0.67	Y	Y
4	10.12	8.25	7.27	6.03	5.12	3.85	2.16	43.2	486	1612	103	22	15	0.76	Y	Y
5	9.34	7.59	6.81	5.92	5.20	4.09	2.44	43.4	402	1342	214	23	14	0.56	Y	Y
6	11.37	9.11	7.99	6.70	5.80	4.46	2.57	43.7	341	1154	117	23	13	0.92	Y	Y
7	11.49	9.16	8.09	6.94	6.03	4.59	2.56	44.0	292	1006	171	14	13	0.62	Y	Y
10	13.71	11.24	9.67	7.84	6.54	4.67	2.53	43.9	407	1396	52	17	13	0.68	Y	Y
11	9.22	7.47	6.59	5.51	4.65	3.35	1.94	44.1	610	2108	90	27	17	0.41	Y	Y
12	9.75	8.02	7.07	5.86	4.97	3.75	2.15	44.3	565	1981	91	27	15	0.67	Y	Y
13	11.30	9.07	7.97	6.82	5.92	4.53	2.56	44.6	314	1116	157	17	13	0.78	Y	Y
14	13.64	10.88	9.34	7.58	6.35	4.56	2.50	44.8	333	1198	62	18	13	0.52	Y	Y
15	9.24	7.33	6.39	5.39	4.57	3.36	1.96	44.8	456	1638	116	29	17	0.27	Y	Y
16	10.03	8.01	6.94	5.69	4.80	3.64	2.13	44.9	455	1641	81	35	15	0.70	Y	Y
17	11.37	9.06	7.88	6.71	5.81	4.47	2.55	44.9	304	1100	138	21	13	0.91	Y	Y
18	13.30	10.66	9.06	7.27	6.11	4.42	2.46	45.2	349	1283	54	22	13	0.88	Y	Y
19	8.91	7.20	6.39	5.39	4.56	3.37	1.96	45.3	575	2118	112	28	17	0.28	Y	Y
20	9.73	7.77	6.86	5.72	4.84	3.61	2.07	44.9	464	1678	108	26	16	0.35	Y	Y
21	11.32	8.91	7.83	6.68	5.79	4.50	2.53	45.1	270	984	171	18	13	1.03	Y	Y
22	12.52	10.01	8.78	7.16	6.02	4.34	2.45	45.1	406	1479	63	21	13	0.31	Y	Y
23	8.89	7.16	6.33	5.35	4.56	3.37	1.95	45.1	524	1908	127	26	17	0.14	Y	Y
24	9.52	7.61	6.77	5.66	4.81	3.60	2.10	45.2	482	1768	112	28	16	0.38	Y	Y
25	11.03	8.72	7.74	6.61	5.75	4.39	2.45	45.3	289	1065	185	15	14	0.66	Y	Y
26	12.29	9.82	8.55	7.06	5.98	4.37	2.45	45.3	362	1332	81	19	13	0.31	Y	Y
27	9.58	7.36	6.38	5.29	4.46	3.31	1.96	45.3	384	1420	100	37	17	0.20	Y	Y
28	9.37	7.53	6.63	5.56	4.73	3.55	2.06	45.6	489	1832	114	28	16	0.24	Y	Y
29	10.85	8.52	7.52	6.45	5.59	4.26	2.44	45.3	293	1080	169	20	14	0.42	Y	Y
30	12.39	9.77	8.48	6.96	5.93	4.34	2.41	45.4	316	1171	89	19	14	0.56	Y	Y
31	9.33	7.16	6.12	4.99	4.21	3.14	1.89	45.7	411	1549	81	47	17	0.13	Y	Y
32	8.11	6.17	5.51	4.78	4.24	3.35	2.01	45.5	299	1118	310	37	17	0.58	Y	Y
33	8.30	6.39	5.64	4.90	4.32	3.42	2.07	45.3	317	1171	258	39	16	0.65	Y	Y
34	9.33	7.27	6.41	5.39	4.58	3.50	2.05	45.3	385	1423	134	32	16	0.49	Y	Y
35	9.16	7.06	6.19	5.31	4.66	3.67	2.23	45.4	310	1148	186	39	15	0.62	Y	Y
36	10.33	8.05	7.06	6.03	5.24	4.06	2.39	45.5	300	1119	159	28	14	0.57	Y	Y
37	10.65	8.29	7.32	6.29	5.48	4.21	2.45	45.5	277	1032	182	22	14	0.45	Y	Y
38	11.59	9.46	8.33	6.98	5.92	4.34	2.39	45.0	432	1566	97	16	14	0.26	Y	Y
39	11.05	8.80	7.76	6.66	5.75	4.36	2.41	44.7	301	1075	179	14	14	0.61	Y	Y
40	12.12	9.67	8.44	6.96	5.91	4.37	2.43	44.6	347	1238	91	19	14	0.60	Y	Y
8	13.14	10.91	9.64	8.08	6.80	4.84	2.50	42.5	289	973	223	1	14	0.19	Y	N
9	12.59	10.40	9.22	7.73	6.55	4.80	1.71	43.6	-	-	-	-	-	7.52	N	N
Average	10.47	8.33	7.31	6.13	5.25	3.95	2.26	44.8	392	1403	134	25	15	0.53		
CV (%)	14	15	14	13	13	12	10	2	25	24	46	32	10	43		

MDT = Mid-depth temperature, TCAC = Temperature corrected asphalt concrete, RCS = Rubblized concrete slab, RB = Roadbed, RMS = Root mean square error

Table J18. Measured pavement deflections and backcalculated layer moduli for M-37 SB -section 6 test site 1

Route	M-37 SB		C.S.	41033		J.N.	26691		BMP	2.477		EMP	7.917			
FWD station	Deflection (mils)							MDT (°C)	Backcalculated modulus (ksi)					RMS (%)	Converged	Accepted
	0	8	12	16	24	36	60		AC	TC AC	RCS	Base	RB			
	D1	D2	D3	D4	D5	D6	D7									
1	5.80	5.02	4.62	4.07	3.62	2.88	1.68	17.6	1199	1059	385	40	15	0.43	Y	Y
4	5.50	4.78	4.41	3.86	3.44	2.69	1.59	18.4	1576	1452	316	49	15	0.32	Y	Y
5	7.08	6.19	5.58	4.84	4.19	3.14	1.71	19.4	1484	1436	173	28	15	0.16	Y	Y
6	5.60	5.03	4.68	4.15	3.70	2.92	1.67	20.3	2183	2220	381	17	16	0.30	Y	Y
7	5.71	5.01	4.63	4.05	3.56	2.75	1.60	21.4	2009	2164	240	43	15	0.23	Y	Y
8	5.59	5.01	4.62	4.09	3.65	2.85	1.63	22.0	2098	2324	347	22	16	0.28	Y	Y
9	6.00	5.35	4.92	4.31	3.76	2.86	1.59	22.5	2484	2831	188	31	16	0.07	Y	Y
14	5.04	4.55	4.23	3.80	3.42	2.72	1.60	23.2	2302	2709	503	16	16	0.15	Y	Y
21	5.32	4.81	4.47	3.90	3.42	2.62	1.45	23.9	3396	4162	210	27	17	0.41	Y	Y
23	5.61	4.97	4.56	4.03	3.59	2.79	1.59	24.3	1757	2198	354	25	16	0.22	Y	Y
24	5.81	5.23	4.81	4.15	3.62	2.70	1.48	23.5	3240	3883	116	38	17	0.30	Y	Y
26	5.72	4.96	4.49	3.89	3.42	2.68	1.54	22.8	1462	1689	250	53	16	0.58	Y	Y
29	6.62	5.80	5.22	4.40	3.77	2.76	1.47	22.5	1960	2231	100	43	16	0.36	Y	Y
30	5.96	5.29	4.85	4.16	3.63	2.74	1.51	22.1	2392	2664	154	39	16	0.42	Y	Y
31	6.63	5.76	5.20	4.42	3.83	2.90	1.64	22.2	1641	1841	128	53	15	0.35	Y	Y
32	6.53	5.74	5.19	4.44	3.81	2.85	1.59	22.1	2072	2308	101	52	15	0.23	Y	Y
33	6.80	6.07	5.50	4.66	3.96	2.83	1.48	21.7	2889	3156	33	70	16	0.21	Y	Y
2	5.39	4.91	4.55	4.00	3.56	2.84	1.58	18.4	2468	2276	394	11	17	0.92	Y	N
11	5.12	4.63	4.31	3.88	3.52	2.79	1.63	25.0	2126	2751	591	7	18	0.28	Y	N
12	5.50	4.94	4.54	4.00	3.56	2.77	1.54	24.4	2108	2649	367	15	17	0.51	Y	N
15	5.32	4.79	4.44	3.91	3.48	2.69	1.50	22.7	2598	2992	345	15	18	0.33	Y	N
17	5.10	4.58	4.23	3.78	3.40	2.73	1.58	24.4	1786	2239	570	14	17	0.65	Y	N
18	5.19	4.68	4.35	3.86	3.40	2.66	1.47	24.4	2723	3413	377	11	19	0.38	Y	N
20	5.27	4.70	4.36	3.87	3.47	2.78	1.57	25.5	1684	2234	546	11	17	0.68	Y	N
25	5.95	5.16	4.75	4.12	3.64	2.81	1.54	21.6	1278	1385	358	20	17	0.53	Y	N
27	5.04	4.44	4.10	3.64	3.26	2.60	1.46	21.5	1379	1494	637	12	19	0.69	Y	N
10	5.79	5.20	4.79	4.19	3.59	2.57	1.45	23.9	-	-	-	-	15	2.18	N	N
13	5.61	5.06	4.63	4.03	3.47	2.50	1.39	24.4	-	-	-	-	16	3.64	N	N
16	5.65	5.09	4.67	4.04	3.43	2.42	1.37	23.8	-	-	-	-	15	6.58	N	N
19	5.77	5.17	4.72	4.04	3.40	2.40	1.38	23.8	-	-	-	-	15	7.81	N	N
22	6.05	5.40	4.90	4.18	3.52	2.44	1.37	24.9	-	-	-	-	16	7.64	N	N
28	6.37	5.68	5.20	4.41	3.72	2.55	1.36	23.2	-	-	-	-	17	11.22	N	N
3	5.94	5.31	4.94	4.28	3.67	2.66	1.45	18.4	-	-	-	-	15	2.45	N	N
Average	5.96	5.27	4.82	4.19	3.67	2.80	1.58	21.8	2126	2372	234	-	16	0.29		
CV (%)	10	9	8	7	6	4	5	9	29	35	55	-	5	42		

MDT = Mid-depth temperature, TCAC = Temperature corrected asphalt concrete, RCS = Rubblized concrete slab, RB = Roadbed, RMS = Root mean square error

Figure J1. Normalized backcalculated subgrade moduli and the inverse of normalized D7 deflections for I-69 EB - section 1 test site 1

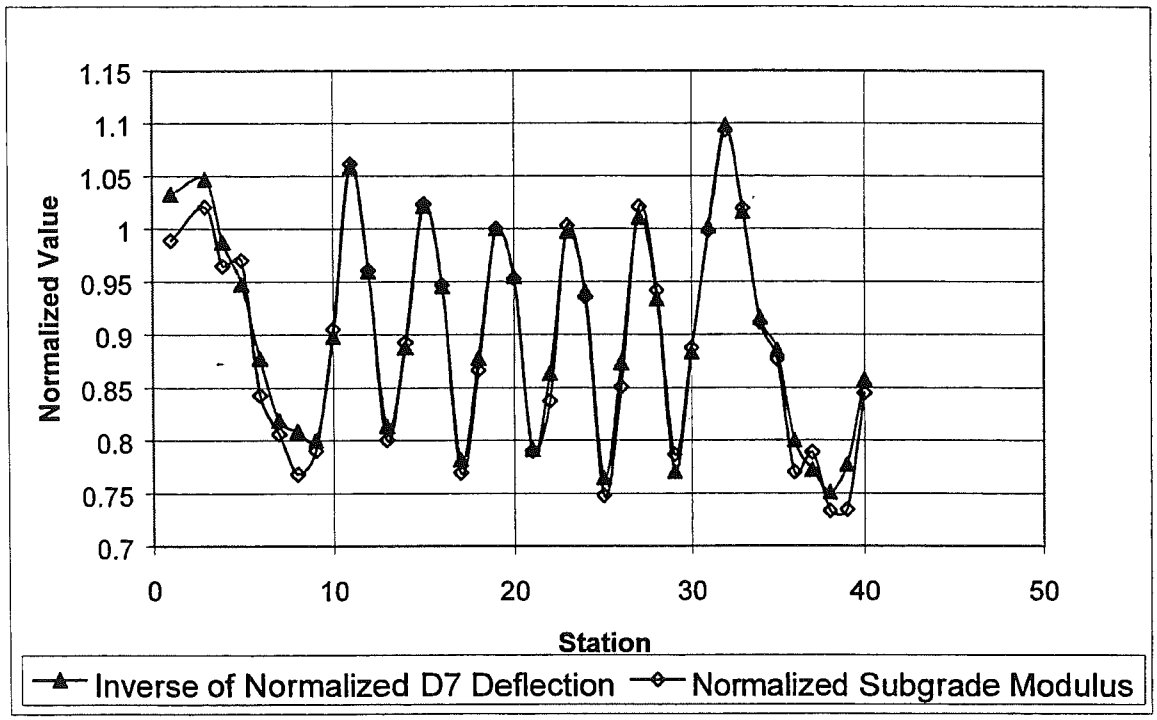


Figure J2. Normalized backcalculated subgrade moduli and the inverse of normalized D7 deflections for I-69 EB - section 1 test site 2

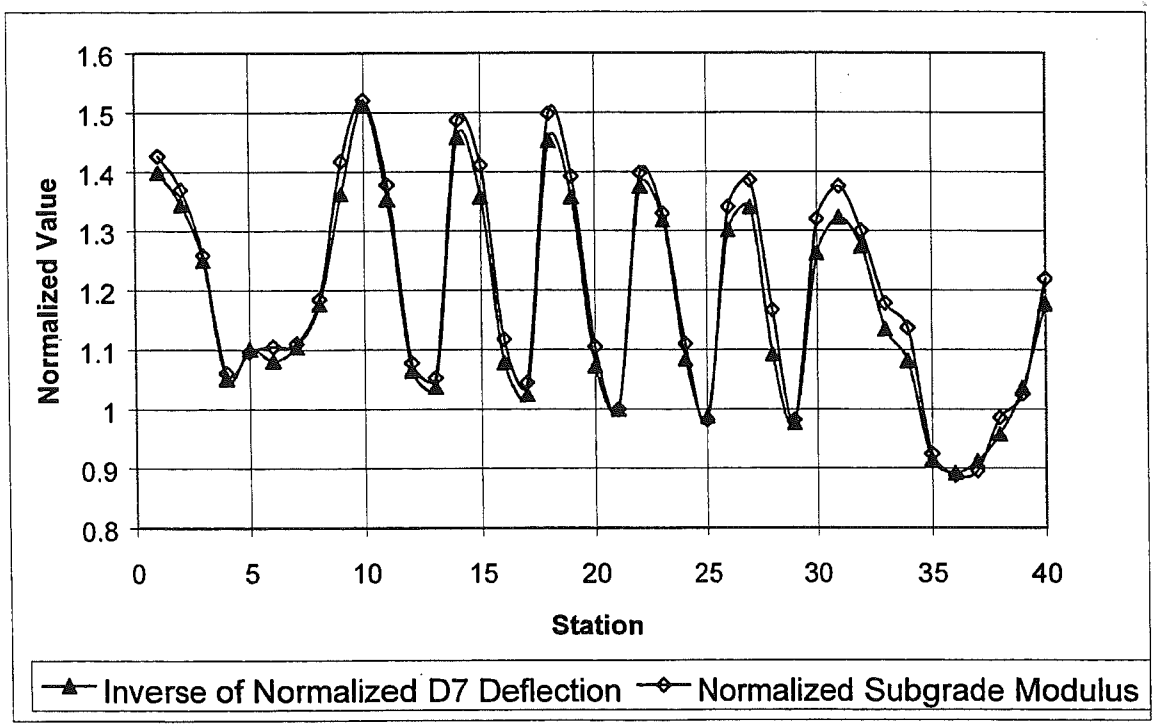


Figure J3. Normalized backcalculated subgrade moduli and the inverse of normalized D7 deflections for I-75 SB - section 1 test site 1

