Correlation Between Backcalculated and Laboratory-Determined Asphalt Concrete Moduli

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Falling weight deflectometer (FWD) testing was done on eight test sections of an experimental overlay project in Arizona incorporating both virgin and recycled asphalt concrete mix and various overlay thicknesses as well as on a new pavement test section. The layer moduli were backcalculated by an elastic layer analysis program. Cores of the asphalt concrete layer retrieved from FWD test points were tested by ASTM Method D4123 to determine the resilient moduli. Visual distress surveys were also conducted on each test section in accordance with PAVER procedures, and pavement condition index (PCI) values were calculated. The results indicated that the laboratory-determined asphalt concrete moduli at individual test locations were not in good agreement with the backcalculated moduli. However, the average laboratory-determined moduli for sections with higher PCI values were close to the average backcalculated moduli. Linear regression between PCI values and average ratio of laboratory to backcalculated moduli indicated significant correlation between these two parameters. This shows that the condition of the existing pavement is a primary determinant in better agreement between laboratory-determined and backcalculated moduli. The finding was verified by comparing backcalculated asphalt concrete layer moduli from FWD test results on a new pavement section with the resilient moduli determined in the laboratory. It was found that the average backcalculated modulus of the asphalt concrete layer matches closely the average modulus of all the cores. It was recommended that the backcalculated asphalt concrete moduli instead of laboratory-determined moduli be used in rehabilitation design.

Nondestructive testing (NDT) is now widely recognized as an important tool for pavement structural evaluation. State-of-the-art NDT evaluation measures a pavement's deflection response to a known load. The load generated by an NDT device may be static (Benkelman beam), steady-state vibratory (Dynaflect and Road Rater) or impulse [falling weight deflectometer (FWD)]. Although surface deflection data analysis is a matter of continuing research, nondestructive testing for measuring surface deflection is accepted by most highway agencies as a standard practice. Currently, falling weight deflectometer has gained acceptance as the most developed deflection testing device for its ability to apply heavy load and to simulate actual truck traffic wheel loadings (*1–3*).

Deflections measured with an FWD are used to estimate the moduli of pavement layers. The pavement is modeled by a suitable approach, such as linear elastic theory or linear or nonlinear finite element methods. Moduli estimates are determined with a backcalculation technique. For a specific test load and pavement structure, computed deflections are compared with measured deflections. The moduli of the layers are varied until the computed and measured deflections are approximately equal. The surface layer and other asphaltic layer moduli thus obtained are modified to take into account the temperature at the time of testing. These moduli are then used to compute the effective structural capacity of the pavement according to a pavement design procedure such as the AASHTO guide (*4*).

Currently, a gap exists between analysis of the deflection data and application in practice. Part of the problem arises from the fact that there is no "guarantee" that the backcalculated layer moduli uniquely represent the in situ layer moduli. Ali and Khosla compared the backcalculated asphalt concrete moduli from several automated backcalculation schemes with laboratory resilient moduli (*5*). In general, good agreement was observed between the backcalculated layer moduli from two schemes and laboratory-determined asphalt concrete resilient moduli. Only four samples from two sites in North Carolina were used in their study. Also, the conditions of the pavements used in the study were not reported. Lee et al. reported a verification study of backcalculated layer moduli from an elastic layer analysis backcalculation program (*6*). Sixteen sites from the state of Washington were included in the study. Laboratory asphalt concrete resilient moduli were determined according to ASTM D4123 (*7*). In general, the backcalculated and laboratory asphalt concrete moduli ranged from being essentially similar to differing by over 400 percent. Overall, differences of 20 to 50 percent were common. Higher differences were found for sites with alligator and extensive longitudinal cracking. They also observed that the differences between the backcalculated and laboratory moduli were significantly less than the spatial variation of the layer moduli. Mamlouk et al. studied the correlation between the laboratory and backcalculated layer moduli for 19 sites in Arizona (*8*). The ratios of laboratory-determined asphalt concrete resilient moduli to backcalculated moduli varied from 0.07 to 0.70 with the mean ratio being 0.27. The coefficient of determination, R^2 value, for the linear regression between the laboratory and backcalculated moduli was found to be 0.002. Unfortunately the study did not include a detailed condition survey of the test sites, although the apparent discrepancy between the backcalculated and laboratory moduli was explained in terms of in situ pavement condition at the time

