Evaluation of Effect of Uncrushed Base Layers on Pavement Performance

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In 1974, the Alaska Department of Highways decided to save money and fuel by removing the base course and placing the asphalt concrete surface directly on the subbase of the Glenn Highway widening project. In 1969, the original two lanes had been constructed with a crushed base course, thus providing an excellent comparison of the performance of the two bases. Laboratory testing showed that the uncrushed base (subbase) was uniformly graded with a maximum size of 2 in. with 37 percent aggregate fracture, whereas the crushed base was uniformly graded with a maximum size of 1 in. with 85 percent aggregate fracture. Base course resilient modulus was back-calculated from falling weight deflectometer readings and subsequently measured in the laboratory. Contrary to previous research and experience in crushed and uncrushed gravel, the uncrushed base course performed better than the crushed base course; the resilient modulus was higher, and the permanent deformation was lower. The uncrushed base is apparently superior because of a larger maximum particle size and greater maximum density. An analysis of the future performance of the roadway with equal thicknesses of asphalt indicates that the pavement over the uncrushed base would have a longer life than the pavement over the crushed base by 54 percent.

In 1974, the Alaska Department of Highways decided to save money and fuel by deleting the base course and placing the asphalt concrete surface directly on the subbase of the Glenn Highway widening project. The original two lanes, constructed in 1969, were built with a crushed base course. The additional two lanes were constructed adjacent to the original roadway, providing an excellent comparison of the performance of the uncrushed subbase and the crushed base course. An investigation was undertaken to analyze the two roadways to see if the difference in fracture led to a difference in performance.

LOCATION

The Glenn Highway is located in south-central Alaska (Figure 1). The project lies between Anchorage and Palmer, just north of Eagle River in the northeast section of the Cook Inlet physiographic region. The northbound lanes were originally constructed in 1969. The 1983 average annual daily two-way traffic was 13,500 vehicles. The cross section consisted of two 14-ft driving lanes with 8-ft shoulders and a 4-ft ditch (Figure 2). The design pavement structure consists of 1.5 in. of hot asphalt concrete over 6 in. of base course Grading D-1 over 6 in. of subbase and 36 in. of select material. Both projects were overlaid with 1.5 in. of hot asphalt concrete (AC) during the summer of 1983. The subgrade soils are predominantly Pleistocene ground moraine (silty gravel and gravelly silt) and outwash deposits (sandy gravel). Surface drainage at the test sites was rated as fair.

The southbound lanes were constructed in 1974. The cross section is the same as the northbound lanes with a 4-ft ditch between them. The design template consisted of 1.5 in. of hot AC over 6 in. of subbase, Grading B, over a variable depth of selected material over unclassified embankment.

Table 1 summarizes the project specification gradation of each of the projects. The crushed base course (D-1) was specified as a 1-in. (or less) uniform gradation, with 3 to 10 percent passing the No. 200 sieve, and the material retained on the No. 4 sieve to have a 75 percent single-faced fracture. The uncrushed base course (Subbase B) was specified as a coarser uniform gradation with a maximum size of 2 in., 3 to 8 percent passing the No. 200 sieve, and no fracture requirement.

Problems were encountered in tight blading the surface before paving because of the 2-in. (or less) unfractured aggregate. Aggregate particles rolled under the grader blade, leaving a loosened scarified surface. A steel wheel roller was used just ahead of the paver to keep the surface tight. It was also necessary to keep the grade well watered. However, it was still difficult to maintain a uniform grade as the pavement haul trucks created troughs and depressions even though no turning movements were permitted. It was believed that this procedure would result in a greater AC thickness than that designed, but cores showed that no excess AC was used.

FIELD INVESTIGATION

Two test sites were selected for evaluation along the project: a 550-ft-long cut section and a 1,000-ft-long embankment fill section. During the spring of 1983, falling weight deflectometer (FWD) deflection tests were performed every 50 ft in the cut section and every 100 ft in the fill section. Four points in each section were selected that represented the average deflection for that section. Test trenches were dug adjacent to these points at the edge of pavement to a depth of 6 ft. Samples of the pavement structure were taken out of the wall of the trench. Bulk disturbed samples of the crushed and uncrushed base courses were also taken from a pavement cut near the test sections. The pavement was cored in the driving lane adjacent to each test trench.