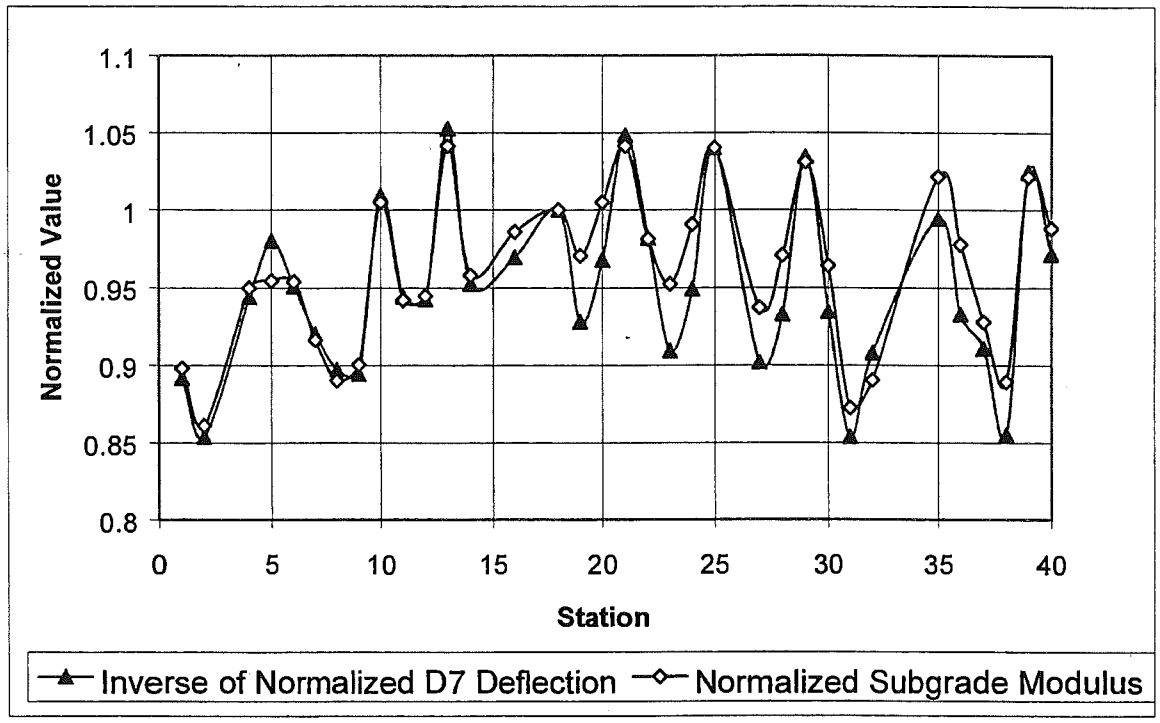


Figure J4. Normalized backcalculated subgrade moduli and the inverse of normalized D7 deflections for I-75 SB - section 1 test site 2

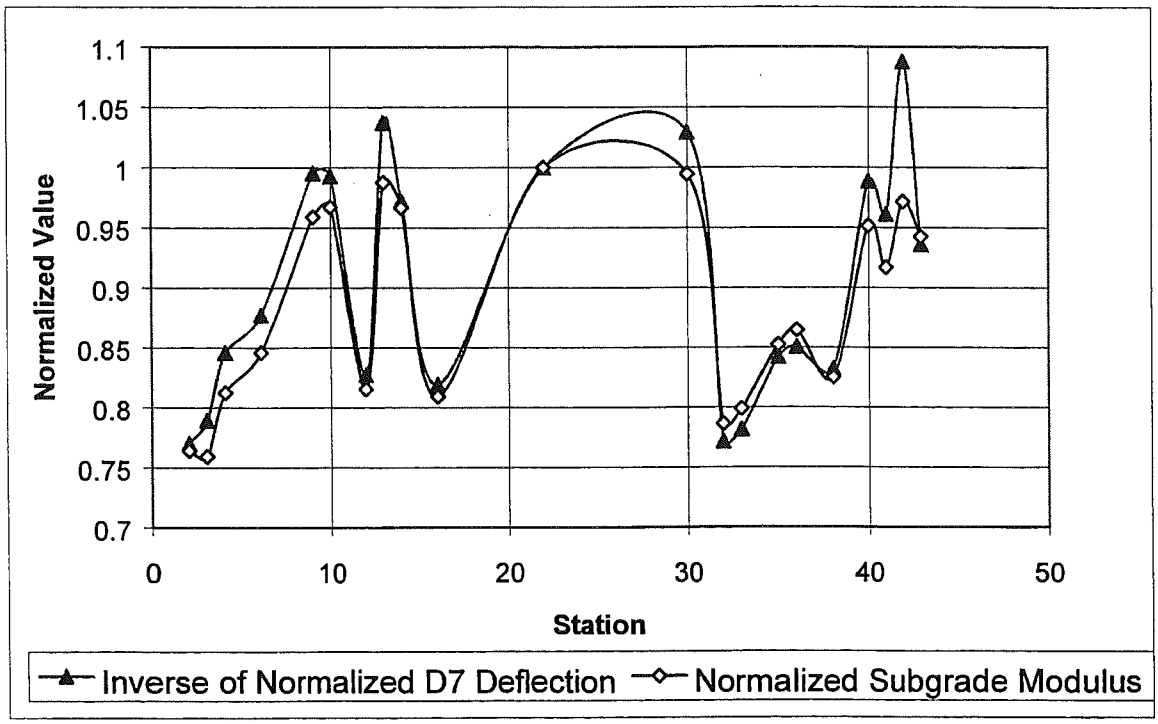


Figure J5. Normalized backcalculated subgrade moduli and the inverse of normalized D7 deflections for I-194 NB - section 2 test site 1

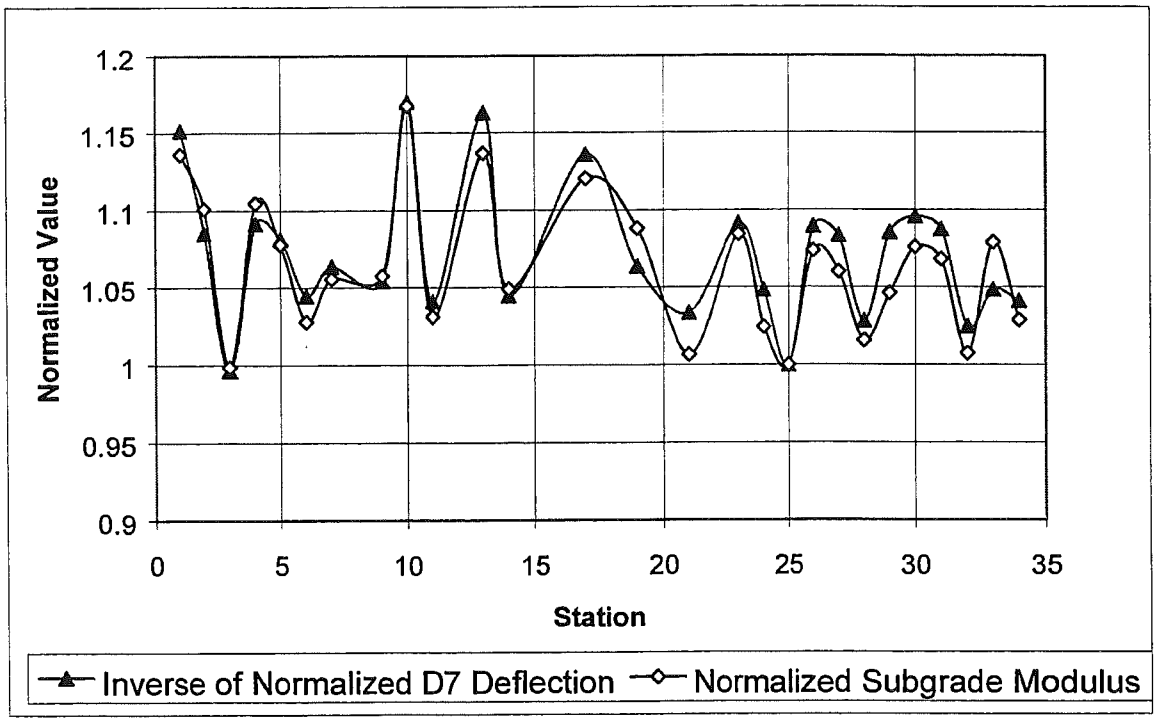


Figure J6. Normalized backcalculated subgrade moduli and the inverse of normalized D7 deflections for I-194 NB - section 2 test site 2

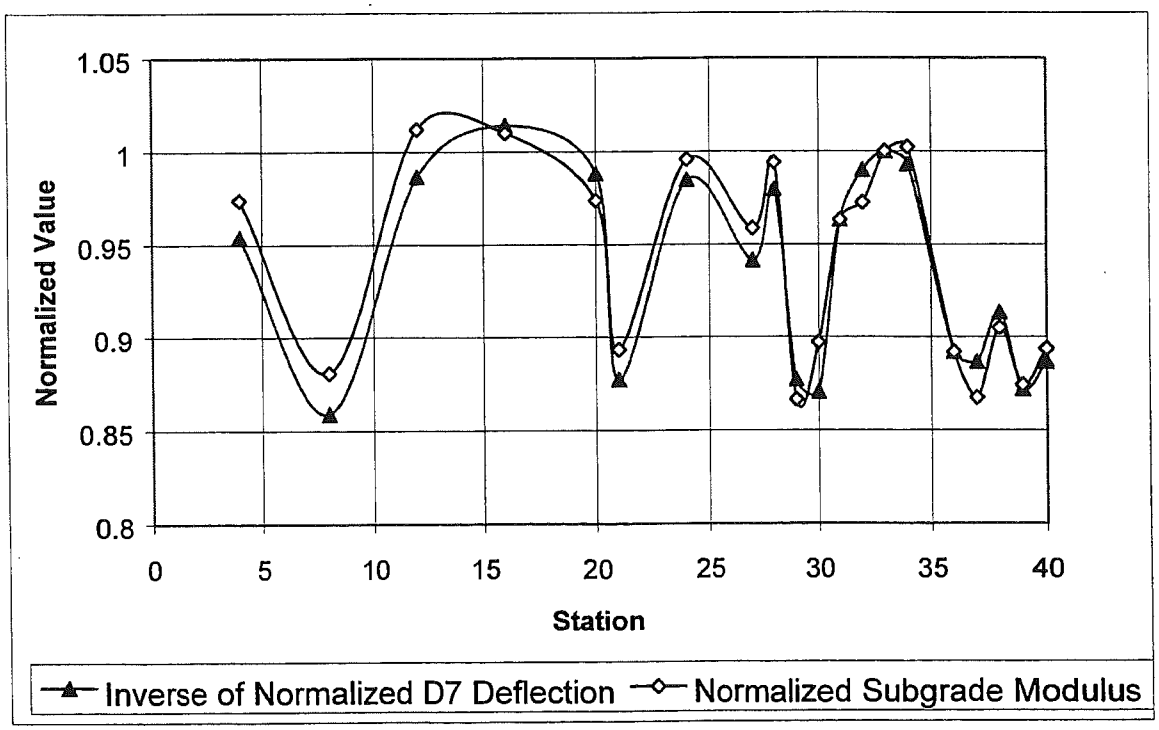


Figure J7. Normalized backcalculated subgrade moduli and the inverse of normalized D7 deflections for US-10 EB - section 1 test site 1

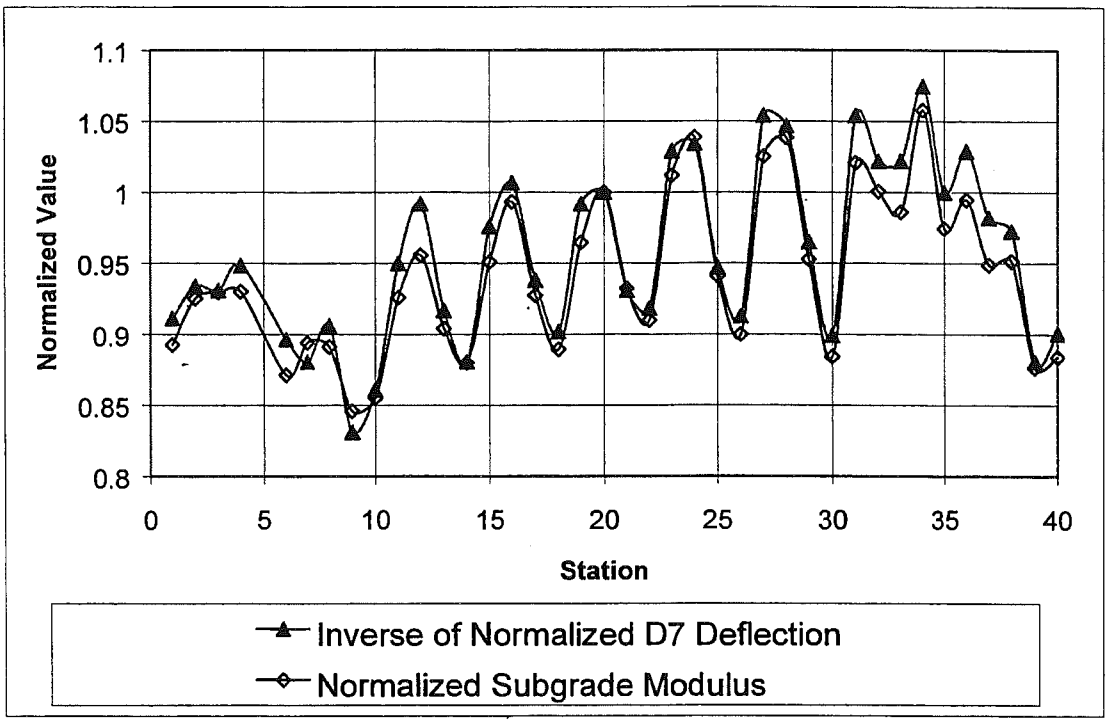


Figure J8. Normalized backcalculated subgrade moduli and the inverse of normalized D7 deflections for US-10 EB - section 1 test site 2

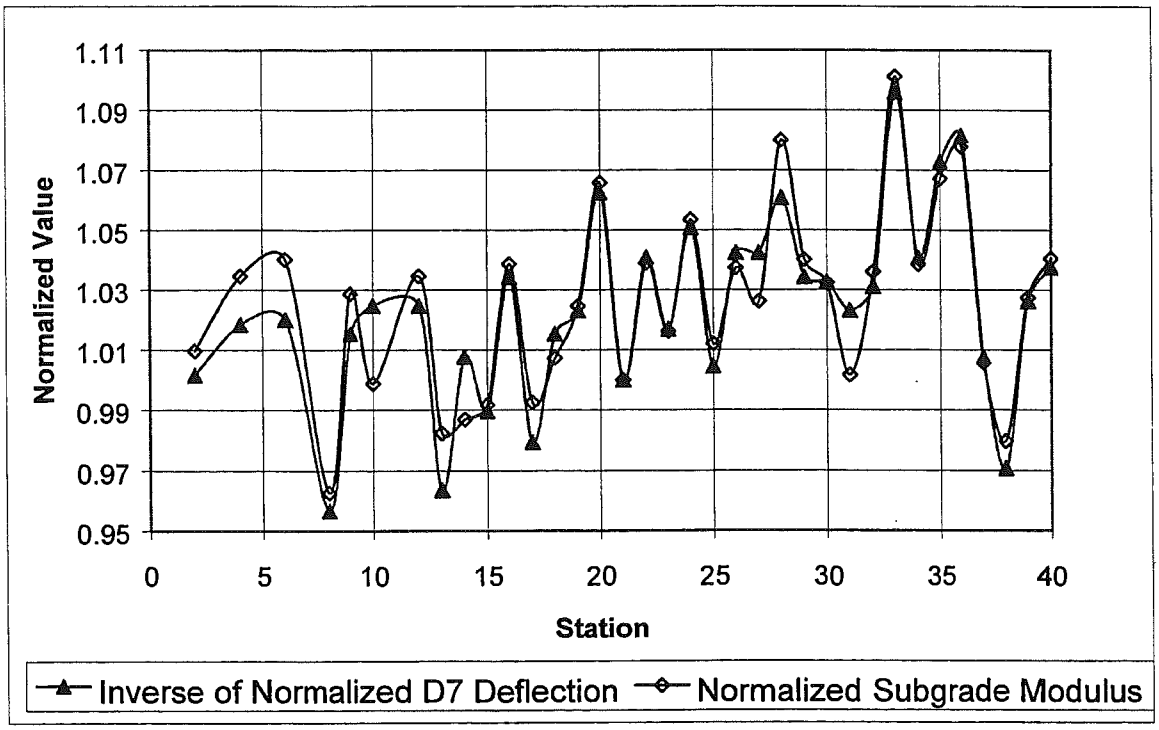


Figure J9. Normalized backcalculated subgrade moduli and the inverse of normalized D7 deflections for US-23 SB - section 1 test site 1