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of FWD testing. This paper addresses the correlation between laboratory-determined moduli of the asphaltic concrete layer and backcalculated layer moduli from FWD data collected on nine test sections in Arizona as a function of pavement condition.

LAYOUT OF TEST SECTIONS AND DESCRIPTION

Eight test sections were selected from a project built in 1981 with virgin and recycled materials with various overlay thickness. The project is located in southwestern Arizona on Interstate 8. During a distress survey of this project in 1990, various sections exhibited various degrees of structural distress. Figure 1 shows the layout of the test sections and Figure 2 shows the structural sections. The existing new pavement section used in this study is on SR-87 in the Phoenix metropolitan area. This section was built in 1986 and currently shows no distress. Figure 2 also shows the structural section of this test section.

DEFLECTION TESTING AND CORING

Deflection data were collected on each of the eight test sections on I-8 with a Dynatest 8000 FWD in May 1990. FWD tests on SR-87 were conducted during July 1990. Very high

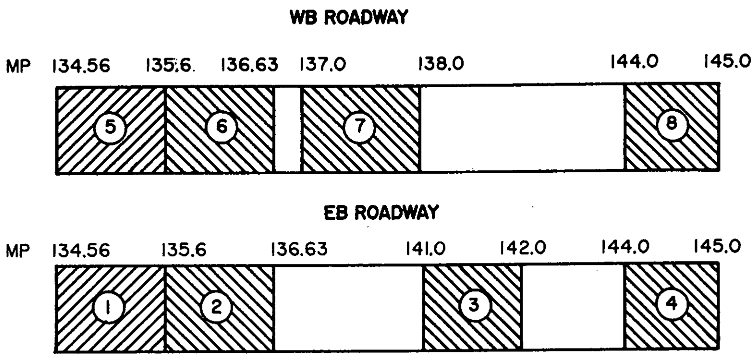
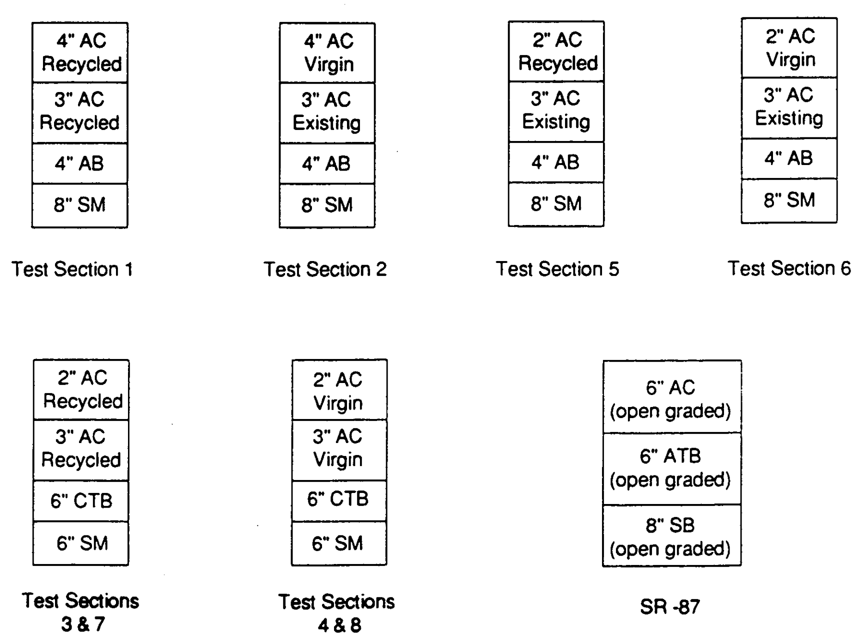


FIGURE 1 Layout of test sections on I-8.