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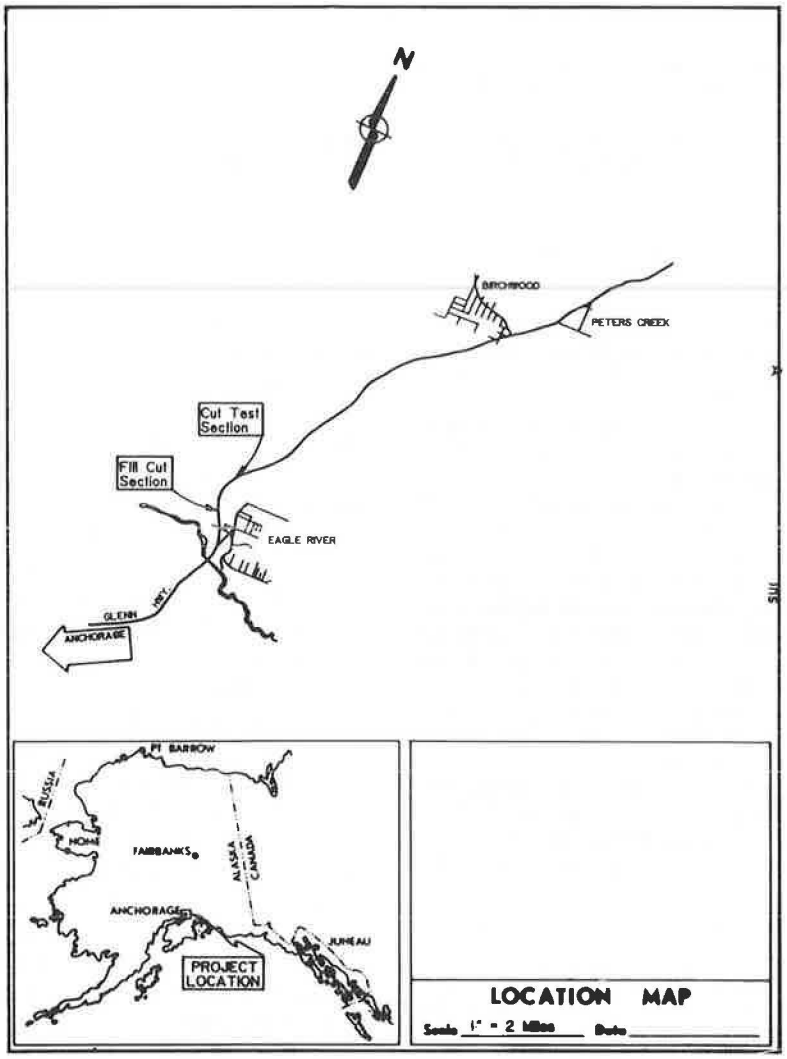

FIGURE 1 Location map.

Pavement Condition

A formal pavement condition survey was not performed as the test sections were overlaid shortly after this investigation was begun in 1983. From a visual inspection prior to the overlay, no major pavement distress was noted in either the northbound or the southbound lanes. No rutting or pavement distortion was apparent and only transverse thermal contraction cracks were noted.

Pavement Structure

Test trenches were used to verify the designed pavement structure. Both the crushed and the uncrushed base courses were

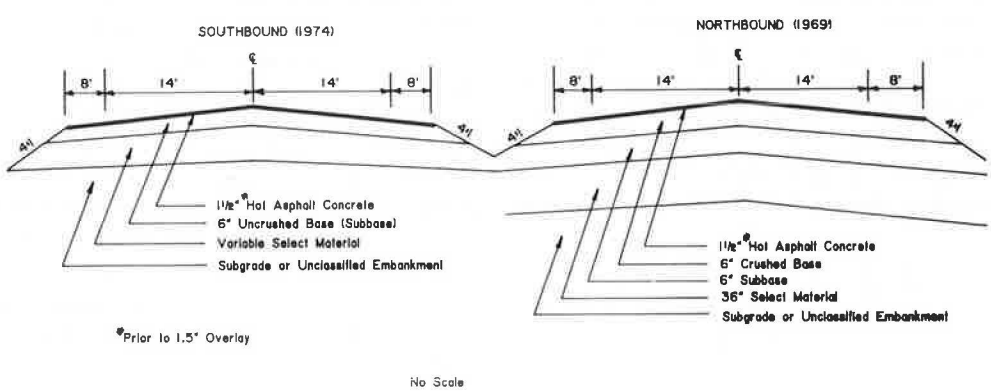

FIGURE 2 As-designed typical sections.

TABLE 1 CRUSHED BASE COURSE AND UNCRUSHED BASE CURSE (SUBBASE) SPECIFICATION AND MEASURED GRADATIONS

	Northbound Lanes, Crushed Base Course			Southbound Lanes, Uncrushed Base Course (Subbase)		
	Specification	Test Results		Specification	Test Results	
Sieve	D-1 (% passing)	Average (% passing)	Range (% passing)	B (% passing)	Average (% passing)	Range (% passing)
2 in.	100	100		100	100	
1.5 in.					97	95–98
1 in.	100	100			80	77–82
3/4 in.	70–100	94	91–95	60–90	69	64–73
1/2 in.		74	72–77		56	52–60
3/8 in.	50–80	62	60–66		48	43–53
No. 4	35–65	43	41–46	30–60	34	29–36
No. 8	20–50	33	29–35		25	21–28
No. 10		30	27–32		23	20–25
No. 40	10–30	14	12–16		9	8–9
No. 200	3–10	7	6–8	3–8	6	4–9
0.02 mm	3–10	4.3	3–5		5.3	3–8
Fracture (%)	75	81	76–85	–	37	19–53
Optimum moisture (wt %)	4.5				4.1	
T180 Proctor density (pcf)	143.9				148.4	

within project specifications (see Table 1). Figure 3 is a 0.45 power plot of the average gradation of the crushed and uncrushed base courses. The crushed base single-faced fracture on the No. 4 sieve averaged 81 percent, whereas the uncrushed base averaged 37 percent. Minor crushing of the uncrushed base was necessary to produce the Subbase B gradation, resulting in some fracture that was not specified. From the project records (Table 1), the T180 Proctor density for the uncrushed base was 148.4 lb/ft^3, much higher than the 143.8 lb/ft^3 for the crushed base.