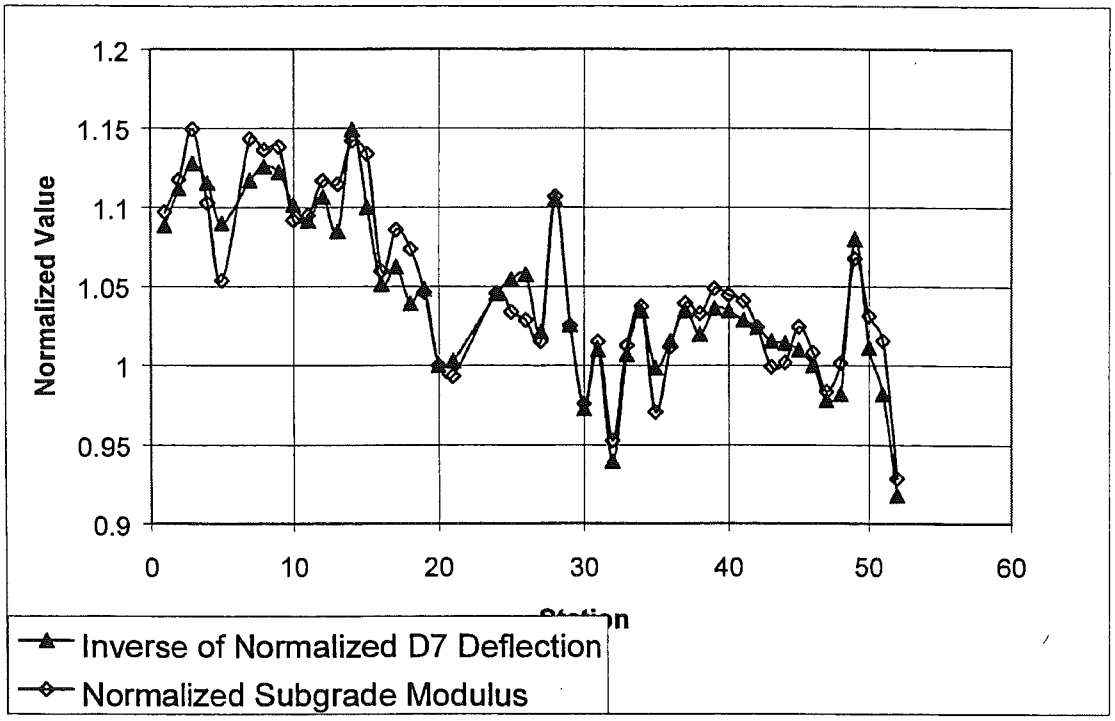


Figure J10. Normalized backcalculated subgrade moduli and the inverse of normalized D7 deflections for US-23 SB - section 1 test site 2

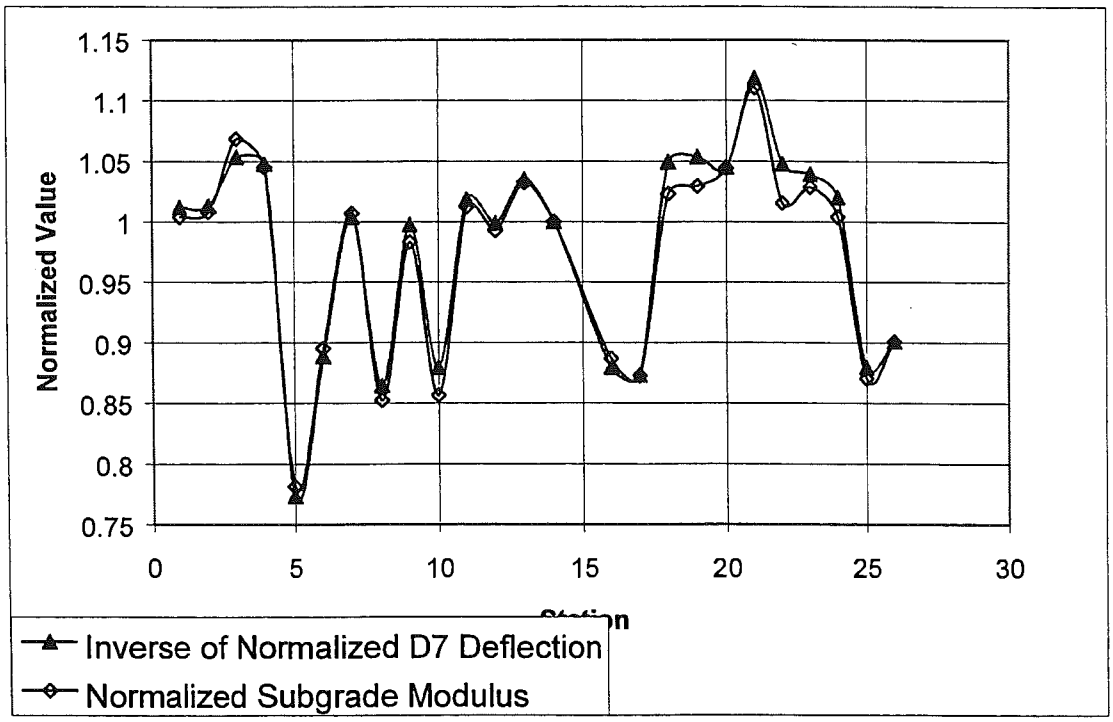


Figure J11. Normalized backcalculated subgrade moduli and the inverse of normalized D7 deflections for US-27 SB - section 2 test site 1

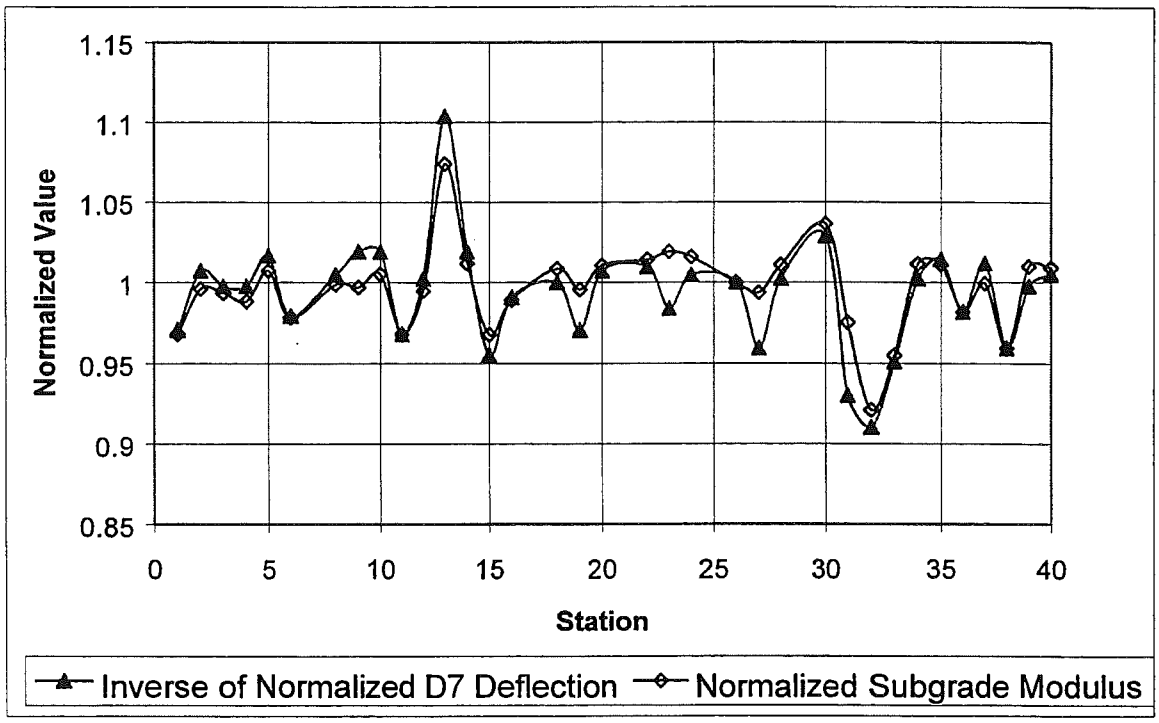


Figure J12. Normalized backcalculated subgrade moduli and the inverse of normalized D7 deflections for US-27 SB - section 3 test site 1

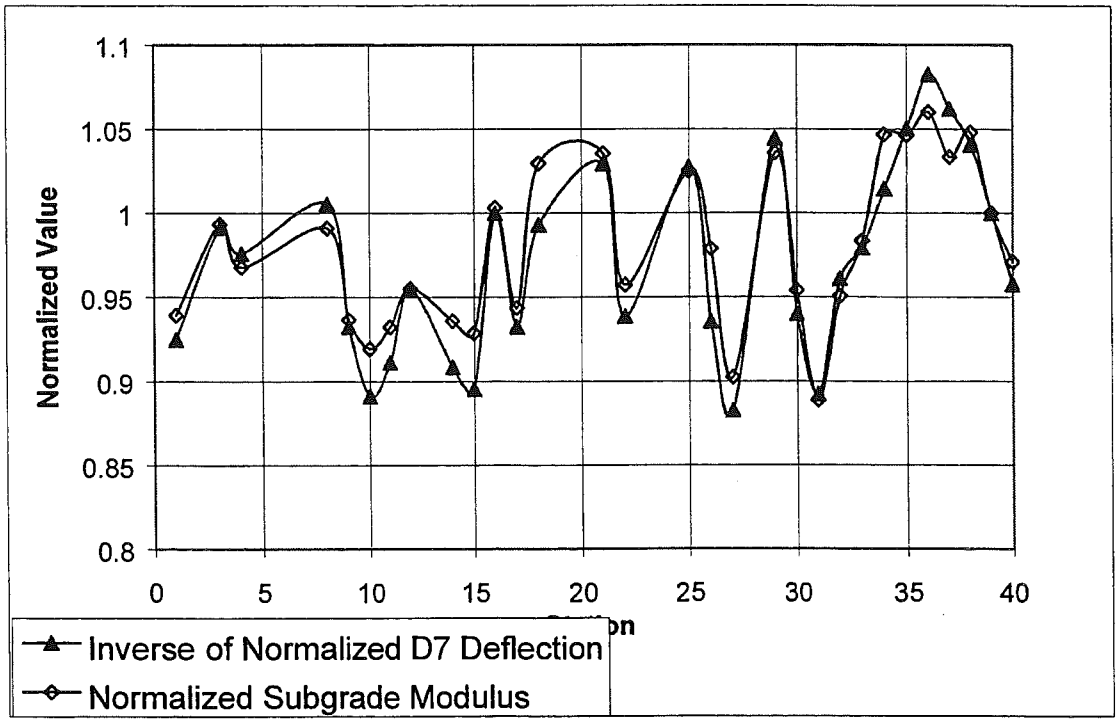


Figure J13. Normalized backcalculated subgrade moduli and the inverse of normalized D7 deflections for US-27 SB - section 4 test site 1

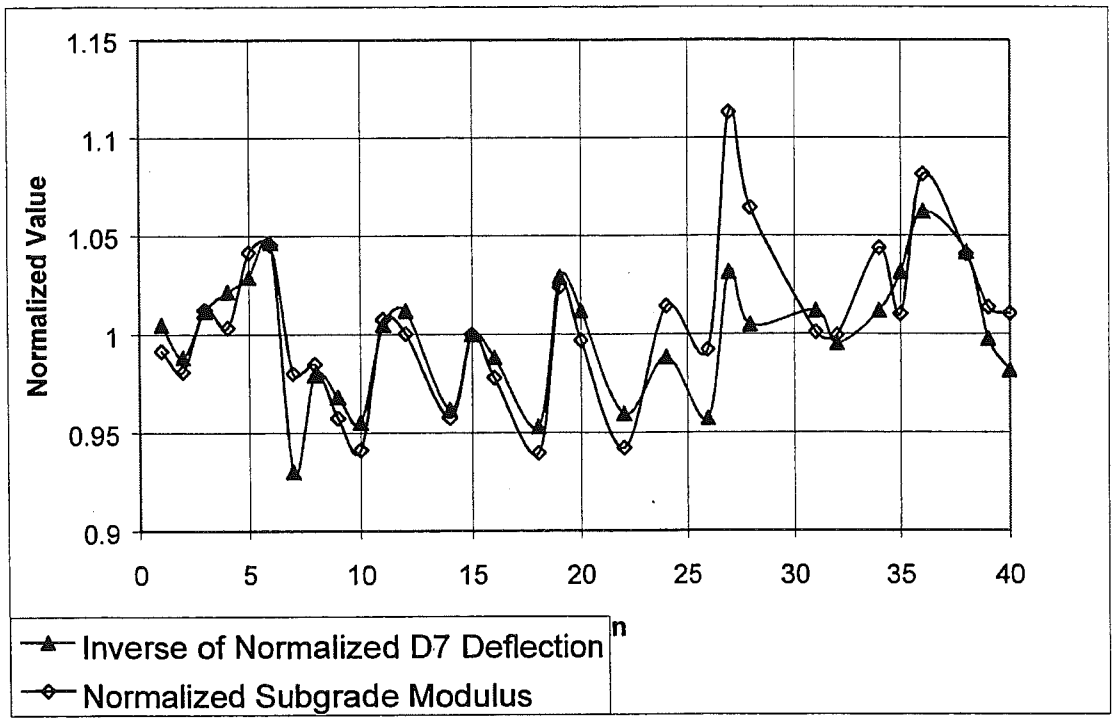


Figure J14. Normalized backcalculated subgrade moduli and the inverse of normalized D7 deflections for US-31 NB - section 1 test site 1

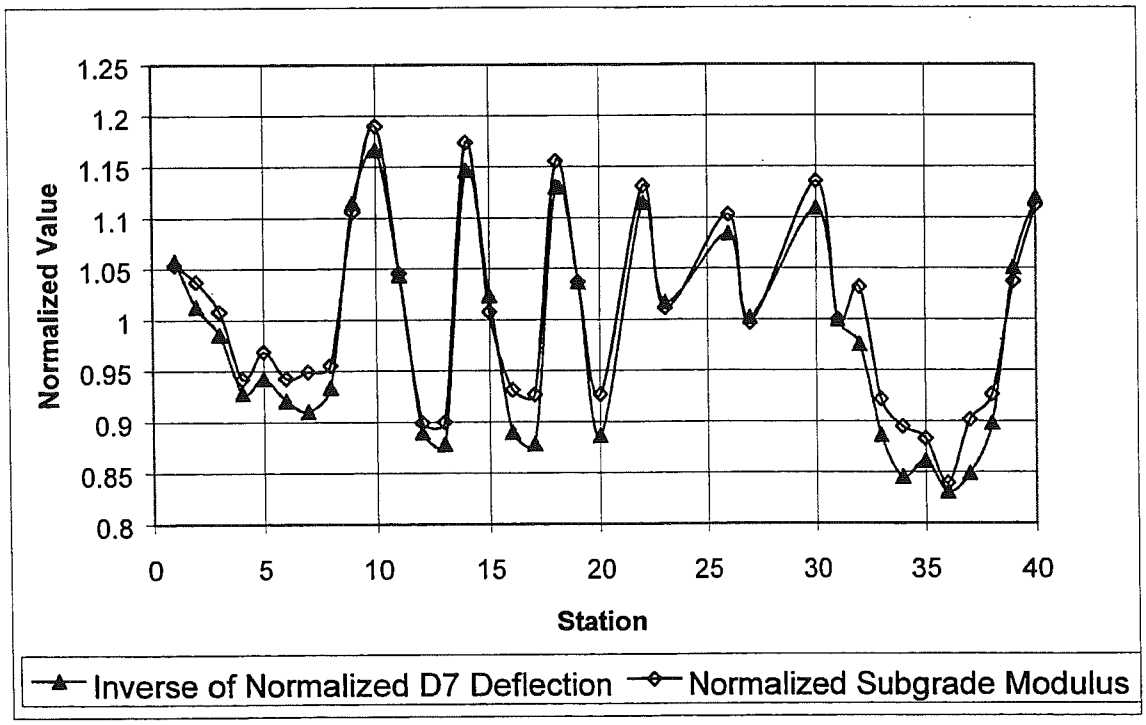


Figure J15. Normalized backcalculated subgrade moduli and the inverse of normalized D7 deflections for M-15 SB - section 1 test site 1

