EFFECTS OF AN UNCRUSHED BASE LAYER
ON PAVEMENT PERFORMANCE

FINAL REPORT

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16. Abstract

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 surface of the Glenn Highway Widening project. The original two lanes had been constructed with a crushed base course in 1969, 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 inches with 37 percent aggregate fracture while the crushed base was uniformly graded with a maximum size of 1 inch with an 85 percent aggregate fracture. Base course resilient modulus was back calculated from FWD 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 thickness of asphalt indicates that the pavement over the uncrushed base would have a longer life than the pavement over the crushed base by by 54%.

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ABSTRACT

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. The original two lanes had been constructed with a crushed base course in 1969, 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 inches with 37 percent aggregate fracture while the crushed base was uniformly graded with a maximum size of 1 inch with an 85 percent aggregate fracture. Base course resilient modulus was back calculated from FWD 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 partical 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%.

ACKNOWLEDGEMENTS

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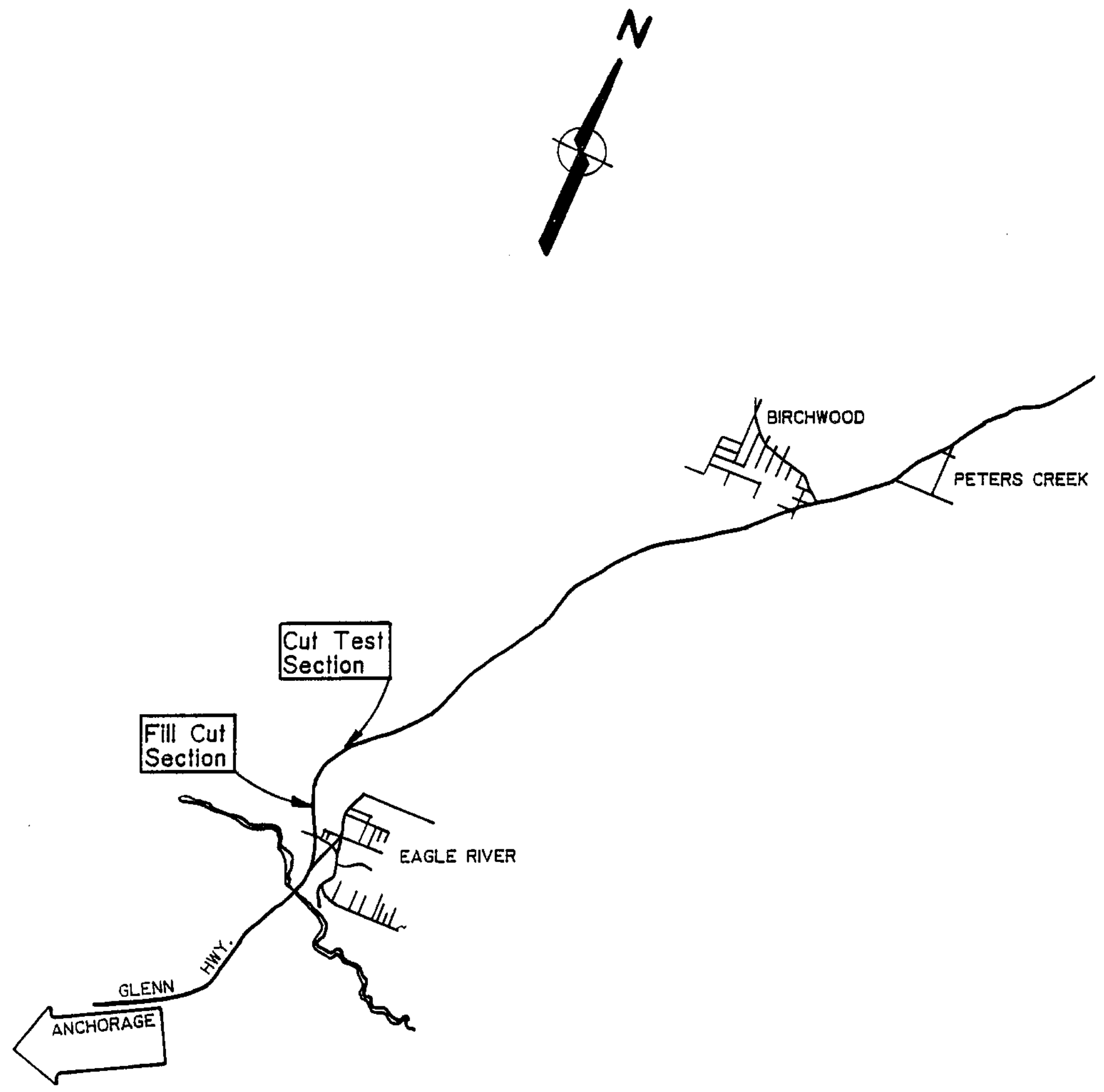
INTRODUCTION