Table 2 gives a summary of the pavement structure components and their characteristics as measured in the test trenches. The hot AC over the crushed base averaged 4.0 in., whereas the AC over the uncrushed base averaged 3.1 in. (The test sections were overlaid with 1.5-in. AC during the summer of 1983.) The total pavement structure above the subgrade in the cut averaged 42 in. in the crushed-base section (northbound lanes) and 48 in. in the uncrushed-base section (southbound lanes). In the fill sections, the embankment thickness was greater than 60 in. All imported materials are classified as A-1-a and no water was

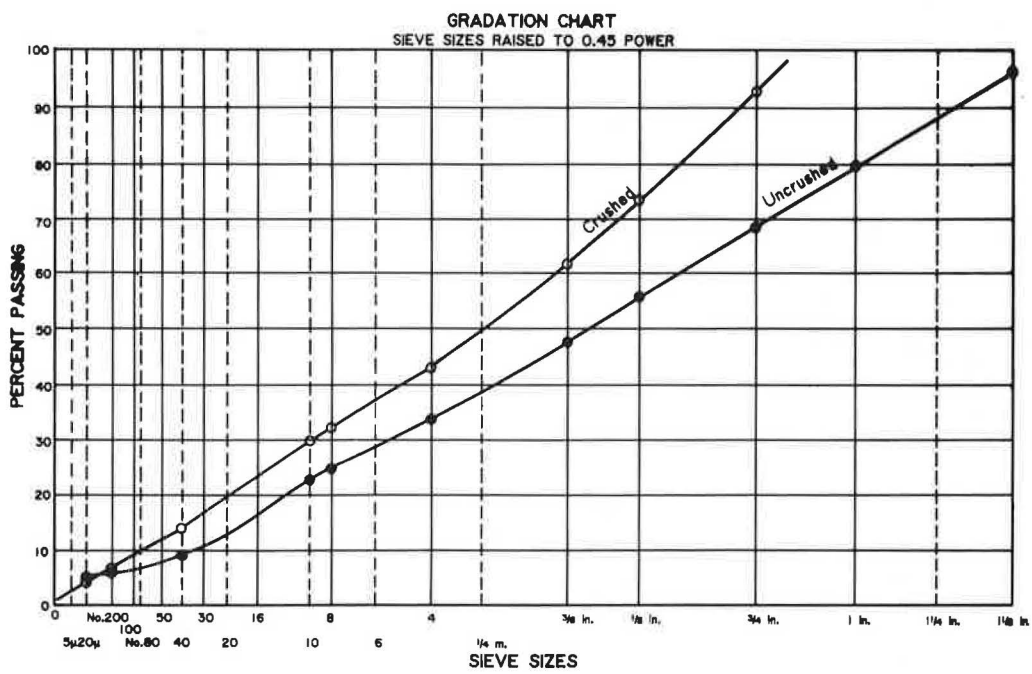

FIGURE 3 A 0.45 power gradation chart of crushed and uncrushed base courses.

TABLE 2 PAVEMENT STRUCTURES (AS-BUILT)

	Northbound Lanes, Crushed Base				Southbound Lanes, Uncrushed Base (Subbase)			
	Average Thickness (in.)	Range (in.)	Maximum Size (in.)	Average P_{200} (%)	Average Thickness (in.)	Range (in.)	Maximum Size (in.)	Average P_{200} (%)
Hot asphalt pavement	4.0[a]	3.4–4.8	–	–	3.1[a]	2.5–3.8	–	–
Base course	6	–	1	7	6	–	2	5
Subbase	6	–	2	7	–	–	–	–
Borrow	30[b]	–	3	7	36[b]	–	4	7
Subgrade	–	–	2	20–29	–	–	2	20–29

[a]After 1.5 in. overlay.
[b]Embankment greater than 60 in. thick.

encountered in any of the trenches. The subgrade in the cut ranged from A-1-b to A-4(0).

Pavement Deflections

An initial series of 20 pavement springtime deflections was measured on each test section using the Dynatest 8000 FWD before the overlay in 1983. Table 3 gives the average springtime deflection and representative basin for each section. For both the cut and embankment sections, the deflections were lower for the uncrushed lanes than for the crushed lanes even though the uncrushed lanes had 1 in. less AC.

In September 1983, after the test sites were overlaid, four test points were selected for additional deflection testing. These sites were adjacent to each test trench. At each site, a series of drops at approximately 45-, 85-, 130-, and 150-psi loadings was performed to investigate the stress sensitivity of the unbound layers. The results of these tests are given in Table 3. Again the deflections were lower for the uncrushed lanes, although the differences were smaller.