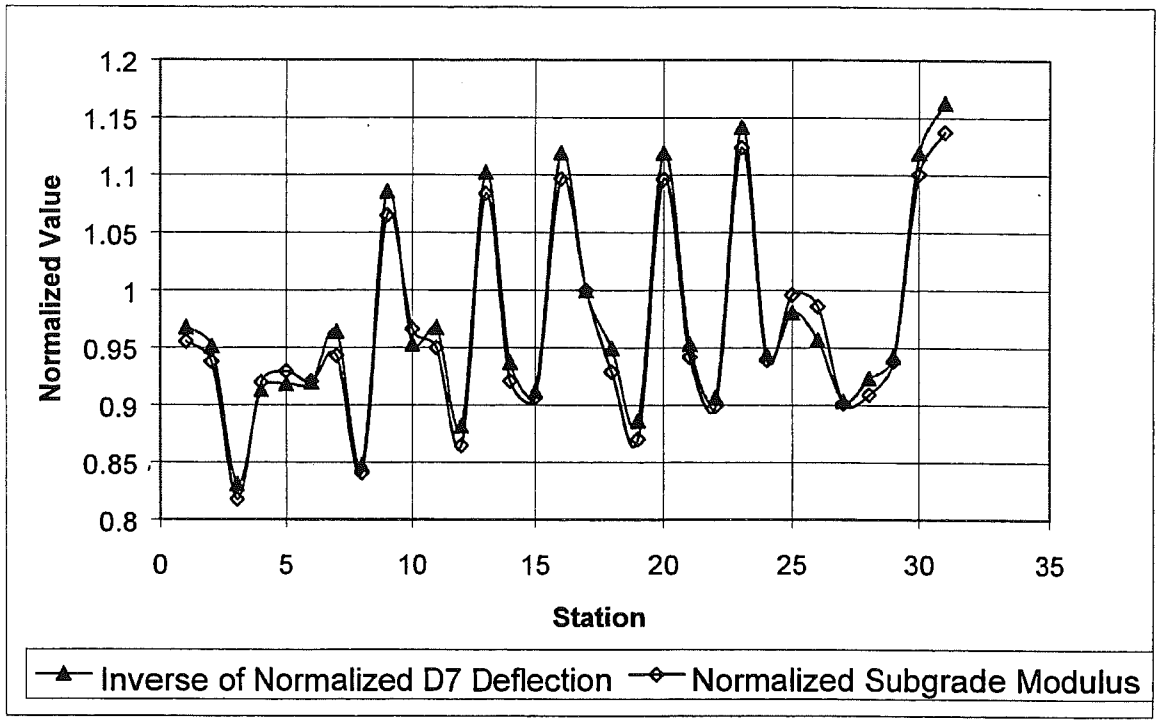


Figure J16. Normalized backcalculated subgrade moduli and the inverse of normalized D7 deflections for M-37 SB - section 5 test site 1

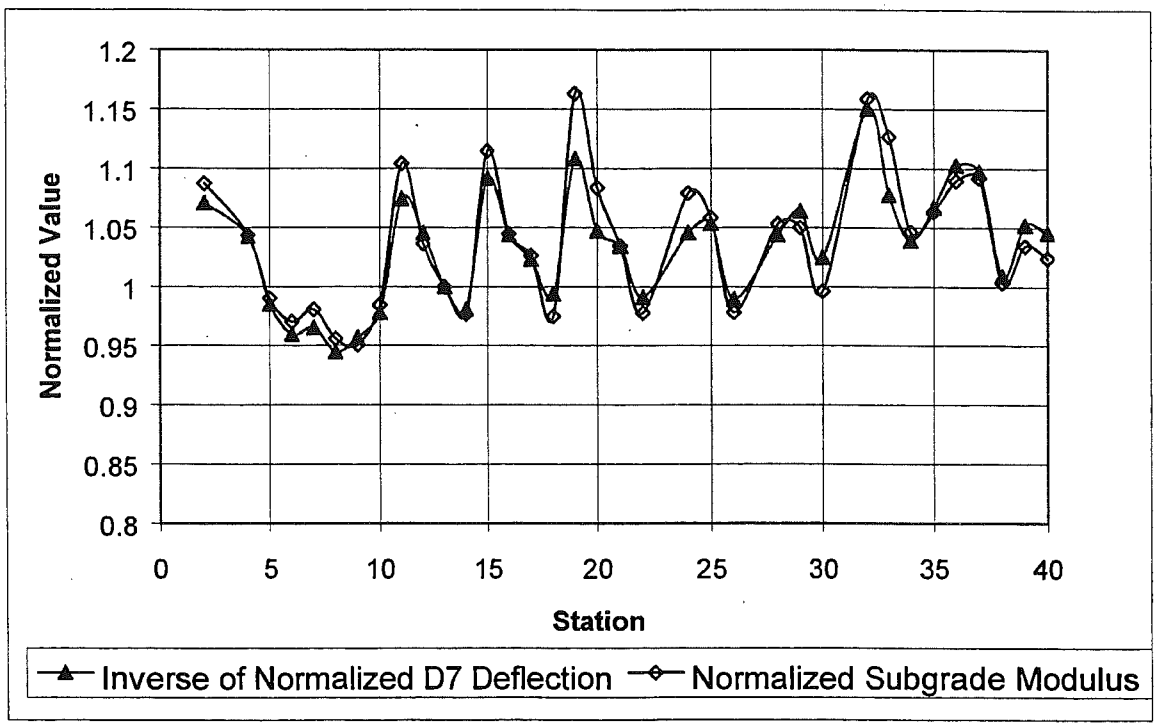


Figure J17. Normalized backcalculated subgrade moduli and the inverse of normalized D7 deflections for M-37 SB - section 5 test site 2

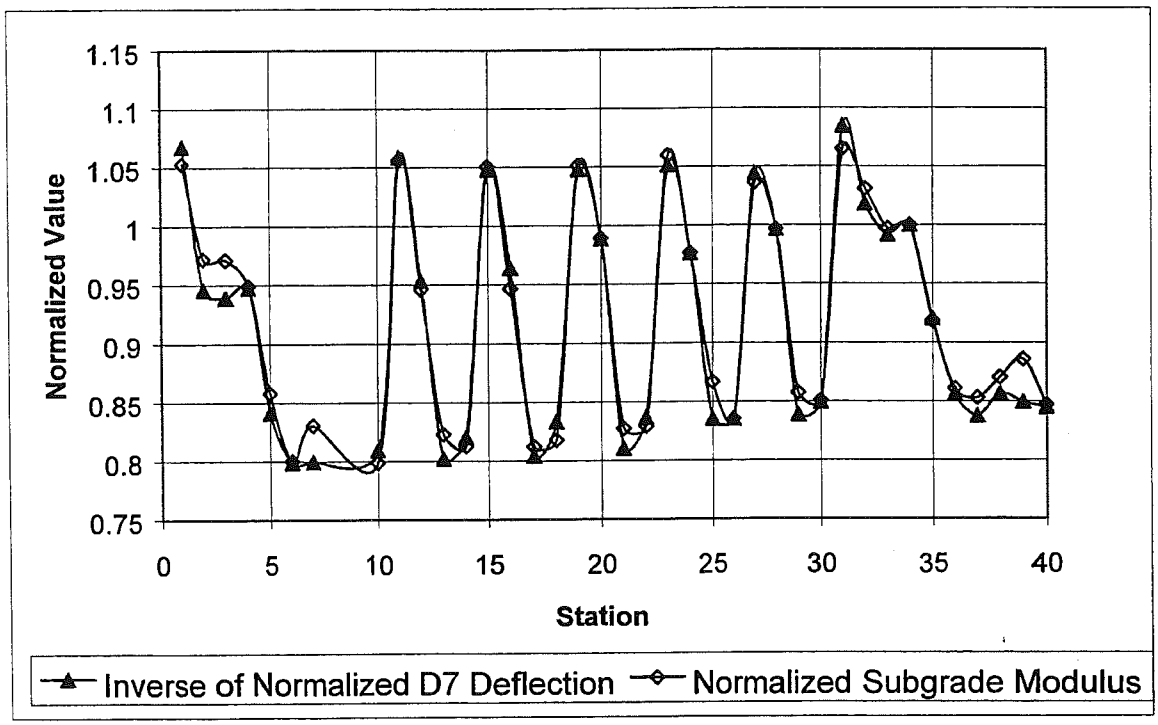
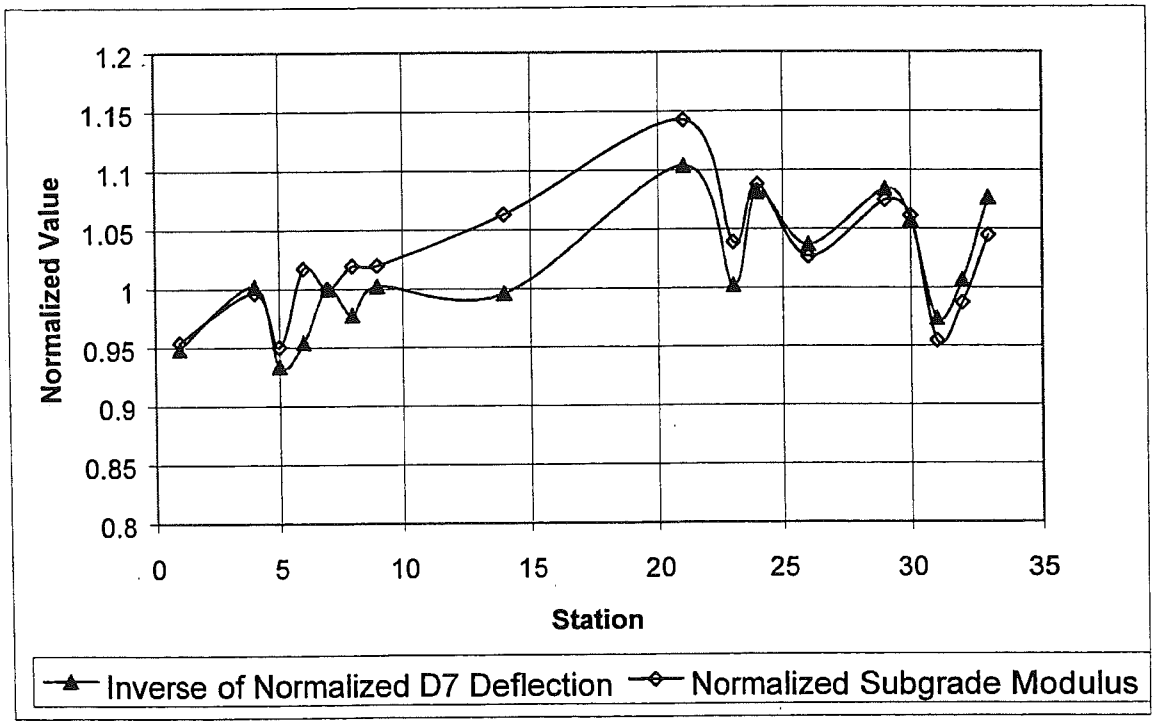


Figure J18. Normalized backcalculated subgrade moduli and the inverse of normalized D7 deflections for M-37 SB - section 6 test site 1



APPENDIX K

LITERATURE REVIEW

APPENDIX K
LITERATURE REVIEW

This appendix presents reviews of literatures regarding top-down cracks and factors affecting pavement performance especially top-down crack potential.

LITERATURE REVIEW

1.0 INTRODUCTION

Top-down cracks (TDC) in conventional asphalt and rubblized pavements initiate at the pavement surface and propagate downward, sometimes throughout the entire depth of the asphalt concrete (AC). Most of TDC in flexible pavements were observed in the vicinity of the wheel paths. It has been observed that the growth of TDC occurs in stages. The first stage consists of a single short longitudinal crack appearing just outside the wheelpath. Over time, a second stage develops where the short longitudinal TDC grow longer and new parallel sister cracks develop within 1 to 3 feet (0.3 to 1 meter) from the original crack. Finally, the TDC evolve into a third stage where the parallel longitudinal TDC are connected via short transverse TDC (1). The problem with TDC is that the cracks cannot be identified as TDC by the distress surveyor or by reviewing a video tape of the pavement. Hence, in the pavement management system distress data, TDC are reported as longitudinal and transverse cracks.

TDC has been increasingly investigated and reported as a prominent distress in flexible pavements throughout the world. It has been studied in various countries including Japan, France, Kenya, South Africa and Netherlands. In the United States, some State Highway Agencies such as Florida and Washington have studied and documented TDC on various asphalt pavements. In Michigan, the Michigan Department of Transportation (MDOT) has observed TDC in conventional flexible and rubblized pavements. As a result, this study sponsored by MDOT was conducted to identify the causes of underperformance of rubblized pavements, which is mainly contributed by TDC and reflective cracks. In this Appendix, literatures regarding rubblized pavements, TDC, and factors affecting the performance of the rubblized pavements will be reviewed and summarized as a part of this study. It should be noted that since behavior of rubblized pavements is similar to conventional flexible pavements, the causes of TDC in rubblized pavements and conventional flexible pavements should be similar and will be reviewed together. Finally, for the previously mentioned reason, the results of this study regarding causes of TDC will also be applicable for flexible pavements.

2.0 BACKGROUND

In 1987, Gerritsen et al conducted a study of TDC on pavements in the Netherlands (2). They concluded that the most probable causes of TDC include poor compaction, binder stiffening and/or low binder contents. Also in 1987, Duzauts and Rampal studied TDC in southern France and concluded that thermal stresses in the asphalt surface course are responsible for the initiation of TDC (3). In 1999, Wambura et al conducted a study of TDC and permanent deformation of roadways in Kenya (4). They reported that TDC have been documented in Kenya as early as the 1970's, and were the primary failure mode of the AC surface course. Based on laboratory investigation of pavement cores, they concluded that TDC were associated with the severe oxidation/hardening of the top few millimeters of the AC surface course (4).

In 1992, Matsuno and Nishizawa reported that TDC are a major distress in Japan that occurs near the wheelpaths in pavements ranging from 1 to 5 years old and is absent in shadowy areas such as under bridges (5). They conducted mechanistic analyses using finite element method on two typical pavement cross sections and concluded that traffic loads cause high tensile strains at the AC surface in hot pavements. and that the pavement cross section had little effect on the surface tensile strains. On the other hand, in 2000, Uhlmeyer et al conducted a study of the causes of TDC in conjunction with Washington State DOT (6). They observed that TDC occur in and around the wheel paths in pavements 3 to 8 years old with AC thickness of more than 6.3-inch (16-cm). Hence, they concluded that pavement thickness has an effect on the initiation of TDC.

Recently, Meyers et al conducted a study of TDC in Florida and reported that TDC typically occur outside the wheel paths and that the cracks penetrate to depths ranging from just under the pavement surface to the entire thickness of the asphalt layer (7). They concluded that the main cause of TDC is the increasing use of radial truck tires and that pavement structure has little effect on the surface tensile stresses.

Although various studies have been conducted, there is little consensus as to the causes of TDC.
The main mechanism of TDC is the tensile stresses and strains induced at the top of the pavement structure due to the combination of traffic load, temperature and aging (hardening) of the asphalt binder which may cause shrinkage and differential stiffness between the various asphalt courses (surface, leveling and base). Hence, to determine the causes of TDC, it is necessary to addresses the material, construction, environmental, and load factors that increase the TDC potential and hence have impact on pavement performance as it relates to TDC.

3.0 ASPHALT CONCRETE

Asphalt concrete (AC) is a composite material consisting, in general, of four major components: asphalt cement, coarse and fine aggregates, mineral fillers, and air. Occasionally, certain types of additives or modifiers are added to the asphalt concrete mix to alter some of its properties. Hence, an asphalt concrete is composed of a carefully graded aggregate matrix embedded in asphalt cement that fills part of the space between the aggregate particles and binds them together. The physical and engineering properties of asphalt concrete are dependent upon the properties of the constituent materials. These are summarized below.

3.1 Aggregate

The American Society for Testing and Materials (ASTM) defines aggregate as the inert material, such as gravel, sand, shale, slag, or broken stones or combination thereof with which cementing materials are mixed to form mortars or concrete, or alone as in base course, railroad ballast, etc. In general, aggregates comprise 70 to 75 percent of the total

volume of portland cement concrete and about 80 to 90 percent of the total volume of asphalt mix.