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 (F-042-1(40)). The original two lanes, constructed in 1969, (project F-042-1(30)), had been 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 to 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 southcentral 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 is 13,500. The cross section consisted of two 14 feet driving lanes with 8-foot shoulders and a 4-foot ditch (figure 2). The design pavement structure consists of 1.5 inches of hot asphalt concrete over 6 inches of base course grading D-1 over 6 inches of subbase and 36 inches of select material. Both projects were overlaid with 1.5 inches of hot asphalt concrete 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.



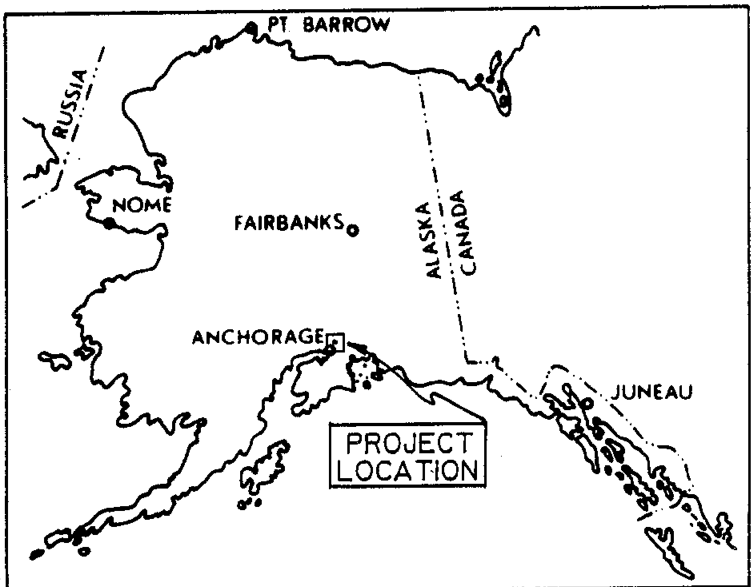
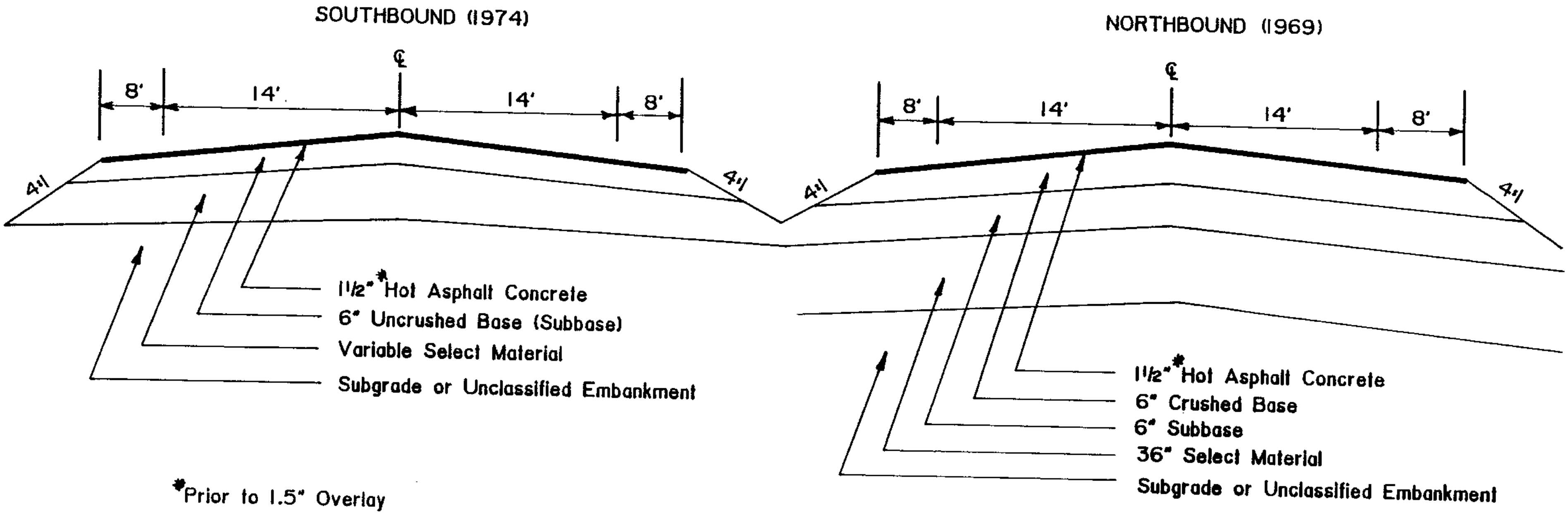