TABLE 3 AVERAGE PAVEMENT (DEFLECTION AND REPRESENTATIVE DEFLECTION BASINS (85-psi LOADING)

	Uncrushed (Southbound)		Crushed (Northbound)	
	Cut	Fill	Cut	Fill
Avg. Deflection (April 1983) (Inches 10^{-3})	12.45	10.76	16.30	16.30
Representative Deflection Basin (Inches 10^{-3})				
Sensor 1 (0.00")	13.58	12.01	18.27	16.30
Sensor 2 (7.87")	9.53	7.99	11.54	10.43
Sensor 3 (11.81")	6.77	5.47	7.20	6.38
Sensor 4 (17.72")	3.94	3.11	3.78	3.07
Sensor 5 (25.59")	0.75	1.89	1.81	1.69
Sensor 6 (35.43")	0.68	1.18	0.71	1.10
Sensor 7 (47.24")	0.31	0.75	0.39	0.87
Avg. Deflection (Sept. 1983) (Inches 10^{-3}) (After Overlay)	11.82	8.82	13.08	12.23
Representative Deflection Basin (Inches 10^{-3})				
Sensor 1 (0.00")	12.87	9.17	12.72	10.87
Sensor 2 (7.87")	9.29	7.05	9.72	8.23
Sensor 3 (11.81")	7.13	5.75	8.07	6.69
Sensor 4 (17.72")	4.53	4.02	5.79	4.53
Sensor 5 (25.59")	2.80	2.60	3.82	2.76
Sensor 6 (35.43")	1.69	1.61	2.40	1.57
Sensor 7 (47.24")	1.34	1.14	1.65	1.10

TABLE 4 SUMMARY OF ASPHALT PAVEMENT CORE DIAMETRAL RESILIENT MODULUS TESTING

Sample	Northbound Lanes (Crushed Base) Resilient Modulus (M_r) ksi @ 487 lbs.	@ 974 lbs.	Sample	Southbound Lanes (Uncrushed Base) Resilient Modulus (M_r) ksi @ 487 lbs.	@ 974 lbs.
221A	509	487	222	611	558
221B	571	465	312	396	380
311	566	503	522	381	381
521A	552	482	812	544	609
521B	410	332			
1011A	468	452			
1011B	121	118			
Average	457	406		483	482
Std. Dev.	159	139		113	119

AC Moduli

Cores at each of the sites were taken in October 1983. The cores were sent to Oregon State University for diametral modulus testing. The samples were tested at 10°C at a frequency of 1 Hz and load duration of 0.1 sec. Table 4 presents the results of the modulus testing. Because of the thickness, three cores had to be sawn to fit the test frame. They are shown as Samples A and B. The average modulus of 483 ksi for the pavement over the uncrushed base is larger than the average of 432 ksi for the pavement over the crushed base.

Base and Subgrade Moduli

The base and subgrade modulus at each test point was backcalculated for each applied load. Two computer programs, ELMOD and MODCOMP2, were used to backcalculate the base modulus. ELMOD uses the method of equivalent thicknesses developed by Dynatest Consultants, Inc.; MODCOMP2 uses elastic layer theory developed by Lynne Irwin *(2)*. The pavement structures were analyzed as a three-layer system, with an AC layer, a base, and subgrade. The AC surface thickness was set equal to the core thickness. The laboratory-determined AC modulus was corrected for temperature based on Van der Poel's nomograph *(1)* and used as an input for each test point for the MODCOMP2 program. ELMOD does not allow user input of the AC moduli for AC thicknesses greater than 3.75 in., but requires user input for AC thicknesses less than 3.75 in.

MODCOMP2, written for a given layer's nonlinear stress-dependent moduli given multiple loads, was unable to obtain a solution for any of the multiple load data from this project. The layer moduli for the unbound layers were solved individually for each load. This was probably because the stress sensitivity of these materials did not fit a power function. In all instances, ELMOD gave higher backcalculated moduli for the base than the MODCOMP2 program. Figure 4 shows a comparison of

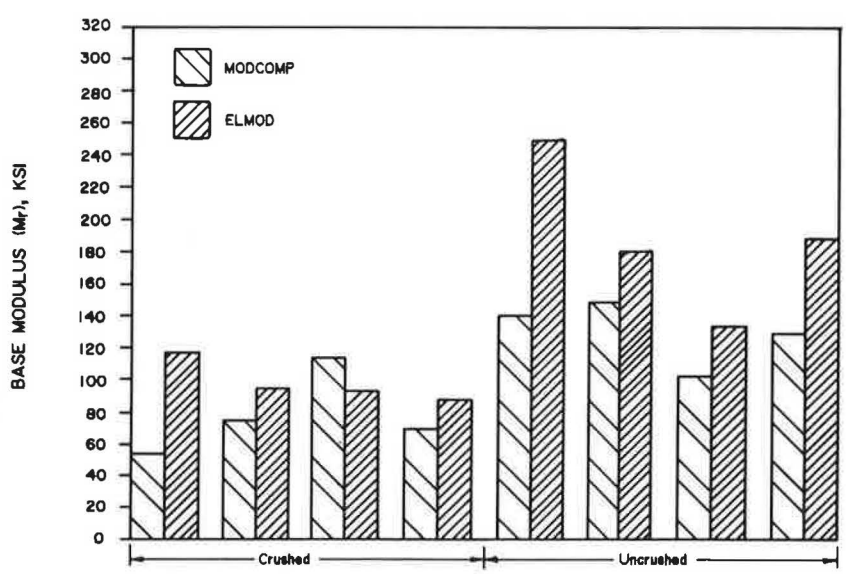

FIGURE 4 Comparison of backcalculation of base course moduli by MODCOMP2 and ELMOD computer programs at 85-psi surface load.

the results from the two programs for the base course at each test point at approximately 85-psi surface loading. The uncrushed-base moduli are higher than the moduli for the crushed base course. Table 5 presents the results of the moduli for all layers at all test points from the MODCOMP2.