The term "aggregate" refers to both coarse and fine aggregate. Coarse aggregate consists of all materials retained on sieve number 4 (4.75 mm) whereas fine aggregate consists of all materials retained on the number 200 sieve (0.075 mm) and passes the number 4 sieve (4.75 mm). The gradation of aggregate affects its performance. A dense graded aggregate would have a particle size distribution such that, when it is compacted, the voids between the aggregate particles, expressed as a percentage of the total volume, are relatively small. An open-graded aggregate, on the other hand, has a particle size distribution such that, when it is compacted, the void between the aggregate particles is relatively large.

Aggregates can be divided into seven different types as follows:

1. Crushed Stone – The product of mechanical crushing of blasted rocks. Almost all faces of crushed stones have resulted from the crushing operation.

2. Gravel - Coarse aggregate resulting from natural disintegration of rocks.

3. Crushed gravel - The product of mechanical crushing of large stones such as cobbles or boulders to create more angular material. Specifications may require that at least one or more faces be the result of the crushing operation.

4. Slag - The nonmetallic product developed in a molten condition simultaneously during the manufacture of iron, steel, or other products. Slag can be divided into several types as follows:

   - Air-Cooled Slag - Solidified under atmospheric condition, sometimes accelerated by the application of water to the solidified surface.

   - Granulated Slag - Glassy, granular material formed when molten slag is rapidly chilled, as by immersion in water.

5. Lightweight Aggregate - Expanded cellular materials obtained by controlled, special processes from molten slag, clay, or shale, etc.

6. Sand - Fine aggregate resulting from natural disintegration of rock, or manufactured through crushing of rock or gravel.

7. Recycled Aggregate - Aggregate produced from crushing and screening of broken fragmented concrete or asphaltic concrete pavements; or other previously cemented mixtures, usually including much of the cementing medium, which is reclaimed in the process.

The basic properties of aggregate materials greatly depend upon the mineral constituents present in their parent rock formation. Rocks are grouped in three major classes, several subclasses, and great many types within each class as shown in table K.1. All of the three classes of rock have been used successfully as road aggregate and/or aggregate in concrete and asphalt mixes. The suitability of aggregate from a given source must be estimated from a combination of tests, supplemented by mineralogical examination. Unfortunately, data obtained from even the most widely used tests is sometimes misleading due to errors in sampling and lack of precision in the test method itself. The best possible indicator or index of aggregate suitability for a specific job is its known performance in earlier service of the type contemplated. Hence, for any job, historical performance data along with the types and source of the aggregate used should be kept for future reference and/or decision on whether or not to use the same type of aggregate.

Relative to TDC, since it has recently been recognized as a significant distress, the suitability of various aggregate types, shapes and/or gradations to resist TDC formation has not been investigated.

3.2 Asphalt Cement

Asphalt cement is a dark brown to black cementitious material, solid, semisolid, or liquid in consistency, in which the predominant constituent is bitumen. Bitumen is a mixture of hydro carbonates of natural or pyrogeneous origin, or a combination thereof.

Asphalt cement may be found in scattered seeps and pools (e.g., La Brea "Tar" pits in Hancock Park, Los Angeles) or in deposits of asphalt-impregnated rock (e.g., in Alabama, Texas), (8 and 9). At the turn of the century, asphalt material was obtained as the by-product of controlled refining of crude petroleum. In general, asphalt cement contains three major constituent materials. The three constituents and their approximate proportions by the total volume of asphalt are listed below.

1. Oils at about 50 percent by volume.
2. Resins at about 27 percent by volume.
3. Asphaltene at about 23 percent by volume.

The use of asphalt cement in civil works started as early as 6000 B.C. Engineers used asphalt as mortar with stones for buildings and with blocks for paving; as sealer material in reservoirs and canals; as paving materials in Babylon, as caulking material for Noah's Ark, and even as sealer in Moses' basket in which he was set adrift on the Nile river. Today, the annual worldwide consumption of asphalt is over 100,000,000 tons.

There are several terms that are relating to asphalt and its uses in pavements. These include:

1. Asphalt - A dark brown to black material in which the predominant constituent is bitumen, which occur in nature or is obtained from petroleum processing.

Table K.1 Classes and subclasses of igneous, sedimentary and metamorphic rocks

Igneous Rocks		
Coarse Grained (Deep Intrusion)	Fine Grained (Shallow Intrusion)	Fragmented (Volcanic)
Granite	Rhyolite	Ash
Diorite	Andesite	Tuff
Gabbro	Basalt	Agglomerate

Sedimentary Rocks		
Mechanically Deposited (Consolidated)	Chemically Deposited	
	Calcareous	Siliceous
Shale	Limestone	Chert
Siltstone	Dolomite	Opal
Sandstone		
Conglomerate		

Metamorphic Rocks		
Metamorphosed shale	Metamorphosed limestone	Metamorphosed sandstone
Slate	Marble	Quartzite

2. Asphalt Cement - Asphalt that is refined to meet specifications for paving, industrial, and special purposes (ASTM designations D 946 and D 3381).

3. Bitumen - A mixture of hydro carbonates of natural or pyrogeneous origin, or a combination of both; frequently accompanied by nonmetallic derivatives which may be gaseous, liquid, semisolid, or solid; and which are completely soluble in carbon disulfide.

4. Cutback Asphalt - Asphalt cement, which has been liquefied by blending with petroleum solvents. Upon exposure to atmospheric conditions, the solvents evaporate, leaving the asphalt cement to perform its intended function of cementing and waterproofing. Cutback asphalt may be made in three grades as follows:

   - Rapid Curing (RC) - Asphalt cement mixed with high volatility solvents such as naphtha and/or gasoline (ASTM designation D 2028).

   - Medium Curing (MC) - Asphalt cement mixed with medium volatility solvents such as kerosene (ASTM designation D 2027).

   - Slow Curing (SC) - Asphalt cement mixed with low volatility solvents such as oils (ASTM designation D 2026).

5. Emulsified Asphalt - An emulsion of asphalt cement and water that contains a small amount of an emulsifying agent. Emulsified asphalt can be made of either the anionic (electro negatively charged asphalt globules), or cationic (electro positively charged asphalt globules) depending upon the emulsifying agent (ASTM designation D 977).

Different asphalt cement grades are produced based on the fluidity as measured by viscosity or penetration. For all asphalt cement grades, the viscosity is typically measured at 140°F on the material coming directly out of the refinery whereas for the AR grades, the viscosity of the residue from the Thin Film Oven Test is measured. The selected asphalt cement grade for paving in any area is typically determined based upon the environmental factors of that area. When the average temperature in an area is cold, lower viscosity grades should be chosen to resist low temperature cracking. Likewise, in warm climates higher viscosity grades (stiffer asphalts) should be used to resist rutting. Experience would indicate which grade is best suited for a particular area. Since asphalt grade has substantial impact on the stiffness and fatigue characteristics of the asphalt concrete mix, the selection of such grade has direct impact on pavement design inputs and on pavement performance (10, 11, 12, 13, 14, and 15).

The characteristics of asphalt cements have changed over time due to changes in the crude oil source. For example, because of the oil trade embargo of the early 1970s, asphalt cements were obtained from sources other than the Middle East. The difference in the asphalt cements from one source to another can be characterized by the differences in the proportionality of the constituent materials such as oils, resins and asphaltene.

Although asphalt technologies have seen rapid development, due mainly to the Strategic Highway Research Program (SHRP) and other studies, distresses in asphalt pavements have

been increasing. The reasons are that the performance of asphalt pavements is a function of the many characteristics of the asphalt cement and the constituent materials of the asphalt mix. These include long- and short-term aging, temperature hardening, compaction, mineral fillers, loss of volatile, storage, etc. These and other characteristics and their impact on pavement performance are reviewed, summarized and reported in the remaining parts of this report. Such summary should assist highway engineers in understanding the various factors affecting pavement performance and hence, establish a better pavement performance prediction models.

4.0 IMPACT OF ASPHALT CEMENT CHARACTERISTICS ON PAVEMENT PERFORMANCE

The asphalt cement characteristics can be divided into three broad categories; physical, engineering, and morphological. The physical characteristics include color, the volumetric proportion of the various constituents in the asphalt cement and the density/specific gravity of the asphalt cement. The engineering characteristics on the other hand include stiffness and viscosity (viscoelasticity) or dynamic modulus, rate of expansion and contraction, ductility and rate of hardening/aging. Finally, the morphological characteristics include the elemental composition, molecular structure, and molecule size distribution of asphalt cement. The engineering characteristics hold the most significance to the pavement response and overall performance, including the initiation of TDC, and therefore are the only set of characteristics examined throughout the remainder of this report.

4.1 Asphalt Cement Grading System

The grading systems of asphalt cements are based on their consistency. There are three well known asphalt grading systems in the United States, penetration, viscosity, and the latest superpave performance grades (PG). The ASTM standard penetration grading system of asphalt cements is based on the penetration of a standard needle of prescribed dimensions into the asphalt cement at 77°F. The needle is loaded with 100 g weight and penetrates the sample for 5 seconds. Penetration grades are specified as, 40-50, 60-70, 85-100, 120-150, and 200-300. Lower penetration number means the asphalt is hard whereas higher penetration number represents softer asphalt. The standard unit of penetration grade expresses the needle penetration in mm multiplied by 10. For example, a 40-50 penetration grade means the standard needle penetrates the asphalt 4 to 5 mm in 5 seconds. The penetration test is empirical in nature and the amount of penetration varies with temperature Roberts et al (16).

Table K.2 shows ASTM requirements of each penetration grade, such as flash point, ductility at 77°F, solubility in trichloroethylene, etc.

The most common grading system in the United States is the viscosity grade. In this system, the viscosity of the asphalt cement is measured at 140 °F, which represents the maximum surface pavement temperature. The six categories viscosity grading system classifies asphalt cement as follows: AC-2.5, AC-5, AC-10, AC-20, AC-30, and AC-40. Higher viscosities

Table K.2 ASTM D 946 requirements for penetration graded asphalt cement

	Penetration Grade									
	40-50		60-70		85-100		120-150		200-300	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Penetration at 77°F (25°C) 100 g, 5 s	40	50	60	70	85	100	120	150	200	300
Flash point, °F (Cleveland open cup)	450	...	450	...	450	...	425	...	350	...
Ductility at 77°F (25°C) 5 cm/min, cm	100	...	100	...	100	...	100	...	100*	...
Solubility in trichloroethylene (%)	99	...	99	...	99	...	99	...	99	...
Retained penetration after thin-film oven test (%)	55+	...	52+	...	47+	...	42+	...	37+	...
Ductility at 77°F (25°C) 5 cm/min, cm after thin-film oven test	...	...	50	...	75	...	100	...	100*	...

* If ductility at 77F (25C) is less than 100 cm, material will be accepted if ductility at 60F (15.5C) is 100 cm minimum at the pull rate of 5 cm/min

imply harder asphalts. Hence, AC-2.5 is the softest asphalt, which is usually used in cold region such as Alaska to prevent thermal cracks. Harder asphalt, AC-30 and AC-40, on the other hand, are used in warm no-freeze regions to resist pavement deformation or rutting. The common unit for viscosity is poise, the lower is the poise; the lower is the viscosity of the asphalt cement. Tables K.3 and K.4 show the ASTM requirements for viscosity graded asphalt cements based on tests on the original asphalt and on aged residue (AR) from rolling thin-film oven test, respectively.

The AR grading system of table K.4 is thought to represent the short-term aging during mixing and construction of the asphalt and it is mainly used by California and other southwestern states.

The main disadvantage of the viscosity-grading system is that it is based on the performance of the original asphalt at high temperature of 140°F; the system does not address the asphalt performance at low temperatures. To overcome this disadvantage, the superpave (Superior Performing Asphalt Pavements) grading system was developed and labeled PG (performance grade). The unique feature of the superpave binder specifications is that instead of performing tests at constant temperatures and varying the specified values, the specified value is constant and the test temperature at which this value must be achieved is varied (17).

The superpave system is based on an array of tests such as the Rolling Thin-Film Oven Test (RTFO), Pressure Aging Vessel (PAV), Rotational Viscometer (RV), Dynamic Shear Rheometer (DSR), Bending Beam Rheometer (BBR), and Direct Tension Tester (DTT). The RTFO and PAV tests simulate short- and long-term aging of asphalt binders, respectively. The RTFO test results express the aging characteristics of the asphalt binder during construction whereas the PAV results express the characteristics of the asphalt binder aged 5 to 10 years. The RV test is used to determine the viscosity of asphalt binders at construction temperatures above 100°C to ensure that binders are fluid enough for pumping and mixing. The DSR test is used to determine the viscous and elastic behaviors of the binders at high and intermediate temperatures. Finally, the BBR and DTT tests are used to examine the behavior of asphalt binders at low temperatures. The BBR results express the ability of virgin asphalt binders to resist low temperature cracking while the DTT test is typically used to measure the creep stiffness (ductility) of modified asphalt binders at low temperatures.

The superpave PG grading system is based on three pavement performance attributes; fatigue, rut, and thermal cracking (17 and 81). Superpave binders must have good resistance to fatigue, low temperature cracking and rutting. Thermal cracks are mainly transverse cracks that may initiate at the pavement surface and propagate downward or may take place throughout the thickness of the asphalt mat simultaneously. Hence, thermal cracks may or may not be considered as TDC. Therefore, one can state that the superpave performance grading criteria do not address TDC. This is significant in that as TDC is becoming more prevalent on asphalt pavements, even the most advanced mix design methods fail to address it.

Table K.5 shows the PG grading system. Each grade consists of the letters PG (performance grade) and two numbers; the first number expresses the high temperature while the second

Table K.3 Requirements for viscosity graded asphalt cement, the grading is based on the original asphalt.

Test	Viscosity Grade					
	AC-2.5	AC-5	AC-10	AC-20	AC-30	AC-40
Viscosity, 140°F (60°C), P	250±50	500±100	1000±200	2000±400	3000±600	4000±800
Viscosity, 275°F (135°C), min, cSt	125	175	250	300	350	400
Penetration, 77°F (25°C), 100 g, 5 s, min	220	140	80	60	50	40
Flash point, Cleveland open cup, min, °F(°C)	325 (163)	350 (177)	425 (219)	450 (232)	450 (232)	450 (232)
Solubility in trichloroethylene, min, %	99	99	99	99	99	99
Tests on residue from thin-film oven test:						
Viscosity, 140°F (60 °C), max, P	1250	2500	5000	10000	15000	20000
Ductility, 77°F (25°C), 5 cm/min, min, cm	100*	100	75	50	40	25

* If ductility is less than 100, material will be accepted if ductility at 60 °F (15.5 °C) is 100 minimum at pull rate of 5 cm/min
Note: AC-5 expresses an average viscosity of 500 poises at 140°F

Table K.4 Requirements for viscosity graded asphalt cement; the grading is based on aged residue (AR) from rolling thin-film oven test.

Test	Viscosity Grade				
	AR-1000	AR-2000	AR-4000	AR-8000	AR-16000
Viscosity, 140°F (60°C), P	1000±250	2000±250	4000±1000	8000±2000	16000±4000
Viscosity, 275°F (135°C), min, cSt	140	200	275	400	550
Penetration, 77°F (25°C), 100 g, 5 s, min	65	40	25	20	20
% of original penetration, 77°F (25°C), min	...	40	45	50	52
Ductility, 77 °F (25 °C), 5 cm/min, min, cm	100[B]	100[B]	75	75	75
Tests on residue from thin-film oven test:					
Flash point, Cleveland open cup, min, ° F(°C)	400(205)	425 (219)	440 (227)	450 (232)	460 (238)
Solubility in trichloroethylene, min, %	99	99	99	99	99

[A] Thin-film oven test may be used but the rolling thin-film oven test shall be the referee method

[B] If ductility is less than 100, material will be accepted if ductility at 60 °F (15.5 °C) is 100 minimum at a pull rate of 5 cm/min

Note: AR-1000 expresses an average viscosity of 1000 poises at 140°F

Table K.5 The superpave performance grades of asphalt binders

High Temperature Grade (°F)	Low Temperature (°F)
PG 46	-34, -40, -46
PG 52	-10, -16, -22, -28, -34, -40, -46
PG 58	-16, -22, -28, -34, -40
PG 64	-10, -16, -22, -28, -34, -40
PG 70	-10, -16, -22, -28, -34, -40
PG 76	-10, -16, -22, -28, -34
PG 82	-10, -16, -22, -28, -34

expresses the low temperature. For example, PG 70-16 implies that the asphalt binder is expected to perform well with minimal signs of rutting, fatigue, or thermal cracks in the temperature range of 70°F to -16°F. Hence the binder should have adequate physical and engineering properties under both the maximum and the minimum temperatures. Such properties (specifications) can be found in AASHTO MP1-93.