Figure 1

Test Site

LOCATION MAP

Scale 1" = 2 Miles **Data** ____



*Prior to 1.5" Overlay

No Scale

Figure 2
As Designed Typical Sections

The southbound lanes were constructed in 1974. The cross section is the same as the northbound lanes with a 4 foot ditch between them. The design template consisted of 1.5 inches of hot asphalt concrete over 6 inches 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 one inch minus uniform gradation, with 3 to 10 percent passing the No. 200 sieve, and the material retained on the No. 4 sieve had 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 inches, 3 to 8 percent passing the No. 200 sieve, and no fracture requirement.

Problems were encountered in tight blading the surface prior to paving because of the 2 inch minus 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 thought that this would result in a greater asphalt concrete thickness than designed but cores showed that no excess asphalt concrete was used.

FIELD INVESTIGATION

Two test sites were selected for evaluation along the project: a 550 feet long cut section and a 1000 feet long embankment fill section. During the spring of 1983 falling weight deflectometer deflection tests were performed every 50 feet in the cut section and every 100 feet 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 feet. 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.

Pavement Condition

A formal pavement condition survey was not performed as the test sections were overlayed 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

The test trenches were employed to verify the designed pavement structure as stated above. Both the crushed and the uncrushed base course were within project specifications (see Table 1). Figure 3 is a 0.45 power plot

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

	North Bound Lanes Crushed Base Course			South Bound Lanes Uncrushed Base Course (Subbase)		
	Specification	Test Results		Specification	Test Results	
Sieve	D-1	Average	Range	B	Average	Range
2 inch	100	100		100	100	
1.5 inch					97	(95-98)
1 inch	100	100			80	(77-82)
3/4 inch	70-100	94	(91-95)	60-90	69	(64-73)
1/2 inch		74	(72-77)		56	(52-60)
3/8 inch	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		4.3	(3-5)		5.3	(3-8)
Fracture,	75	81	(76-85)	–	37	(19-53)
Optimum Moisture,	4.5				4.1	
T180 Proctor Density	143.8 pcf				148.4 pcf	