Figures 5 and 6 show the base resilient moduli (backcalculated from MODCOMP2) for the crushed and uncrushed base plotted against the average bulk stress for each of the four loads applied by the FWD. The average bulk stress was calculated using PSAD2A *(1)*. Again, the crushed base course exhibited lower moduli than the uncrushed base. The crushed-base moduli also showed more scatter and did not fit the power function for the stress sensitivity of an unbound layer:

$$M_R = K_1 \ \theta^n$$

where

M_R = resilient modulus,
θ = bulk stress, and
K_1, n = constants.

TABLE 5 SUMMARY OF BACKCALCULATED MODULI FROM MODCOMP2 (SEPTEMBER 1983 DEFLECTIONS)

Test Point	AC Thickness (inches)	Lab. AC Modus (ksi)	Load (psi)	Base Modulus (ksi)	Subgrade Modulus (ksi)
311					
Crushed, Fill	3.35	581	44.8	47.5	26.0
			86.8	75.5	29.6
			132.4	93.0	31.0
			151.8	99.5	34.2
1011					
Crushed, Fill	4.78	329	42.8	44.1	31.6
			86.1	70.1	33.8
			132.0	85.9	36.6
			149.8	89.0	36.5
221					
Crushed, Cut	3.95	550	43.1	25.2	30.2
			86.1	53.0	30.0
			132.4	69.4	30.8
			149.4	78.3	30.8
521					
Crushed, Cut	3.90	470	42.8	75.5	21.9
			85.1	114.4	24.9
			130.7	137.1	26.1
			147.4	119.6	26.2
312					
Uncrushed, Fill	3.83	438	42.5	100.0	31.5
			84.1	149.2	35.1
			129.7	189.6	39.6
			146.0	202.7	40.8
812					
Uncrushed, Fill	2.50	702	42.2	70.0	27.5
			84.4	129.9	31.9
			130.4	167.2	34.7
			146.8	186.4	35.8
222					
Uncrushed, Cut	2.58	644	41.3	103.6	34.4
			84.6	141.2	43.1
			130.4	178.2	48.1
			147.8	190.7	49.9
522					
Uncrushed, cut	3.43	438	42.5	64.3	20.9
			84.1	101.4	22.9
			130.4	125.4	25.2
			147.4	122.2	26.4

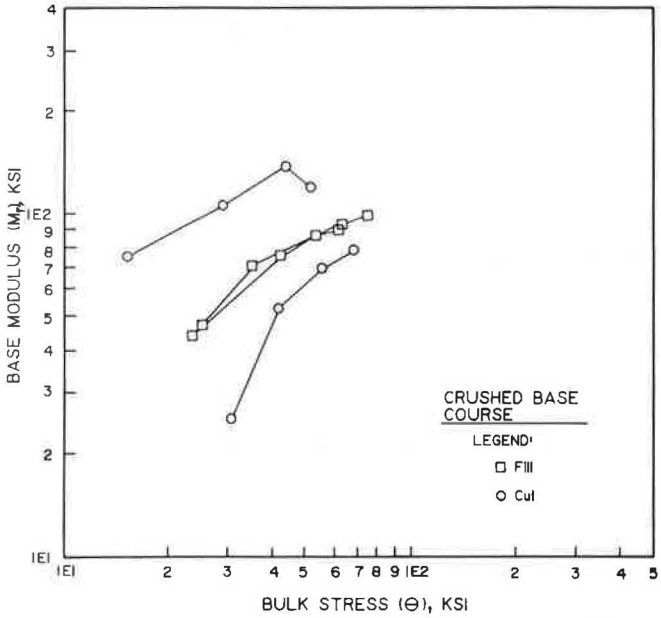

FIGURE 5 Backcalculated, crushed base course moduli from FWD deflections.

LABORATORY INVESTIGATION

To verify the field results, laboratory resilient modulus tests were performed on the two base materials at Oregon State University. The samples were prepared at approximately 96 percent of AASHTO T180 density and at optimum moisture (see Table 1). The test procedures used were in accordance with AASHTO T274-82 as much as possible. The loading frequency was 30 rpm with a load dwell of 0.12 sec. The uncrushed base had a lower optimum moisture content but a higher Proctor density.

Modulus Results

The average laboratory values of the resilient modulus versus the bulk stress are presented in Figure 7 along with the average values determined from the field. Although the laboratory values were approximately one-half of those determined in the field, the uncrushed material still performed better than the crushed material. These results, rather surprising in light of past and present research involving crushed and uncrushed gravels, may be attributable to the fact that the maximum size of the uncrushed material is 2 in. whereas the maximum size of the crushed base is only 1 in.