It is very important to select a suitable PG grade for given climatic conditions. Failure to do so may result in poor pavement performance.

4.2 Binder Stiffness

The stiffness or the stiffness modulus of an asphalt binder is expressed in terms of the relationship between stress and strain as a function of the time of loading and temperature (16). At low temperatures and at short loading time, the asphalt binder behaves as elastic material and its stiffness is relatively high. High loading times and/or high temperatures cause the asphalt binder to behave like viscous material and its stiffness to decrease. The stiffness of an asphalt binder can be empirically estimated by using nomographs such as the Shell nomograph or by conducting tests in the laboratory.

As stated earlier, in warm regions, stiffer binders are generally used to prevent pavement deformation or rutting. Softer asphalt binders are typically used in lower temperature regions to prevent thermal cracking. In addition to the climatic temperature variation, daily temperature cycling of the thermal gradient will result in variations of stiffness throughout the asphalt layer, and the overall temperature susceptibility of the asphalt will have a significant impact on the day-to-day response of the pavement.

4.3 Complex Shear Modulus

The dynamic shear rheometer (DSR) test is used to determine the complex shear modulus (G*) and the phase angle (δ) (time lag between the applied shear stress and the shear strain) of the asphalt binder. The complex shear modulus, G* and the phase angle, δ are important parameters in the description of the asphalt rheology. The complex modulus expresses the total resistance of asphalt to deformation under repeated shear. In other words, G* is the ratio between maximum shear stress, τ_{max} and maximum shear strain, γ_{max} in which the time lag between stress and strain is the phase angle, δ.

$$G^* = \frac{\tau_{max}}{\gamma_{max}} \qquad \text{(K.1)}$$

Asphalt is a viscoelastic material in which its behavior is somewhere between elastic and viscous material. Thus, the complex shear modulus of asphalt consists of two components, storage modulus (G') and loss modulus (G"). The two components can be calculated by the following equations.

$$G' = G^* \cos(\delta) \qquad \text{(K.2)}$$

$$G'' = G^* \sin(\delta) \qquad \text{(K.3)}$$

G* and δ are highly depended on temperature. At high temperature, the binder behaves like viscous fluid. Hence, G' would be small and δ would approach 90°. At low temperature, on the other hand, G' would be large and δ would approach 0° (16 and 18).

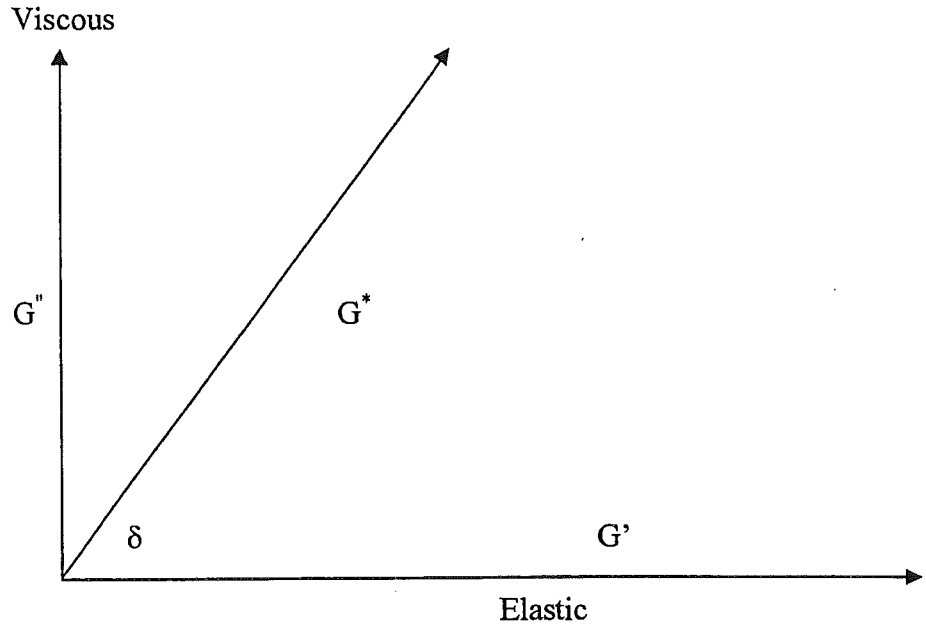
For better understanding of G* andδ, Roberts et al (16) suggested plots consisting of two axis, horizontal (elastic) and vertical (viscous) components as shown in figure K.1. The figure shows two asphalt binders having the same G* (same diagonal length) but different phase angleδ. Asphalt No. 2 has smaller δ indicating a more elastic behavior than that of Asphalt No.1. Thus, asphalt No. 2 under stress will behave more elastically (recoverable strain) and less viscous (non-recoverable strain) than asphalt No. 1. This also shows that G* alone is not sufficient to characterize asphalt binders, the phase angle is also needed.

4.4 Low-Temperature Hardening

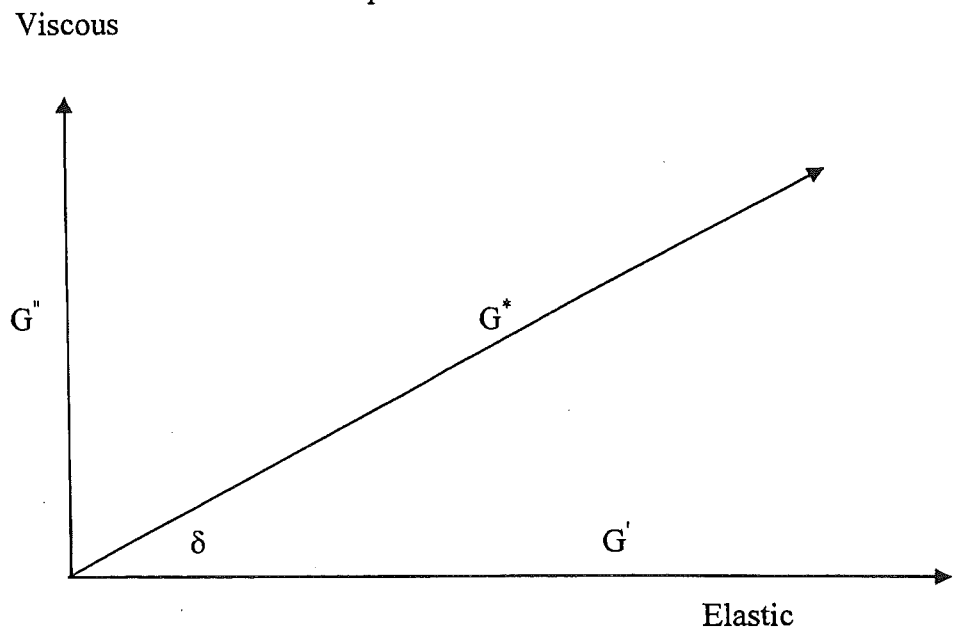
As stated earlier, the behavior of asphalt binders is temperature dependent. Low temperatures cause hardening of the asphalt binder in terms of increasing elasticity, increasing viscosity, decreasing plasticity and decreasing ductility (10, 11 and 12). Anderson et al (19) tested several asphalt binders at low temperatures using the bending beam rheometer (BBR). He reported that the binder stiffness increased by about 83 percent as the temperature decreased from -12 to -18°C. Low temperatures may also cause thermal cracking. Bahia et al studied strain at failure and strength of AC mixes to predict thermal cracking potential in pavements (80).

Numerous studies have shown that the sensitivity of the asphalt binders to low temperatures has a direct impact on pavement performance. For example, the increase in the viscosity and decrease in plasticity of the asphalt binder at low temperatures are beneficial in that they decrease rut potentials. The decrease in ductility, on the other hand, causes an increase in low temperature cracking potential. Stoffels et al stated that extreme temperature, cycling of temperature changes and cooling rate are the three factors influencing low temperature distress (20). Roberts et al (16) concluded that decreasing ductility causes an increase in the load-related longitudinal cracking potential in flexible pavements. Such longitudinal cracks are likely TDC.

The effect of temperature on asphalt cement has a corresponding effect on the properties of the asphalt mixture. Stresses induced by expansion and contraction of mixture have been attributed to various distresses. Jung and Vinson and Jackson and Vinson indicated that friction between the base and the asphalt layer results in stresses that may exceed the tensile strength of the asphalt (21 and 22). They stated that if cracks do not form during a single temperature cycle, the repetitive cycling would result in thermal fatigue. They also suggested that other mechanisms may be at work that causing distress. The cracks observed in these studies were transverse cracks, but longitudinal TDC has also been attributed to thermal fatigue elsewhere. Researchers in France have attributed TDC to thermal fatigue, and developed a cracking model based on extreme temperature variation, daily temperature cycling and crack propagation in asphalt. They observed that their model correlated well with observed TDC cases in southern France (3).



Asphalt No.1



Asphalt No.2

Figure K.1 Viscous and elastic behaviors of asphalt binders (after 35)

The low temperature cracking potential of asphalt binders was analyzed relative to the applied thermal stress and relative to the glass transition temperature. Khattak (18) cited Hills and reported that the critical thermal stress at which the asphalt binder cracks is 73 psi. In real life, flexible pavements are subjected to thermal and load-induced tensile stresses that may combine to cause cracks. Such cracks may be longitudinal and/or transverse and they are likely TDC. Recent three dimensional finite element analyses showed that the load-induced tensile stress at the pavement surface could be as high as 100 psi (1). When such a stress is combined with the tensile thermal stress, the resulting total tensile stress could be higher than the tensile strength of the asphalt. Other researchers determined the temperature at which critical stresses were induced; such temperature is known as the fracture temperature. Jung and Vinson and Jackson and Vinson indicated that the fracture temperature is sensitive to the asphalt type and the degree of aging and to a lesser degree to the aggregate shape (21 and 22).

Various studies were also conducted to determine the limiting stiffness value at which the asphalt binder cracks. Results obtained by Kandhal showed thermal cracks develop in flexible pavements when the binder stiffness increases above 20,000 psi for a period longer than 20,000 seconds (5.5 hour) (14 and 23). Stroup-Gardiner et al, on the other hand, found that thermal cracks occurred when the asphalt binder stiffness reaches 29,000 psi (15). McLeod determined the limiting mix stiffness to be 1,000,000 psi at –10oF for a 20,000 second loading time which was later confirmed by Kandhal (23 and 24). It should be noted however, that the relationship between binder stiffness from BBR tests and mix stiffness from indirect tensile creep tests showed a weak relationship (10, 11, 12, 14 and 25). This suggests that physical hardening in asphalt binders might not necessarily translate into asphalt mixture properties.

4.5 High Temperature Properties

Asphalt cement is a temperature susceptible material. At high temperatures, the viscosity of the binder decreases, resulting in higher penetration (softer asphalt), higher viscous flow, lower shear resistance and higher rut potential. However, at high temperatures, asphalt binders become more flexible, which decreases fatigue cracking potential. It has been suggested that the increase in the binder flexibility due to high temperatures causes crack healing. Studies in Japan indicate that at low temperatures (such as during the night) the pavement surface may exhibit surface cracking while at high temperatures (during the day) the kneading action of the tires "heal" the surface initiated cracks. Cracks in asphalt pavements become visible when the binder has experienced age hardening and cannot effectively heal itself (5).

The viscoelastic behavior of asphalt binders can be modeled using a system of shock absorber and spring as shown in figure K.2 (18). At high temperatures, the binder becomes highly viscous and the elastic component decreases. At low temperatures, the viscoelastic component diminishes and the elastic component becomes large. Hence, the spring in figure K.2 becomes larger with higher spring constant. This implies that the asphalt binders recover much more deformation than at high temperatures. At very low temperatures, the asphalt looses its ductility and becomes brittle material that cracks due to low strain.

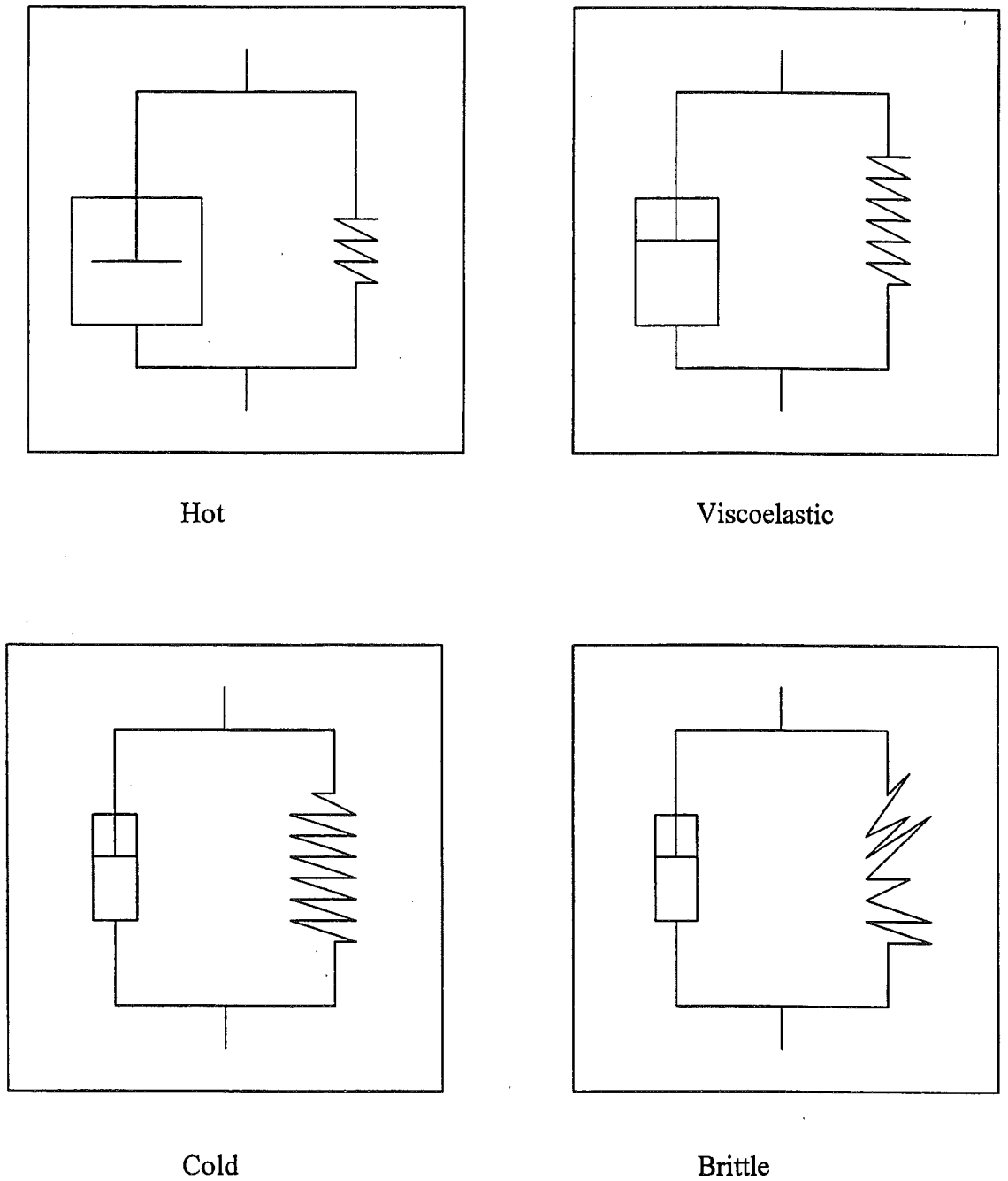


Figure K.2 Schematic of viscoelastic model for asphalt binder (after Khattak, 61)

4.6 Aging

Aging or hardening of asphalt binders occurs during the mixing and construction process (short-term aging) as well as during long-term service (long-term aging) (26 and 27 and 76). In the pug mill or drum mixer, oxidation and volatilization may result due to the elevated temperature. In the lab, this short-term aging is simulated using the Rolling Thin Film Oven Test (RTFOT). After construction, exposure to the atmosphere and sunlight can cause long-term aging close to the pavement surface. This can produce a differential stiffness in the AC courses, which Svasdisant et al stated is the one of the causes of TDC (1). In the laboratory, the Pressure Aging Vessel (PAV) is used to simulate long-term aging of binders during the service life of the pavement (26). Short- and long-term oven aging are also used to assess the impact of short term aging (mixing, storage and paving operations) and long term aging on pavement performance (77 and 78).