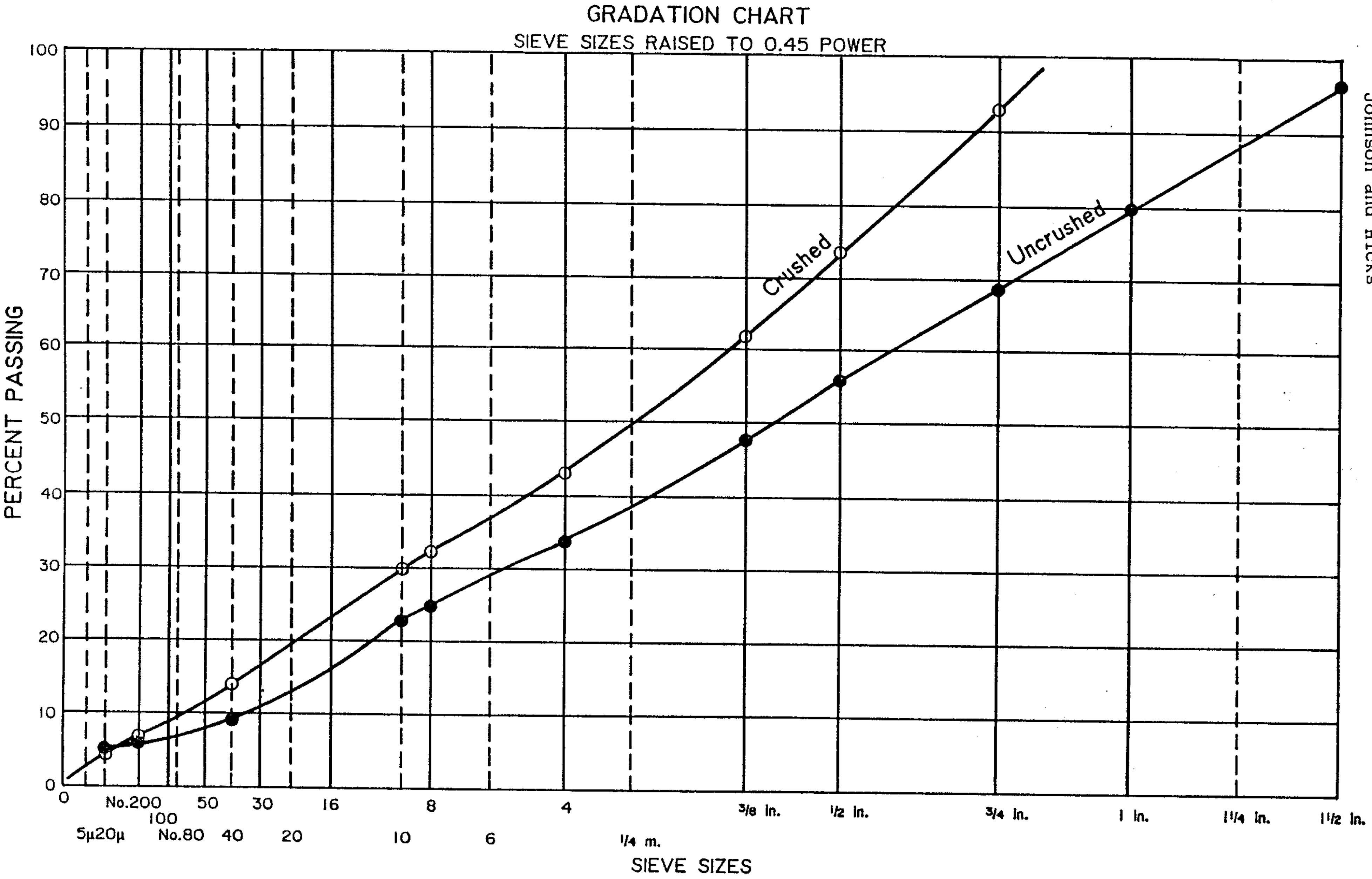


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FIGURE 3 0.45 Power Gradation Chart of Crushed and Uncrushed Base Courses of the average gradation of the crushed and uncrushed base courses. The crushed base single faced fracture on the No. 4 sieve averaged 81 percent, while the uncrushed base averaged 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, as shown in Table 1, the T180 Proctor density for the uncrushed base was 148.4 pounds per cubic foot, much higher than the 143.8 pounds per cubic foot for the crushed base.