Note: AC = Asphalt Concrete, AB = Aggregate Base, SM = Select Material/ Subbase
CTB = Cement Treated Base, ATB = Asphalt Treated Base, SB = Subbase

FIGURE 2 Pavement cross sections of test sections.

pavement surface temperatures (up to 114°F) were encountered during most of the testings on I-8. Seven sensors were used, with the first sensor being at the center of the loading plate and six others at a uniform radial distance of 12 in. apart. Three drops of FWD load were used for target loadings of 6,000, 9,000 and 15,000 lb. Data were collected at five random locations on the outer wheel path of the travel lane for each section. Additional tests were also conducted in between-the-wheel-path locations for some sections. In total, FWD data were collected at 60 locations.

Cores of asphalt concrete were retrieved from the test points at each of the 60 locations. However, four cores were disintegrated during storage and handling. The cores were retrieved for the full depth of asphalt concrete layer.

BACKCALCULATION ANALYSIS SCHEME

The FWD deflection data were used in a backcalculation scheme, BKCHEVM, to calculate the layer moduli. BKCHEVM is a microcomputer-based backcalculation program developed at Arizona State University (*8*). The program is a modification of the program CHEVDEF (*9*). The modifications have been relatively minor and designed primarily to simplify use and to improve convergence. In addition, the iterative scheme has been modified to obtain a closer match between measured and computed deflections for the inner three sensors so that a better estimate of asphalt concrete moduli is possible. Four distinct layers were assumed in the analysis and a rigid layer was introduced automatically (within the program) when it was judged appropriate, on the basis of the seventh-sensor deflection value. However, in this analysis no rigid bottom was encountered for any section. The default values of all the layer moduli were provided. The program yielded a solution in the form of a set of layer moduli whenever "convergence" was reached. If no convergence was possible, the "best-fit" set of layer moduli (based on the sum of errors of the computed deflections) was included as output (*8*).

BKCHEVM is part of the mechanistic overlay design procedure, CODA, being implemented by the Arizona Department of Transportation. In this study, the deflection basin corresponding to the second drop of FWD mass (with target load of 9,000 lb) was used in the backcalculation analysis. The asphalt concrete layer thickness used in backcalculation was determined from the core thickness at each location. Temperature correction was applied to the backcalculated asphalt concrete moduli using AASHTO (*4*) factors.

LABORATORY TESTING

Asphalt concrete (AC) cores of the pavements for all sections with AC layer thickness greater than 4 in. were sliced to represent the top and bottom lifts in construction. The resilient moduli tests were performed at 104°F according to ASTM D4123 test procedures. This test temperature was selected because most of the FWD testing was done at a very high temperature. Also, the AASHTO temperature correction factors to be used were found to be very sensitive to higher temperatures (*10*). The backcalculated moduli on the test sections were also adjusted to 104°F using AASHTO temperature correction factors to compare with the laboratory-determined moduli. However, the resilient moduli tests on cores from SR-87 were conducted at 77°F. This temperature was used to minimize damage to the cores that were open graded asphalt concrete. The backcalculated moduli for the locations on SR-87 were adjusted to 77°F using AASHTO curves. Each specimen was tested at two positions (90 degrees apart) and at three different frequencies (1, 0.5, and 0.3 Hz) with a load duration of 0.1 sec. The applied load was between 90 and 120 lb, with the majority around 100 lb. The horizontal deformation was measured, and the resilient moduli computed assuming a Poisson ratio of 0.35 at 77°F and 0.40 at 104°F. For the test results of cores on I-8, both instantaneous and total resilient moduli were calculated and used in the analysis. The instantaneous and total resilient moduli of asphalt concrete cores on SR-87 were found to be essentially the same, and only instantaneous resilient moduli were used in the analysis. No frequency correction was applied to laboratory-determined resilient moduli to take into account the difference between the load duration of FWD and laboratory resilient moduli test load.