Laboratory resilient modulus tests were also run on samples prepared at 1.5 percent more than the optimum moisture content in an effort to simulate springtime conditions. Figure 8 shows the results of these tests as compared to the average values at optimum. Both materials show a loss in modulus, with the uncrushed material indicating a reduction of 27 percent, higher than the crushed material, which only indicated a reduction of 16 percent. This difference appears to indicate that the fracture may have a benefit during spring thaw when the base course is saturated, as has been suggested by other research *(6)*. Because these percentages are based on only one test each more than optimum, further research should be considered to evaluate the effects of moisture on the base-subbase modulus.

Permanent Deformation Results

Permanent deformation tests were also performed on the field samples using AASHTO T274-82. Samples were tested using a 10-psi confirming stress and a deviator stress of 20 psi. The permanent deformation was measured at logarithmic load repetition intervals for a total of 10,000 repetition. Two tests on

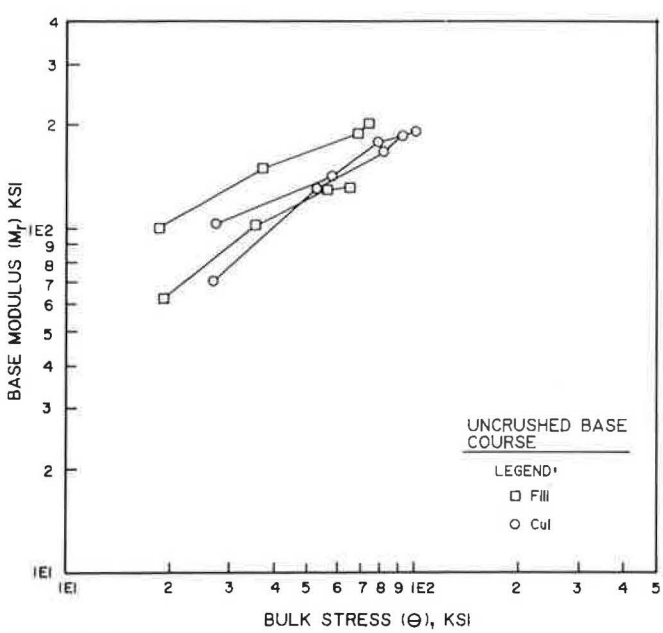

FIGURE 6 Backcalculated, uncrushed base course moduli from FWD deflections.

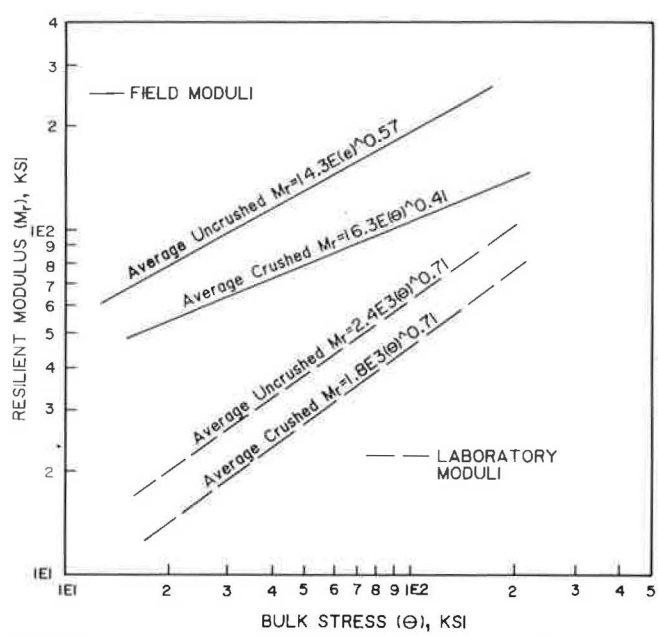

FIGURE 7 Comparison of laboratory-measured base course moduli to backcalculated moduli from FWD deflections.

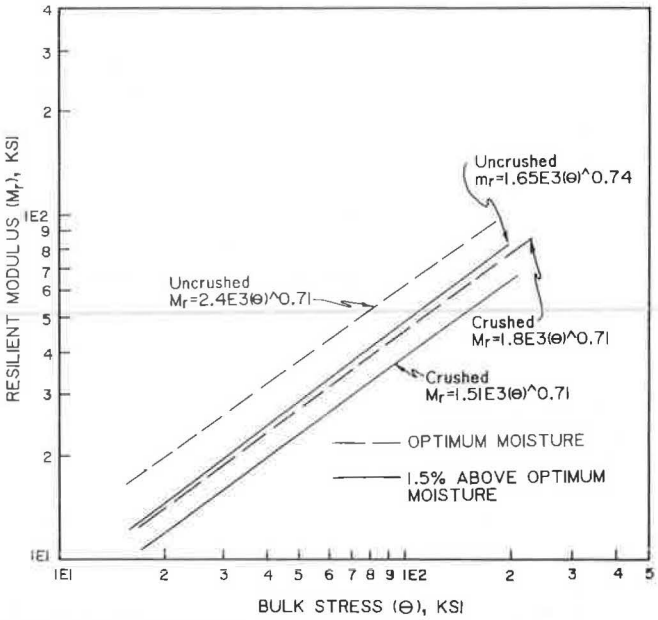

FIGURE 8 Comparison of laboratory-measured base course moduli tested at optimum moisture content and 1.5 percent more than optimum moisture content.

both the crushed and uncrushed bases were run at optimum moisture and one test at 1.5 percent more than optimum moisture. Figure 9 shows the results of the average of two tests at optimum moisture as well as the one at more than optimum moisture for both the crushed and uncrushed bases. Again, the uncrushed base performed better, yielding smaller permanent deformations than the crushed base. Both the crushed and uncrushed bases showed about the same percentage increase in permanent deformation upon saturation. Again, because this result is based on one test of each material, it should be investigated further.