Recent study on TDC suggested that aging decreases the tensile strength and the tensile strain at failure, which causes increases in cracking potential in asphalt pavements. Such cracks are likely to initiate from the top of the pavement and overtime propagate downward (1). Wambura et al conducted a study on pavements known to be exhibiting TDC in Kenya. They reported that penetration tests on recovered binder indicated severe age-hardening of the asphalt in the top few millimeters of the pavement (4). Other researchers, such as Matsuno and Nishizawa, Gerritsen et al. and Hugo and Kennedy have all attributed age hardening to occurrences of TDC (5, 2, and 28).

Roberts et al (16) suggested six factors that may cause age hardening of asphalt cement, these are:

Oxidation - Oxidation is the result of reaction between oxygen and the asphalt cement. It causes asphalt binders or mixtures to become stiffer and less ductile. The rate of oxidation depends on the temperature and characteristics of the asphalt cement. Higher air voids in the asphalt mixtures are likely to accelerate the rate of oxidation.

Volatilization – Most losses of volatile materials occur during mixing and construction. Loss of volatile causes higher stiffness in the asphalt binder.

Polymerization and Thixotropy - Polymerization is the formation of larger molecules by combining like molecules, which causes progressive hardening. Thixotropy, on the other hand, is a progressive hardening due mainly to the formation of a structure within the asphalt cement over a period of time. Such hardening can be destroyed by reheating (16).

Syneresis - Syneresis is a phenomenon when oily liquid rise to the surface of asphalt film and when it is destroyed by environmental condition, it may cause asphalt to get harder.

Separation - separation occurs when oily material in the asphalt is absorbed by some porous aggregates.

Aging causes higher asphalt binder stiffness and less flexibility that cause increases in the load-related cracking potential in flexible pavements. Such cracks (longitudinal and/or transverse) are likely TDC that start at the top of the pavement surface and propagate downward (1).

The quantity of age hardening in term of percent retained penetration and aging index can be determined by using equations K.4 and K.5, respectively.

$$\%\mathrm{Re}tainedPenetration = \frac{Penetration(asphalt_{aged})}{Penetration(asphalt_{original})} \times 100 \qquad \text{(K.4)}$$

$$AgingIndex = \frac{Vis\cos ity(asphalt_{aged})}{Vis\cos ity(asphalt_{original})} \qquad \text{(K.5)}$$

Since the properties of the asphalt cement are affected by aging, the properties of the asphalt mixture are affected as well. Short term aging in asphalt mixtures is simulated by heating the uncompacted mixture for 4 hours at 135°C while long term aging is simulated by heating a compacted mixture for 5 days at 85°C.

The modulus of the asphalt mixtures for all types of aging increased with the duration (extent) of the aging (27 and 29). Additionally, aging decreases the tensile strength and strain to failure. The net result is that the mix becomes excessively hard and brittle and therefore susceptible to segregation and cracking1. Aging is also more pronounced in asphalt with higher air voids. This is because more of the asphalt is in direct contact with the atmosphere. Corbett and Merz observed that aging was observed in weathered and raveled pavements (30).

There is evidence that aging may have different effects on pavements having different thicknesses. Harvey and Tsai suggested that fatigue life increases for thicker pavements experiencing aging near the surface (31). Mukhtar elaborated by stating that aging increases the stiffness of the compression zone near the asphalt surface and decreases the stress in the fatigue tension zone at the bottom of the asphalt layer (32). Furthermore, Kandhal and Wenger indicated that aging alone may not cause pavement distress but may act only as a mechanism by which other factors (such as water infiltration) may distress the pavement (14).

5.0 IMPACT OF ASPHALT MIXTURES CHARACTERISTICS ON PAVEMENT PERFORMANCE

5.1 Asphalt Mixture Design Procedure

The Marshall, Hveem and Superpave methods are the most well known asphalt mixture design procedures in the United States and in most countries. The detailed descriptions of these mix designs can easily be found elsewhere, and therefore are not discussed here. The Hveem method is mainly used by California and other southwestern states, while others use Marshall Mix Design. The two criteria in Marshall Design method are density and voids properties of the mix, which is correlated to asphalt mix durability. The equipment related to the design is inexpensive and portable. However, the Marshall compaction does not simulate field compaction. Also, the stability of the mix is not correlated to the shear strength of the mix or its rut potential.

Likewise, the Hveem method focuses on density and void properties of HMA. However, the Hveem method is more accurate in simulating real densification characteristics occurring in real pavement than the Marshall method, and it also predicts mix shear strength more accurately. The Hveem method is difficult, expensive, not portable, and the method is barely used in routine testing.

The Superpave mix design includes two types of aggregate properties; consensus and source. The consensus properties include the angularity of coarse and fine aggregates and the number of flat and elongated particles and clay content. The Superpave procedure specifies these properties for different mix levels depending on traffic volume and position of the layer in the mix. The angularity of aggregates increases internal friction, which increase shear strength resulting in higher resistant to rutting. Flat and elongated particles are easy to break during transporting or handling which will result in lower mix stiffness. Therefore the superpave method limits the amount of flat and elongated aggregates and clay particles, the latter decrease the adhesive bonding between aggregates and the asphalt cement (17).

The source properties include toughness, soundness, and deleterious materials. These source properties are identified by some types of testing. For example, toughness of aggregates is determined by LA abrasion test. In addition, the Superpave procedure specifies aggregate gradation based on the 0.45-power gradation chart. The gradation must meet the required proportion of sand and coarse aggregates to ensure adequate shear strength to resist pavement deformation. It also specifies the air void in the mix for durability purposes. It should be noted that because of the crushed materials in the superpave mix, it is difficult to reach the specified air voids due to particles interlock.

Finally, Superpave mixes are compacted in the laboratory using a Superpave Gyratory Compactor (SGC). The hot mix asphalt (HMA) is subjected to performance based testing that include the Superpave Shear Test (SST) and Indirect Tensile Test (ITT). The test results are used for better prediction of pavement performance (17).

It is very important to select a suitable mix design procedures that most likely simulate the asphalt mixtures in the field. Failure to do so may result in poor pavement performance prediction.

5.2 Air Voids

The performance of compacted asphalt mixture is dependent on the percent air voids content. Lower air voids contents (below 2 percent) increase rutting and bleeding (flushing) potentials (33). Higher air voids contents (above 6 percent) cause increases in fatigue cracking, rutting and shoving potentials (32). Reducing the air void contents from 8 to 5 percent causes an increase in the fatigue life from 100 to 200 percent (31, 32 and 33). The air voids contents also affect the stiffness of the mix. Various researchers including Baladi (33) and Harvey and Tsai (31) found high correlation between air void and stiffness and fatigue life of the mix. Linden et al. suggested that a 1 percent increase in the percent air voids content reduces the pavement performance by about 10 percent (34).

In addition, higher air voids contents cause an increase in the rate of oxidation (hardening). It was reported that after 4 years of service, asphalt penetration is reduced by about 6 percent for each 1 percent increase in the percent air voids content (34). Lower penetrations increase the pavement cracking potential. Such cracking may be manifested as temperature cracks, fatigue cracks or top down cracks (1). In general, the as compacted air voids content of an asphalt mat decreases as the thickness of the AC increases. The reason is that thicker pavement section retains heat for longer time period permitting better compaction during construction (34 and 35).

5.3 Large Aggregate Size and Contents

Asphalt mixtures containing larger size aggregates require less asphalt content to coat the aggregate and have higher modulus values than those containing smaller aggregate sizes (36 and 37). However, larger aggregate sizes are not desirable because standard equipment such as the 4-inch mold cannot be used for testing the materials. Various researchers investigated the effects of large aggregate sizes on asphalt mixture performance. They reported that larger aggregate sizes (32, 36 and 38):

- Improve the tensile strength of the mix by about 10 percent thereby decreasing cracking potential.
- Increase the modulus of the mix by about 50 percent at both low and high temperatures thereby reducing the potential for rutting and temperature cracking.
- Decrease permanent deformation potential (50, 79).
- Enhance aggregate to aggregate contact.
- Increase the mix stability thereby decreasing shoving potential.

It should be noted that too coarse of an aggregate gradation may lead to insufficient asphalt content. This causes decreases in durability, increases in raveling potential, and increases in the required compaction effort (37).

Coarse aggregate (+ sieve number 4 material) contents also affect pavement performance. Increasing coarse aggregate content to 70 percent causes decreases in rut and fatigue cracking potentials (32 and 33). Low coarse aggregate contents cause the aggregate to float in the sand matrix and to loose face to face contact.

5.4 Rounded and Crushed Aggregate

High rounded fine and coarse aggregate contents in asphalt mixtures cause increases in the rutting potential, decreases in shear strength and increases in the stripping potential (32, 37, 38 and 39). Crushed aggregates tend to interlock providing higher resistance to deformation and higher shear strength. For these reason many State Highway Agencies and the superpave mixes specify a minimum crushed aggregate content in their acceptance criteria.

5.5 Fine aggregate (Sand) Content

The term fine aggregate or sand refers to all particles passing the number 4 sieve and retained on the number 200 sieve. Higher sand contents in asphalt mixtures cause increases in the rut and fatigue cracking potentials (32 and 33). Mukhtar (32) developed a statistical equation correlating the rate of rutting to various mix variables including sand contents. He stated that increasing the sand content by about 30 percent (e.g., 30 to 60 percent) causes about 35 percent increase in the rut potential.

5.6 Mineral Filler

Mineral fillers include all materials passing the number 200 sieve. Since 1890, mineral fillers were included in asphalt mixtures (40). The purpose of adding mineral fillers to asphalt mixtures is to increase its stiffness and decrease its air voids content. In addition, the chemical reaction between mineral fillers and the asphalt binder produces a water insoluble compound thereby increasing the mixture durability (41).

The degree of stiffening depends on the characteristics of the mineral filler and the asphalt properties. Such characteristics include particle size, particle shape, presence of agglomerates, degree of dispersion, and asphalt –filler interface (42). These factors are somewhat difficult to control since the size of the fillers is generally small (about 75μm). In general, smaller particle sizes produce stiffer asphalt mix than large sizes (42). This is because particle size is inversely related to the specific surface area. When particle size decreases, the specific surface area increases. This means that the small particles have higher ability to absorb more asphalt, which increases the interaction between the filler surface and the asphalt binder causing higher stiffness and complex shear modulus (42 and 43). Dispersion of the fillers in the asphalt mix also affects the stiffness of the asphalt mixture. Well dispersed mineral fillers (the particles are separated from one another) produce lower stiffness and higher workability mixtures than conglomerated particles. Finally, the particle shape or the aspect ratio (the ratio of length to width) also influences the mixture stiffness. Higher aspect ratio causes higher stiffness and lower workability (42).

Mineral fillers also affect the workability of the mix, and thus play an important role in the compaction and performance of bituminous mixtures. A high amount of filler produces high stiffness mix, which increases the difficulty for placement and compaction or increases the potential of premature cracking. Low filler contents, on the other hand, require higher asphalt content, which may cause the asphalt mixture to drain after lay down. Further, asphalt mixtures containing high mineral filler contents are difficult to compact thereby decreasing the mix stability and increasing the potential for aging and fatigue cracking (31 and 44).

5.7 Additives and Asphalt Modifiers

Additives or asphalt modifiers are commonly used in asphalt mixtures to increase pavement performance. Some additives cause increase in mixture stiffness at high temperatures, which reduces rutting potential) and softening at lower temperatures, which decreases low temperature cracking potential. Some others improve bonding between aggregates and binder thereby reducing raveling, and improving resistance to aging. The effects of asphalt modifiers on pavement performance depend mostly on the crude oil sources (45 to 48).

Polymer type additives are the most commonly used in asphalt mixtures. Polymers can be separated into two categories, elastomers (rubber) and plastomers (plastic). The former increases mixture stiffness at high temperatures, decreases fatigue and low temperature cracking potentials, and decreases stripping and raveling potentials (18, 45 and 49). Most common rubbers are styrene-butadiene rubber (SBR) latex, styrene-butadiene-styrene (SBS) block copolymers, styrene-isoprene-styrene (SIS) block copolymers, polychloroprene latexes, and crumb rubber modifiers (ground tires). SBR decreases temperature susceptibility, increases rut resistance and reduces stripping. The SBR polymer is generally used in chip seals since it increases the adhesion and decreases raveling.

Crumb rubber is another commonly used polymer to improve pavement performance by decreasing fatigue cracking and rut potentials. It is composed of grounded tire rubbers whose sizes do not exceed the number 10-sieve size (45). Two processes are used to add crumb rubbers in HMA, wet (asphalt-rubber) and dry (rubber modified mix). In the first, the rubbers are added into hot asphalt binder, in the dry process, crumb rubbers are mixed first with aggregates before adding the asphalt binder. Higher amount of crumb rubbers can be used for in the dry process. However, the wet process is easier to perform and thus more commonly used.

The addition of plastomers (plastic-type polymer) to asphalt mix requires increasing the mixing temperature to about 380°F, which may cause short term aging of the asphalt binder. Plastic type polymer increases the stiffness and viscosity of the asphalt mixtures causing decrease in workability. Plastic type polymers improve the fatigue life and reduce the rut potential of asphalt mixtures (18 and 46).

Another type additive is palletized carbon black with oil, which is a filler-type additive. The process of adding it to the mix is quite expensive and thus it has not been very widely used.

Carbon black improves bonding between aggregates and asphalt cements, increases resistance to rutting, reduces oxidation, and increases resistance to wear and abrasion.

5.8 Asphalt Content

In general, based on their appearances, asphalt mixtures are labeled fat (excessive asphalt contents), dry (abnormally low asphalt contents) and normal. The percent asphalt content in asphalt mixtures plays important roles in their performance. It affects the stiffness of the mix and its fatigue life, rutting, raveling, shoving and flushing potentials. High asphalt contents may cause increases in fatigue life and increases in the rutting, shoving, and flushing potentials (25 and 31). Low asphalt contents may cause shorter fatigue life, raveling, and TDC (51 and 1).

5.9 Compaction

Compaction of asphalt mixtures is the process of converting the mix from the loose plastic state to a coherent mass processing high tensile strength (52, 53 and 75). The mix factors that influence compaction are aggregate gradation, size, shape, and angularity, asphalt grade and content, and temperature. Other factors include subgrade stiffness, roller type and weight and the number of passes. The quality of compaction affects the air void content in the mix which influences the rate of oxidation or hardening (53). This in term would decrease the fatigue life and increase the potential for TDC (1, 34 and 35). Over compaction, on the other hand, may produce a net of micro cracks which adversely affect pavement performance (53) or low air voids (lower than 3 percent), which may cause rutting (16).

Pavement distresses that can be directly related to compaction include rutting, fatigue cracking, raveling, TDC and premature failure. Gerritsen et al attributed the premature failures of pavements in the Netherlands to poor compaction, among other things (2).

5.10 Stress and Strain Characteristics

Figure K.3 depicts a typical stress-strain curve for asphalt mixtures subjected to cyclic load. As can be seen, the strain is divided into three components; elastic, viscoelastic, and plastic strain.

- The elastic strain is a recoverable immediately after the load is removed and it is stress and temperature dependent.
- Viscoelastic strain is a time dependent strain that can be completely recovered over time.
- Plastic strain is non-recoverable and stress and temperature dependant. The plastic strain is manifested as fatigue cracking and/or pavement rutting.

It should be noted that perfectly elastic materials would never experience fatigue failure or permanent deformation regardless of the number of load repetitions. Since elastic strain is fully recoverable. Plastic strain, on the other hand, is irrecoverable displacement that results in rutting and fatigue cracking (18, 54 and 55).