PAVER CONDITION SURVEY

A PAVER condition survey was conducted on each test section during coring in May 1990 (*11*). Approximately 30 percent of the area in each test section was surveyed. The survey consisted of observing 19 distress types on asphalt concrete pavements on 200-ft sample units, at a rate of eight or nine for each section. The sample units contain most of the FWD test locations. The sample units were chosen systematically on each section, with the first sample unit being chosen at random. Five rut depth measurements were taken on each sample unit at 50-ft intervals. The predominant distresses were found to be alligator cracking, block cracking, and longitudinal and transverse cracking and weathering. Pavement condition index (PCI) was calculated for each sample unit using the Micro-PAVER program. Rutting was omitted from the calculation of PCI because of the difficulty in defining the actual rutted area. Also, cracking was considered to be the predominant distress type affecting FWD deflection test results. Table 1 summarizes the results of the PAVER survey for each test section. From the results it is evident that, once rutting is ignored, the load-associated deduct values dominate the PCI values for each test section.

ANALYSIS AND RESULTS

Test Sections 1 and 2

FWD testing was conducted at five locations in the outer-wheel-path and three locations in between-wheel-path locations in Sections 1 and 2. Resilient moduli testing was performed on the cores taken from the FWD test locations. The cores were sliced into two halves and each half was tested. The reported values are the average of two test results. Table 2 shows the comparison of the backcalculated and laboratory-determined instantaneous resilient moduli. The testing frequencies were

TABLE 1 PAVER Survey Results

Test Section	Mean	PCI* S.D.	C.V.	Load Assoc. Deduct Values	Climate Assoc. Deduct Values	Other Deduct Values	Average Rut Depth (in)
1,EB	71	12	17	44	41	15	0.50
2,EB	69	13	19	50	45	5	0.40
3,EB	50	12	24	58	42	0	0.20
4,EB	32	18	56	68	31	1	0.20
5,WB	37	12	32	66	34	0	0.20
6,WB	41	17	42	62	38	0	0.15
7,WB	38	16	43	46	54	0	0.25
8,WB	15	13	84	56	43	1	0.25

* excluding rutting

TABLE 2 Comparison of Backcalculated and Laboratory AC Moduli for Test Sections 1 and 2

MP Location	Backcalc Modulus	Lab Modulus (1 Hz)	Ratio (lab/back)	Lab Modulus (0.3 Hz)	Ratio (lab/back)
(a) Test Section 1					
134.58	576	265	0.46	265	0.46
134.62	459	581	1.27	506	1.10
134.88	483	261	0.54	254	0.53
135.28	1200	350	0.29	313	0.26
135.36	800	190	0.24	213	0.27
134.58C	576	607	1.05	537	0.93
134.66C	833	579	0.70	549	0.66
134.79C	565	619	1.10	600	1.06
Mean			0.70		0.66
R^2 (Linear Regression)		0.05		0.05	
(b) Test Section 2					
	0	234	0.26	225	0.25
135.76	294	425	1.45	317	1.08
136.03	951	119	0.13	207	0.22
136.17	542	311	0.57	302	0.56
136.46	244	381	1.56	396	1.62
135.65C	233	117	0.50	106	0.45
135.82C	400	368	0.92	333	0.83
136.06C	435	409	0.94	344	0.79
Mean			0.79		0.73
R^2 (Linear Regression)		0.23		0.08	