EFFECT OF BASE PROPERTIES ON PAVEMENT LIFE

Analysis Approach

A pavement analysis was performed using the PSAD2A elastic layer computer program to compare the effects on pavement life of using an uncrushed versus a crushed base course. A section with 3 in. of AC, 6 in. of base course, and 12 in. of subbase over a combined embankment and subgrade was selected for analysis (Table 6). The average laboratory AC moduli and the average field backcalculated moduli for the base course for each section were used as given in Table 7. For the summer months, the subbase moduli were made equal to the combined backcalculated moduli for the combined embankment and subgrade.

To simulate springtime conditions, the base course moduli were reduced by the percentages determined in the laboratory on the saturated samples. The subbase moduli were also reduced to 8 ksi. The pavement moduli were adjusted for temperature throughout the spring and summer months (Table 8). No damage to the pavement was assumed when the embankment was frozen during the winter. The fatigue curve recommended in Volume II of the proposed AASHTO *Guide for*

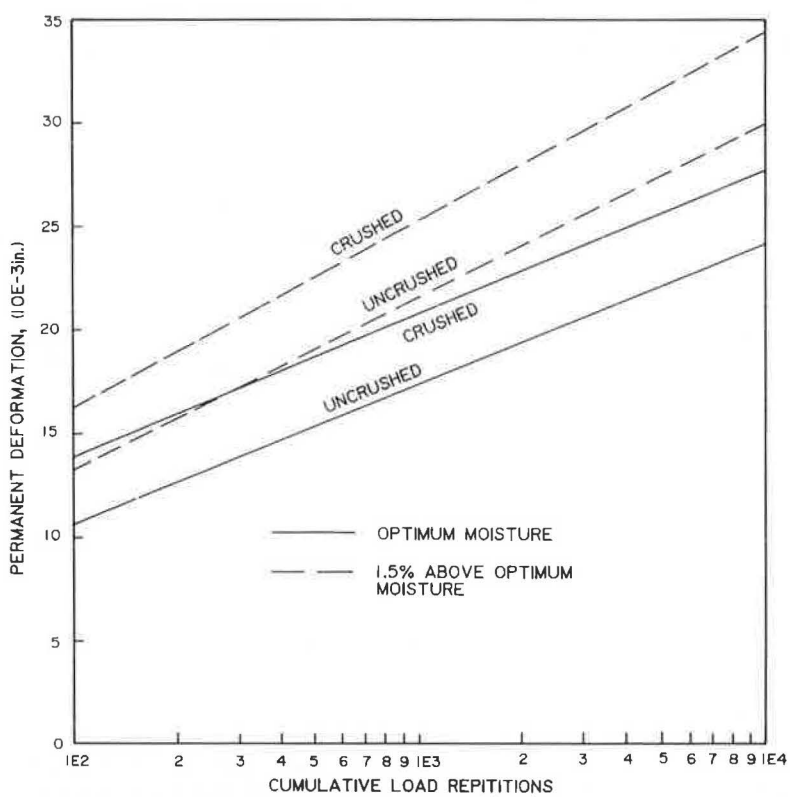

FIGURE 9 Results of laboratory-measured base course permanent deformations at optimum moisture content and 1.5 percent more than optimum moisture content.

TABLE 6 LAYER THICKNESSES USED IN ANALYSIS OF PAVEMENT LIFE

Layer	Thickness (in.)
Asphalt concrete	3.0
Base course	6.0
Subbase	12.0
Subgrade	–

TABLE 7 MATERIALS PROPERTIES USED IN ANALYSIS OF PAVEMENT LIFE

Layer	Modulus (M_R) (ksi) Crushed	Uncrushed
AC at 10°C	468	483
Base course (summer)	$16.3\ \theta^{0.41}$	$14.3\ \theta^{0.57}$
Base course (spring)	$13.7\ \theta^{0.41}$	$10.4\ \theta^{0.57}$
Subbase (summer)	29.6	33.3
Subbase (spring)	8.0	8.0
Subgrade	29.6	33.3

NOTE: θ = Bulk stress.

Design of Pavement Structures (4) was used to determine fatigue life:

$$\log_{10} N_f = 15.988 - 3.291 \log_{10}\left(\frac{t}{10^{-6}}\right) - 0.854 \log\left(\frac{S_{mix}}{10^3}\right)$$

where

N_f = number of allowable load repetitions,
t = strain in the bottom of the AC layer, and
S_{mix} = AC modulus (psi).

The pavement damage was totaled using Miner's hypothesis based on a monthly equivalent axle load (EAL) of 16,000.