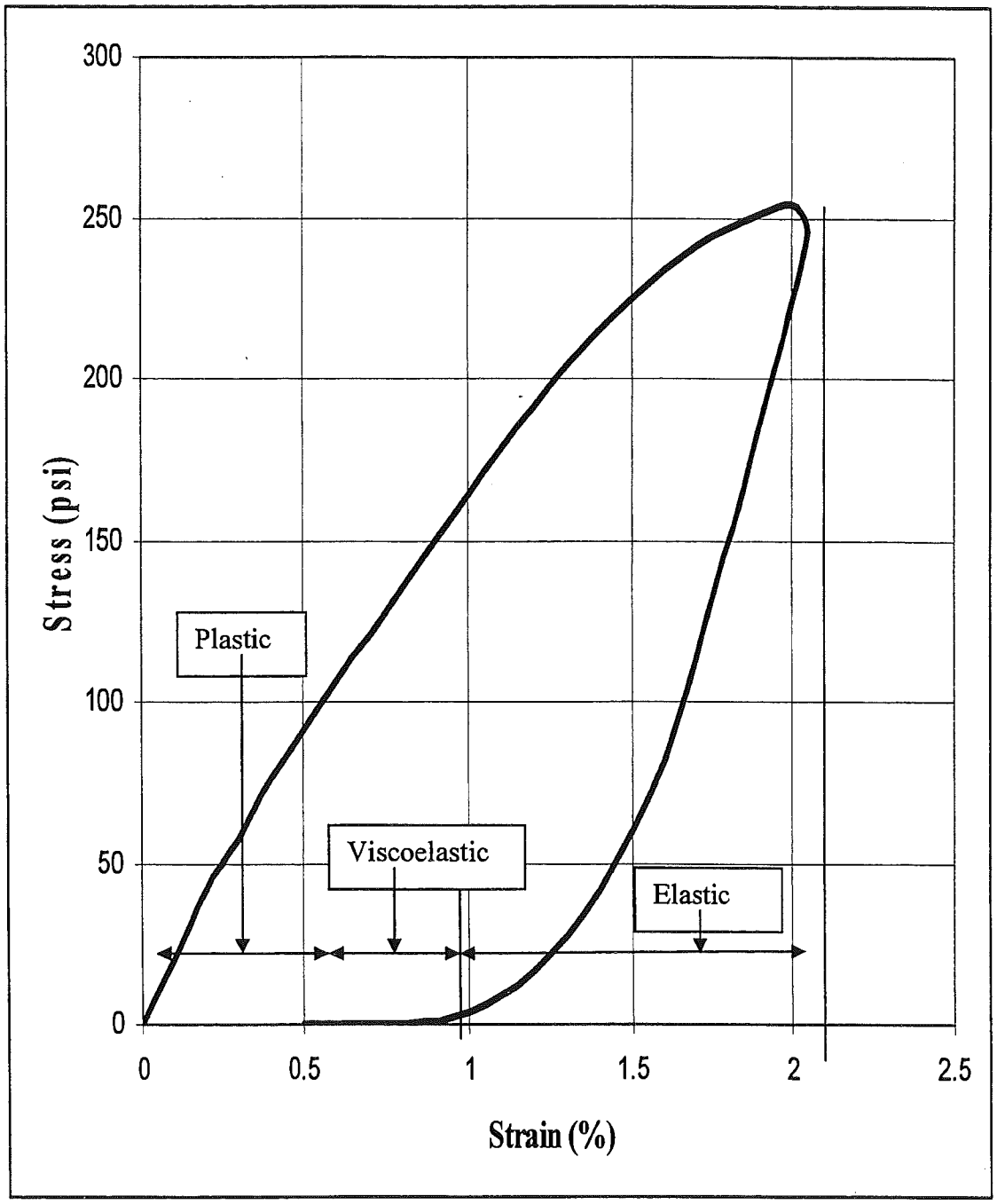


Figure K.3 Stress-Strain characteristics of conventional asphalt mix under cyclic load

5.11 Low Temperature Hardening

The effects of low temperature hardening on asphalt mixtures were discussed in section 4.4.

5.12 Aging in Asphalt Mixtures

The effects of aging on asphalt mixtures was discussed in section 4.5

6.0 EFFECT OF LOAD ON PAVEMENT PERFORMANCE

The application of load to pavements has long been regarded as the primary mechanism causing distress. To determine the effect of load on pavement performance, three steps must be taken (56, 57 and 58)

- Selection of the appropriate method to determine the critical failure parameters based on material properties.
- Application of the selected method.
- Determination of the relationship between the magnitude of the failure parameters and the performance of the pavement.

In flexible pavements, the primary distresses (fatigue cracking and rutting) occur as a function of load-induced tensile strains at the bottom of the asphalt layer and compressive strains at the top of the roadbed soil and other pavement layers. For this reason, engineers have continuously searched for better ways of determining the load-induced stresses and strains throughout the pavement system and correlating them to the overall pavement performance. Currently, this is of critical importance in determining the causes of TDC because of the load-induced tensile stresses at the top of the asphalt layer. Several methods are available for determining the load-induced stresses and strains in flexible pavements. These are divided into two categories and are presented below.

6.1 Closed Form Solutions

Several closed form solutions that are based on various assumptions and the application of the theory of elasticity are available. Despite differences in the outcomes between them, they are all based on similar assumptions including:

- The load is applied on the surface of a half space that is infinite in depth and extent.
- The half space is composed of a single material or layers of material that are assumed to be linearly elastic, homogeneous and isotropic.
- Full friction is developed at the layer interfaces.
- No shear forces are developed at the surface of the pavement.
- Load induced stresses and displacements are zero at the infinite depth (a boundary condition).

The elastic condition also implies that the system response can be characterized by two material parameters, elastic modulus and Poisson's ratio (57). The obvious weakness of each assumption is of significance in pavement analysis. No pavement is infinite in extent, and therefore the response changes due to edge effects. Also, no material in the pavement system is homogeneous, isotropic, and behaves in a linear elastic fashion. As have been discussed previously, asphalt itself is a viscoelastic-plastic material, and most soils also demonstrate viscous behavior. Despite these drawbacks, closed form solutions have been employed in pavement analysis for many years because they are easy to use, they provide reasonable results, and more advanced numerical methods had simply not been available (58).

Boussinesq developed the first method of determining stresses due to a concentrated load on a linearly-elastic half-space. Once stresses had been calculated, Hook's Law could be applied to determine strains. Various researchers, such as Foster and Ahlvin (57), have presented chart-based solutions. In Boussinesq theory, the load is concentrated at a single point, which was later integrated to represent a uniformly loaded circular area. If multiple tires are to be analyzed, the stresses and strains can be computed by superposition due to the linearly elastic assumption of the half-space (57). The single layer theory was later expanded to multiple layers by Burmister, who developed a system for computing first two, then three layers (58). The Burmister solution is hampered, however, by applying similar assumptions as the Boussinesq theory, i.e., each layer is homogeneous, isotropic and linearly elastic. Also, the applied load is assumed to be uniformly distributed over a circular are, which produces uniform pressure.

6.2 Numerical Solutions

Various researchers have shown that the assumptions used in elastic theory present serious shortcomings. For example, the assumption that the tire contact pressure is uniformly distributed over a circular area represents a poor approximation of the pavement-tire interaction. Various researchers have indicated that the contact area can be more closely approximated as a rectangle, with significant variations in contact pressure throughout the contact area (7, 59 and 60). In order to incorporate these and other details such as nonlinear material behavior, numerical solutions were developed and employed to estimate the load-induced stresses and strains. This represented a tremendous leap forward in the analysis of pavement structures.

The most widely known numerical solution is the finite element method. In such a method, various issues such as nonlinear material behavior, pavement edges, nonuniform contact pressure, and others can be modeled. The solution obtained from a finite element method however is approximate in nature whose precision depends to a large extent on element size and geometry (61).

7.0 IMPACT OF HOT MIX ASPHALT PLANT OPERATION ON ASPHALT PAVEMENT PERFORMANCE

7.1 Hot Mix Asphalt Facilities

The hot mix asphalt facility can be briefly described as the plant where heated aggregates are blended with asphalt cement to produce hot asphalt (HMA). There are mainly two types of HMA facilities that are used in USA, batch and drum mixers (16).

7.1.1 Drum Mix Facility

Drum mix facility consists of moving aggregates from the stockpiles area to the cold feed bins by the front loader (the number of bins depends on the number of different size aggregates used in the job mix formula). At the bottom of each bin, computer controlled gate and variable speed feeder proportion the material passing through the gate according to the job mix formula. A conveyor belt brings the aggregates to the cold feed elevator, which feed the aggregates into the drum mixer to be dried and heated. Typically, the aggregates are introduced into the drum through an inclined chute as to discharge the aggregates toward the bottom of the drum and away from the flame to avoid flame quenching and oil contamination of the aggregates (16). Flame quenching and incomplete coating of the aggregates by the asphalt binder cause reduction in the HMA stability and strength (25).

Aggregate dust is removed by passing the aggregate through the exhaust gas and dust collection system (bags). As the aggregates moves down toward the end of the drum, asphalt cement and mineral filler and/or aggregate dust are then added into the drum. The HMA is then transported to hot mix storage silo, which it is discharged into the trucks and transported to the job sites.

7.1.2 Batch Facility

In batch facility, the cold feed proportioning systems is similar to those in a drum mix facility. However, the aggregates are fed at the opposite end of the burner. Since, wet aggregates enter the drum before the exhaust gases exit the dryer; the temperature is lower than that in drum mixers. The burner inside the dryer heats the aggregate to a discharge temperature between 285 and 300°F (16). Hot aggregates cause high rate of oxidation of the asphalt cement, which may cause premature cracking, while cold aggregates increase the difficulties of proper asphalt cement coating. Nevertheless, the heated aggregates are then lifted to the top of the tower plant by hot elevator where they are discharged through a vibrating screen, which separates the dry and heated aggregates into different sizes. The aggregates are then discharged into the pugmill where the proper amount of heated asphalt cement is added to the dry mix.

7.2 Hot Mix Storage

At the end of the mixing process, the HMA is moved into either to a storage silo or surge bins. Storage silos are typically capable of maintaining the HMA temperature for several days whereas the surge bins for one day. Hot mix storage facilitates the paving and plant operations in that the plant keeps operating although no transportation trucks are available. Storage silos help the asphalt plant to keep a constant supply of HMA to the pavers. Long-term storage of HMA in the silos is not recommended, it causes draining and oxidation/aging (62).

7.3 Clean Versus Dirty Aggregates

When the aggregates used in HMA are dirty, the bond between the asphalt binder and the aggregates is weakened. This may result in raveling, loss of aggregates, pitting, and localized potholes and may decrease the strength and durability of the mix causing premature cracking (63). Aggregates that are considered deleterious include clay, clay lumps, soft shale, lignite, coal, mica, shells, organic matter, vegetable matters, and roots.

7.4 Aggregates Dust

Excessive amount of aggregate dust in HMA causes dry appearance of the mix (low asphalt content). This may cause loss of bond between the aggregate and the binder, compaction problems, and raveling (64).

7.5 Segregation

The physical segregation of coarse and fine aggregates could happen at several stages in the mix plant operation if care is not exercised. The most critical stage of the operation that causes segregation is loading the trucks from the storage silo. To decrease segregation potential, it is recommended that the truck be filled on three HMA dumps from the silo (16). The reason is that a single dump tends to cause the coarser aggregates to roll down the side of the dump pile into the truck bed causing segregation, which is labeled on the job as truckload segregation). This situation would worsen when the HMA is dumped slowly on the truck. Quick dump would reduce segregation potential (25)

8.0 IMPACT OF CONSTRUCTION ON PAVEMENT PERFORMANCE

In this section, the term "Construction" refers to the lay down and compaction of the asphalt mat. Several construction factors affect pavement performance including mix transportation (from the storage silo to the truck and from the truck to the hopper of the paver), the paver operation and compaction. Since the latter was addressed earlier and since mix transportation and paver operation impact may cause mix segregation, which impact the TDC potential, only the effects of physical and temperature segregation are addressed in the next subsections.

8.1 Physical Segregation

Physical segregation refers to the separation of coarse and fine aggregates during transportation and lay down. Segregated pavements would have coarse aggregate rich areas and fine aggregate rich areas. The former areas typically have lower density and asphalt contents whereas; fine aggregate rich areas have higher density and higher asphalt contents. Such differential density and asphalt contents may lead to premature distress in the form of cracking and raveling. Recently, researchers have defined three degrees of segregation, heavy, medium and light (65 to 67). Chang described each degree of segregation as follows (65):

- Heavy – Areas of stone against stone that have little or no matrix.
- Medium – Areas showing lack of surrounding matrix and significantly more stone than the surrounding mat.
- Light – Areas showing a matrix but consists of more stone than the surrounding area.

Chang also noted that premature raveling longitudinal cracks develop in heavy segregated areas within few years after construction and propagate throughout the asphalt mat. Recently, Svasdisant et al confirmed that these cracks are TDC that initiate in the segregated areas at the top of the pavement and propagate downward and outward (1). Chang developed time-dependent crack propagation models and estimated the loss in the pavement service life due to segregation (65 to 67). He reported that the service life of medium and heavy segregated areas is less than 30 percent of the original design life.

Likewise, Stroup-Gardiner differentiates between four levels of segregation, no segregation, low, medium, and high levels of segregation (68). Table K.6 shows asphalt-segregated mixtures' characteristics in each level compared to non-segregated mix. Table K.6 also shows the decrease in stiffness and asphalt content of higher level of segregation, and increases in air voids and coarser gradation. The loss of pavement life of 2, 5, and 7 years corresponding to degree of segregation is also shown in table K.6.

The fatigue life of asphalt concrete mixtures decreases with increasing level of segregation in the mix. Further, the lack of coarse aggregate and the high asphalt content in fine rich areas would make the mix more susceptible to rutting (69).

Segregated mix shows a significant decrease in performance compared to non-segregated control mix. Areas exhibiting heavy segregation would experience approximately 70% reduction in the service life (66). Since segregated areas have either lower or higher densities than the surrounding mat, nuclear density meters can be used to determine whether or not the pavement is segregated. As stated earlier, segregated areas also exhibit higher percent air voids than the surrounding mat. The higher air voids cause a decrease in the pavement stiffness and strength and increases in permeability, which increases the stripping potential (70 to 74).

According to Brown et al (71), gradations ranged from finer side (lower degree of segregation) of the mix to coarser side (higher degree of segregation). Tensile strength

Table K.6 Characteristics of Asphalt Segregated Mixtures compared to non-segregated mix (33)

Level	Remained Stiffness (%)	Increased Air Voids (%)	Lower Asphalt Content (%)	Percent coarser	Pavement Life Loss (years)
Low	70-90	0-4	0.3-.75	5	2
Medium	50-70	2-6	0.75-1.3	10	5
High	30	>4	>1.3	15	7

decreased rapidly with increasing degree of segregation. The decrease in tensile strength may lead to excessive cracking in the pavement or raveling of the mixtures. Such cracks are likely TDC that start at the top of the pavement surface and propagate downward (1). Brown et al. also agrees with Stroup-Gardiner (68) that segregation is significant when the percent retained on the No. 8 sieve varies by 10 percent or more from the job mix formula. They reported that segregated areas are approximately 8 to 15 percent coarser than non-segregated areas on the No. 8 sieve. The voids are generally 3 to 5 percent higher, and the asphalt content is 1 to 2 percent lower. Further, segregated areas that were found to consist of the No. 4 sieve of greater than 8 to 10 percent can lead to raveling (73). Their data also showed that pavement surface having macro-texture of 0.5 mm or greater is the indication of raveling.

Coarser graded mixes are more prone to segregation than fine-graded mixes (70). According to Brown et al, segregation can be prevented by increasing the asphalt contents of the mix by approximately 0.2% (71).

8.2 Temperature Segregation

Temperature segregation refers to differences in the mix temperature during the lay down ands compaction operations. Such differences in temperature are problematic in that they cause differences in density, stiffness and strength. Colder areas will have lower density, stiffness and strength than hotter areas. This may result in premature cracking, rutting, and raveling (68).

9.0 SUMMARY

Pavement performance can be briefly defined as how well the pavement serves the users over time. Pavement performance can be measured using pavement condition, such as distress and/or roughness. Asphalt pavement performance is basically impacted by the characteristics of the asphalt material. Asphalt is a viscoelastic material whose behavior is time and temperature dependent. At high temperature, asphalt cement behaves like viscous material that has low stiffness but high flexibility and ductility. On the other hand, at low temperatures, the asphalt cement becomes brittle and its stiffness increases and ductility decreases. Therefore, in the cold region, lower viscosity graded asphalt (lower stiffness) is used to resist temperature cracks, while higher viscosity grades (higher stiffness) are used in warm climate to prevent rutting.

The characteristics of the asphalt concrete also have a major impact on pavement performance. High asphalt content was found to decrease stiffness and may lead to rut especially in warm climate. Lower asphalt contents, on the other hand, may lead to raveling and cracking due to low tensile strength of the mix. The performance of asphalt mixes improve as the percent crushed aggregate increases, which decrease the rut potential. High amount of mineral fillers can cause difficulty in compaction resulting in higher air voids and increases in the rate of oxidation or aging in pavement.

Physical and temperature segregations of the asphalt mix during transportation lay down and compaction have major impact on pavement performance. Heavy segregated areas are expected to loose more than 70 percent of its intended design life.

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