Note: C indicates between wheel path location

1 Hz and 0.3 Hz. It is evident that the between-wheel-path locations show better agreement between backcalculated and laboratory-determined moduli. The average ratios of laboratory-determined moduli to backcalculated moduli for Sections 1 and 2 were found to be 0.70 and 0.79, respectively. The ratios vary from as low as 0.13 to as high as 1.62. The PCI values ranged between 58 and 85, with a mean value of 71 for Section 1. The general rating of the section is very good. The percentage of load-related deduct values was 44 percent, and that for climate/durability was 41 percent. For Section 2, the mean PCI value was 69 with a range from 39 to 83; which was rated as good. The percentages of load-associated and climate-associated deduct values for this section were similar to those for Section 1 and were 50 percent and 45 percent, respectively. Distresses found on these two sections were alligator, block, longitudinal, and transverse cracking and weathering. Test Section 2 also showed a very high amount of rutting. The mean rut depth was 0.48 in., with ranges between 0.39 and 0.62 in.

Test Sections 3 and 4

Test Sections 3 and 4 have 2-in. overlays over 3-in. mill and replace sections. FWD testing was done at five locations at the outer-wheel-path locations in both sections. Resilient modulus testing was done on the cores taken from the FWD test locations. The cores were sliced into two halves to represent the top and bottom layers of the existing pavement, and testing was done on each half. The reported results represent the average of two values. Table 3 shows the comparison of the backcalculated and laboratory-determined instantaneous resilient moduli. The testing frequencies were 1 Hz and 0.3 Hz. The average ratios of laboratory-determined moduli (at 1 Hz) to backcalculated moduli were found to be 1.70 and 2.33, respectively. The ratios vary from as low as 0.42 to as high as 4.76. For Section 3, the PCI values ranged between 20 and 67, with a mean value of 50. The general rating of the section is fair. The percentage of load-related deduct values was 58 percent and that for climate/durability was 42 percent. For Section 4, the mean PCI value was 32 with a range from 13 to 60; it was rated as poor. The percentages of load-associated and climate-associated deduct values for this section were 68 percent and 31 percent, respectively. Distresses found on these two sections were alligator, block, longitudinal, and transverse cracking and weathering. The amount and severity of alligator cracking on these sections were much higher than on Sections 1 and 2.

Test Sections 5 and 6

Test Sections 5 and 6 have 2-in. overlays over the 3-in. existing AC pavements. The sections are in the westbound roadway. FWD testing was conducted at five locations in the outer wheel path and at one location between the wheel path for both sections. Resilient moduli testing was performed on the cores taken from the FWD test locations for the overlay layer only. Because of disintegration of the cores from the existing AC layer, this layer could not be tested. Table 4 shows the

TABLE 3 Comparison of Backcalculated and Laboratory AC Moduli for Test Sections 3 and 4

MP Location	Backcalc Modulus	Lab Modulus (1 Hz)	Ratio (lab/back)	Lab Modulus (0.3 Hz)	Ratio (lab/back)
(a) Test Section 3					
141.06	522	742	1.42	989	1.89
141.26	209	613	2.93	523	2.50
141.54	1610	773	0.48	747	0.46
141.87	420	1355	3.23	1579	3.76
141.94	1325	552	0.42	528	0.40
Mean			1.70		1.80
R^2 (Linear Regression)		0.09		0.12	
(b) Test Section 4					
144.22	664	751	1.13	704	1.06
144.50	465	881	1.89	723	1.55
144.53	502	340	0.68	493	0.98
144.60	174	597	3.43	643	3.70
144.91	148	665	4.49	641	4.33
Mean			2.33		2.32
R^2 (Linear Regression)		0.01		0.006	

TABLE 4 Comparison of Backcalculated and Laboratory AC Moduli for Test Sections 5 and 6

MP Location	Backcalc Modulus	Lab Modulus (1 Hz)	Ratio (lab/back)	Lab Modulus (0.3 Hz)	Ratio (lab/back)
(a) Test Section 5					
134.68	155	550	3.55	501	3.23
134.78	153	485	3.17	417	2.73
135.15	314	250	0.80	250	0.74
135.20	242	414	1.71	386	1.60
135.30	230	335	1.46	406	1.77
134.68C	145	722	4.98	802	5.53
Mean			2.61		2.60
R^2 (Linear Regression)		0.72		0.57	
(b) Test Section 6					
135.76	612	324	0.53	271	0.44
135.80	455	285	0.63	255	0.56
135.85	980	756	0.77	637	0.65
136.14	1138	285	0.25	255	0.22
136.51	2258	740	0.33	773	0.34
136.958C	430	692	1.61	653	1.52
Mean			0.69		0.62
R^2 (Linear Regression)		0.18		0.28	