Results

The analysis presented in Table 8 shows that with 3.0 in. of AC, the pavement with the uncrushed base would have a life of 12.3 years, whereas the pavement over the crushed base would have a life of only 8.0 years. This represents a 54 percent greater life for the uncrushed base than for the crushed base. However, as constructed with 3.1 in. of AC over the uncrushed base and 4.0 in. over the crushed base, the AC pavement with the crushed base has a longer life than that with an uncrushed base by as much as 31 percent.

DISCUSSION OF RESULTS

It appears that the uncrushed base is superior to the crushed base because of the larger maximum size and higher density. The 0.45 power plots of the gradations on Figure 3 show that the uncrushed base points are closer to a straight line. The crushed base line has a slight upward curve. The straighter plot and the larger maximum size explain the higher density. The higher density apparently results in the uncrushed base being stiffer and having a higher resilient modulus. This stiffness in turn leads to better performance. The uncrushed base also has 1 percent more passing the No. 200 sieve than the crushed base.

TABLE 8 RESULTS OF ANALYSIS OF PAVEMENT LIFE

Month	Uncrushed Base: AC Modulus (ksi)	Strain (10^{-6})	Allowable Repetitions (X1000)	Annual** N_i/N_f	Crushed Base: AC Modulus (ksi)	Strain (10^{-6})	Allowable Repetitions (X1000)	Annual** N_i/N_f
April	672	258	435	0.037	690	281	321	0.050
May	600	166	2045	0.008	617	190	1281	0.013
June	391	186	2028	0.008	407	220	1128	0.014
July	333	192	2095	0.008	339	232	1107	0.015
Aug	311	194	2147	0.008	347	230	1117	0.014
Sept	543	171	2020	0.008	560	197	1235	0.013
Oct*	776	152	2195	0.004	793	171	1462	0.006
			TOTAL	0.081			TOTAL	0.125
			Pavement Life	12.3 years				8.0 years

* No damage assumed when embankment is frozen

** 16,000 EALs/month

The optimum moisture of the uncrushed base is also 0.4 percent less than the crushed base. For this project, the uncrushed base has a 37 percent single-faced fracture versus an 81 percent fracture for the crushed base. The larger maximum size and the higher density apparently have a larger beneficial effect than increasing the fracture from 37 to 81 percent.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The results of the study indicate the following conclusions are warranted:

1. In all testing, both in the laboratory and in the field, the uncrushed base (subbase, Grading B) performed better than the crushed base (base course, Grading D-1). It had both a higher resilient modulus and a lower permanent deformation. For the project investigated, the uncrushed base had a maximum size of 2 in., 6 percent passed the No. 200 sieve, and the material retained on the No. 4 sieve had a 37 percent single-face fracture. The crushed base had a maximum size of 1 in., 7 percent passed the No. 200 sieve, and there was an 85 percent single-face fracture.
2. The uncrushed base showed a loss of resilient modulus of 27 percent as compared to a 16 percent loss for the crushed base when water content was 1.5 percent more than optimum, but still showed a higher modulus than the crushed base when saturated.
3. Both the crushed and uncrushed base showed about the same percentage increase in permanent deformation at 1.5 percent more than optimum moisture content.
4. In backcalculating the base modulus from the FWD readings, the ELMOD program using the method of equivalent layers gave consistently higher moduli than the MODCOMP2 program using elastic layer analysis.
5. The backcalculated field moduli were approximately two to three times as great as those measured in the laboratory on the same material. It appears that the laboratory resilient modulus test does not adequately reflect the performance of layered pavement structures.
6. For this project, an analysis of the pavement life using the field-backcalculated moduli for the base courses indicated that with the same AC thickness the AC pavement over the uncrushed base would have a 54 percent longer life than that over the crushed base.
7. It appears that the uncrushed base is superior to the crushed base because of the larger maximum size and higher density. This apparently results in the uncrushed base's being stiffer and having a higher resilient modulus. This stiffness in turn leads to the better performance of the uncrushed base.

Recommendations

1. The results presented in this paper are for one project only. Before any conclusions are implemented as to the use of uncrushed base, other test projects should be investigated to verify these results.
2. Further laboratory testing is recommended to determine the effect of maximum size and gradation on resilient modulus.
3. The percentage loss of modulus presented in this paper is based on one sample each of crushed and uncrushed base courses. Also, the springtime damage to the AC as shown in the pavement life analysis is significant. Further testing is recommended to provide a statistical verification of the results presented in this paper.
4. The permanent deformation results presented in this paper are based on one sample each of crushed and uncrushed base courses. Further testing is recommended to provide statistically valid results.
5. Further work appears necessary to adequately predict field performance of layered pavement structures based on laboratory testing of unbound materials.

IMPLEMENTATION STATEMENT

The results of this study are from one project only and are typical of the conditions found on that project. Although the uncrushed base course was shown to perform better than the crushed base course, the general use of uncrushed base courses should not be implemented until more complete testing is performed, both in the laboratory and at field test sites. At this time, the use of uncrushed base can be considered in areas where it is hard to make specification base course because of degradation during the crushing process. These projects should be nonurban and in locations where there are no horizontal forces on the pavement structure due to stopping and starting.

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