Table 2 summarizes the pavement structure components and their characteristics as measured in the test trenches. The hot asphalt concrete over the crushed base averaged 4.0 inches while the asphalt concrete over the uncrushed base averaged 3.1 inches. (The test sections were overlaid with 1.5" asphalt concrete during the summer of 1983.) The total pavement structure above the subgrade in the cut averaged 42 inches in the crushed base section (northbound lanes) and 48 inches in the uncrushed section (southbound lanes). In the fill sections the embankment thickness was greater than 60 inches. All imported materials are classified as A-1-a and no water was encountered in any of the trenches. The subgrade in the cut ranged from an A-1-b to an A-4(0).

Pavement Deflections

An initial series of 10 pavement springtime deflections were measured on each test section using the Dynatest 8000 Falling Weight Deflectometer prior to the overlay in 1983. Table 3 shows the average springtime deflection and representative basin for each section. It is interesting to

TABLE 2 PAVEMENT STRUCTURES (AS-BUILT)

	North Bound Lanes Crushed Base				South Bound Lanes Uncrushed Base (Subbase)			
	Average Thickness (Inches)	Range (Inches)	Max. Size (Inches)	Average P_{200} (%)	Average Thickness (Inches)	Range (Inches)	Max. Size (Inches)	Averag P_{200} (%)
Hot Asphalt Pavement	4.0**	(3.4-4.8)	-	-	3.1**	(2.5-3.8)	-	-
Base Course	6	-	1	7	6	-	2	5
Subbase	6	-	2	7	-	-	-	-
Borrow	*30	-	3	7	*36	-	4	7
Subgrade	-	-	2	(20 - 29)	-		2	(20-29)

* Embankment greater than 60" thick.
**After 1.5" overlay.

Table 3

AVERAGE PAVEMENT DEFLECTIONS 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

note that for both the cut and embankment sections the deflections were lower for the uncrushed lanes than the crushed even though the uncrushed lanes had an inch less asphalt.

In September 1983, after the test sites were overlayed, 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 were 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.

Asphalt Concrete 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, a frequency of 1 Hz, and a load duration of 0.1 seconds. 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 back calculated for each applied load. Two computer programs were used to back calculate the

TABLE 4

Summary of Asphalt Pavement Core Diametral Resilient Modulus Testing

Sample	Northbound Lanes (Crushed Base) Resilient Modulus (M_r) ksi		Sample	Southbound Lanes (Uncrushed Base) Resilient Modulus (M_r) ksi	
	@ 487 lbs.	@ 974 lbs.		@ 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

base modulus, ELMOD and MODCOMP2. ELMOD uses the method of equivalent thicknesses developed by Dynatest Consultants and MODCOMP2 uses elastic layer theory developed by Lynne Irwin of Cornell University. The pavement structures were analyzed as a three layer system, with an asphalt concrete layer, a base, and subgrade. The AC surface thickness was set equal to the core thickness. The laboratory determined asphalt concrete modulus was corrected for temperature based on Van der Poel's nomograph (Reference 1) and used as an input for each test point for the MODCOMP2 program. ELMOD does not allow user input of the asphalt concrete moduli for asphalt concrete thicknesses greater than 3.75 inches, but requires user input for asphalt thicknesses less than 3.75 inches.

While MODCOMP2 was written to solve for a given layer's nonlinear stress dependent-moduli given multiple loads, it 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 back calculated moduli for the base than the MODCOMP2 program. Figure 4 shows a comparison of the results from the two programs for the base course at each test point at approximately 85 psi surface loading. It can be seen that 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 program.