Note: C indicates between wheel path location

comparison of the backcalculated and laboratory-determined instantaneous resilient moduli. The testing frequencies were 1 Hz and 0.3 Hz. The average ratios of laboratory-determined moduli (at 1 Hz) to backcalculated moduli for Sections 5 and 6 were found to be 2.61 and 0.69, respectively. The ratios vary from as low as 0.22 to as high as 5.53. For Section 5, the PCI values ranged between 23 and 50, with a mean value of 37. The general rating of the section is poor. The percentage of load-related deduct values was 66 percent and that for climate/durability was 34 percent. For Section 6, the mean PCI value was 41 with a range from 17 to 66. It was also rated as poor. The percentages of load-associated and climate/durability-associated deduct values were similar to those for Section 5.

Test Sections 7 and 8

Test sections 7 and 8 have the same structural sections as Test Sections 3 and 4 but are located in the westbound direction. FWD testing was conducted at five locations on the outer wheel path. Resilient moduli testing was performed on the cores taken from the FWD test locations. The testing was done on the cores sliced into two halves. The reported laboratory-determined moduli represent the average of the moduli determined on the top and bottom half of the cores. Table 5 shows the comparison of the backcalculated and laboratory-determined instantaneous resilient moduli. The testing frequencies were 1 Hz and 0.3 Hz. The average ratios of laboratory-determined moduli (at 1 Hz) to backcalculated moduli for Sections 7 and 8 were found to be 2.02 and 2.97, respectively. The ratios vary from 1.10 to 4.16. The PCI values for Section 7 ranged between 4 and 61, with a mean value of 38. The general rating of the section is poor. The percentage of load-related deduct values was 46 percent and that for climate/durability was 54 percent. For Section 8, the mean PCI value was 15 with a range from 0 to 29. It was rated as very poor. Extensive high-severity alligator cracking was responsible for the poor rating of this section.

COMPARISON OF LABORATORY-DETERMINED AND BACKCALCULATED MODULI

As mentioned earlier, FWD testing was conducted on a test section on SR-87 in the outer wheel path at four locations and in between-wheel-path locations at three places. The cores were taken from the FWD test locations. This pavement has an existing 6-in.-thick open graded asphalt concrete layer. The cores were sliced into two halves, and resilient moduli testing was conducted at 77°F on each half. The reported asphalt concrete moduli are the average of the resilient moduli determined on each half. Table 6 shows the comparison of backcalculated and laboratory-determined asphalt concrete

TABLE 5 Comparison of Backcalculated and Laboratory AC Moduli for Test Sections 7 and 8

MP Location	Backcalc Modulus	Lab Modulus (1 Hz)	Ratio (lab/back)	Lab Modulus (0.3 Hz)	Ratio (lab/back)
(a) Test Section 7					
137.30	339	673	1.99	780	2.30
135.55	420	1600	3.81	1916	4.56
137.80	312	591	1.89	563	1.80
137.91	496	644	1.30	588	1.19
137.95	536	595	1.11	465	0.87
Mean			2.02		2.14
R^2 (Linear Regression)		0.0		0.016	
(b) Test Section 8					
144.25	185	769	4.16	749	4.05
144.47	410	778	1.90	747	1.82
144.82	303	834	2.75	765	2.52
144.93	410	778	1.90	747	1.82
144.98	185	769	4.16	749	4.05
Mean			2.97		2.85
R^2 (Linear Regression)		0.03		0.01	

moduli. As evident from the table, the individual backcalculated moduli were different; the average ratio of backcalculated moduli to laboratory moduli was very close to unity (0.82 to 0.91). The coefficient of determination of linear regression between these two sets of moduli was 0.06. The project was surveyed for distresses in 1990 during the FWD testing. The survey was conducted as per PAVER, but no visible distresses were evident. The PCI value was computed to be 95, and the rating of this section was excellent. It is clear that although the correlation between the laboratory-determined and backcalculated AC moduli is poor, the average ratio is close to unity. The agreement between backcalculated and laboratory-determined AC moduli was similar for both outer-wheel-path and between-wheel-path locations.

EFFECT OF PAVEMENT CONDITION

The data indicate that there is an apparent relationship between pavement condition and the average ratio of laboratory-

TABLE 6 Comparison of Backcalculated and Laboratory AC Moduli for Test Section on SR-87

Station Location	Backcalc Modulus	Lab Modulus (1 Hz)	Ratio (lab/back)	Lab Modulus (0.3 Hz)	Ratio (lab/back)
115+00	1053	815	0.77	748	0.71
121+00	720	1017	1.41	1034	1.44
126+00	1323	1125	0.85	780	0.59
134+00	864	1111	1.29	982	1.14
118+00C	883	486	0.55	473	0.54
126+00C	1276	818	0.64	666	0.52
136+00C	702	703	1.00	614	0.87
Mean			0.91		0.82
R^2 (Linear Regression)		0.06		0.03	

Note: C indicates between wheel path location determined moduli to backcalculated asphalt concrete moduli. Table 7 shows the average ratio of backcalculated to laboratory-determined asphalt concrete moduli (at 1 Hz) and average PCI for all the sections included in the study. It is apparent that the higher the PCI value for a section, the better the agreement between the average laboratory-determined and the average backcalculated asphalt concrete moduli. However, the surface distresses may be limited to the top few inches of an asphaltic layer. The existing new pavement showed the best agreement between average backcalculated and average laboratory-determined asphalt concrete moduli. A linear regression analysis was conducted between the average PCI values of the sections and the average ratio of laboratory-determined and backcalculated asphalt concrete moduli. The coefficient of determination, r_2, was found to be 0.60. Student's *t*-test conducted on the correlation coefficient of these two variables confirmed significant correlation at 5 percent level of significance.

For pavements with lower PCI, the laboratory-determined moduli are usually higher than the backcalculated moduli. In the backcalculation process, the entire asphaltic concrete layer consisting of various sublayers was lumped into a single layer of an "equivalent" layer (*8*). However, in the laboratory, only intact samples from the layers were tested. Thus, for a pavement with poor surface condition, deflection tests capture the response of the pavement with surface distresses, whereas in the laboratory, the uncracked distress-free samples of the same pavement are tested. Testing these samples results in a higher ratio of laboratory to backcalculated moduli for pavements with lower PCI. Because the FWD captures the response of the entire pavement to the applied load, the backcalculated moduli from FWD data are more representative of the in situ layer moduli than laboratory-determined moduli on samples taken from crack-free areas of the pavement. Again, in the backcalculation process, a "homogeneous" asphaltic concrete layer was assumed. But, when the pavement

TABLE 7 Relationship Between Ratio of Backcalculated to Laboratory-Determined Moduli and PCI

Section	Avg. Ratio	Avg. PCI	Pavement Rating
1	0.70	71	Very Good
2	0.79	69	Good
3	1.70	50	Fair
4	2.33	32	Poor
5	2.61	37	Poor
6	0.69	41	Poor
7	2.02	38	Poor
8	2.85	15	Very Poor
SR 87	0.91	95	Excellent

Note: R^2 (Linear Regression) = 0.6035

TABLE 8 Comparison of Instantaneous and Total Resilient Moduli

Test	Inst E/Back E (@1 Hz)	Inst E/Back E (@0.3 Hz)	Total E/Back E (@1 Hz)	Total E/Back E (@0.3 Hz)
1	0.70	0.66	0.59	0.60
2	0.79	0.73	0.78	0.73
3	1.70	1.80	1.53	1.34
4	2.33	2.32	1.71	1.95
5	2.61	2.60	2.19	2.14
6	0.69	0.62	0.62	0.61
7	2.02	2.14	1.74	1.55
8	2.97	2.85	2.65	2.78
Mean	1.73	1.72	1.48	1.46

is cracked, this assumption is fully violated. This homogeneity of a pavement section may be the contributing factor for the apparent agreement of average backcalculated and laboratory-determined AC resilient moduli for the new pavement section.

INSTANTANEOUS VERSUS TOTAL RESILIENT MODULI OF ASPHALT CONCRETE

The instantaneous resilient modulus value of asphalt concrete is calculated using the recoverable deformation that occurs instantaneously during the unloading portion in one cycle of ASTM D4123. The total resilient modulus is calculated using the total recoverable deformation that includes both instantaneous recoverable and the time-dependent continuing recoverable deformation during the unloading and rest period portion of one cycle. There is considerable disagreement among the researchers as to which moduli are more representative. In this study, both moduli were correlated with the backcalculated layer moduli from FWD data for the eight test sections used in the study. Table 8 shows the average ratio of laboratory-determined to backcalculated asphalt concrete moduli. On the basis of the analysis of this set of data, it appears that the use of total resilient moduli provides a better correlation with the backcalculated layer moduli.

VIRGIN VERSUS RECYCLED MATERIALS

Comparison was also made between the average ratio of laboratory-determined to backcalculated asphalt concrete moduli (at 1 Hz) of virgin and recycled overlays. Table 9 shows the ratios. The ratios are comparable for the two types of materials. The table also shows the ratios for overlays on both existing and mill and replaced sections. In general, the ratio of laboratory-determined to backcalculated moduli is higher for sections with mill and replace.

CONCLUSIONS

On the basis of this study, the following conclusions can be drawn:

1. The average backcalculated asphalt concrete moduli for a section compares favorably with the average laboratory-determined moduli when the condition of the pavement is good. However, the backcalculated and laboratory-determined moduli are different at individual locations. Pavement condition is a primary determinant for good agreement between backcalculated and laboratory-determined moduli.
2. The FWD testing captures the response of the entire pavement to the applied load. Since FWD deflection testing is usually done for evaluating existing pavements, backcalculated asphalt concrete moduli can more realistically represent the in situ moduli of the asphalt concrete layer. This conclusion appears to be validated by the better agreement between backcalculated and laboratory-determined asphalt concrete moduli for new pavements and also for distress-free pavements in between-wheel-path locations on old pavements.

RECOMMENDATIONS

This study shows that the backcalculated asphalt concrete moduli from FWD test results on existing pavements can represent more realistically the in situ layer moduli and should be used in pavement rehabilitation design. It is recommended that the backcalculated asphalt concrete moduli from FWD deflection testing for a certain analysis section be used in the mechanistic overlay design process. The backcalculated asphalt concrete moduli are more representative of in situ conditions than laboratory-determined asphalt concrete moduli on cores from existing pavements.

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TABLE 9 Comparison of Backcalculated and Laboratory AC Moduli for Virgin and Recycled Overlays

Virgin Overlays			Recycled Overlay		
2 inches		4 inches	2 inches		4 inches
3" mill	Existing		3" mill	Existing	
4 EB 8 WB	6 WB	2 EB	3 EB 7 WB	5 WB	1 EB
2.3	0.7	0.79	1.7	2.6	0.7
2.9			2.0		

Note: Numbers on the body of the table indicate (E_{lab}/ $E_{backcalc}$)

PAVER survey was done by Sylvester Kalevela and Gregory Rollins of Arizona Transportation Research Center. Resilient moduli testing was done at the Highway Materials Laboratory of the Arizona State University. The assistance of M. S. Mamlouk in this regard is highly appreciated.

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