Figures 5 and 6 show the base resilient moduli (back calculated from MODCOMP2), for the crushed and uncrushed base plotted against the average

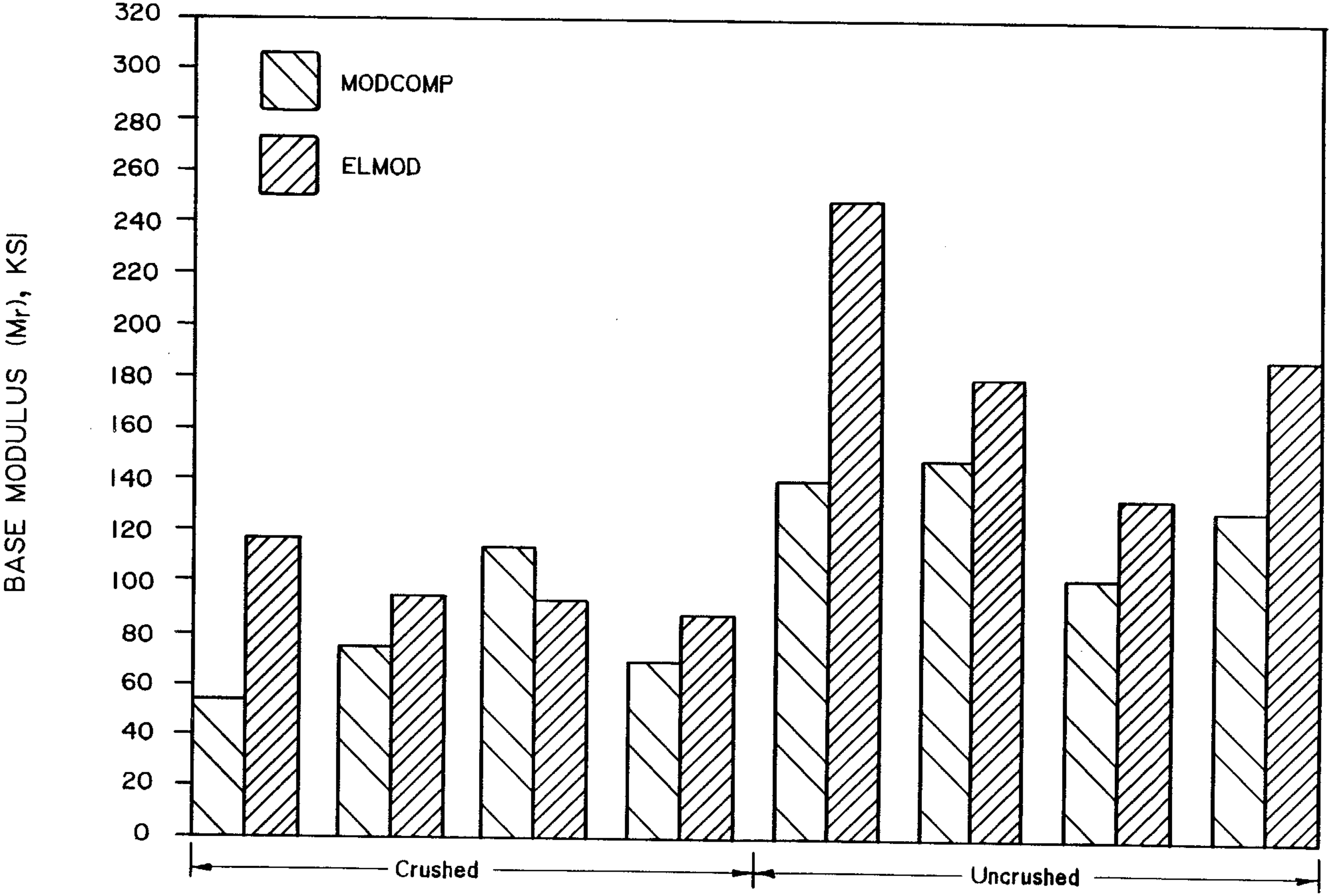

Figure 4 Comparison of base course moduli by back calculated MODCOMP2 and ELMOD at 85 psi surface load.

Table 5

SUMMARY OF BACK-CALCULATED MODULI FROM MODCOMP 2 (Sept. 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

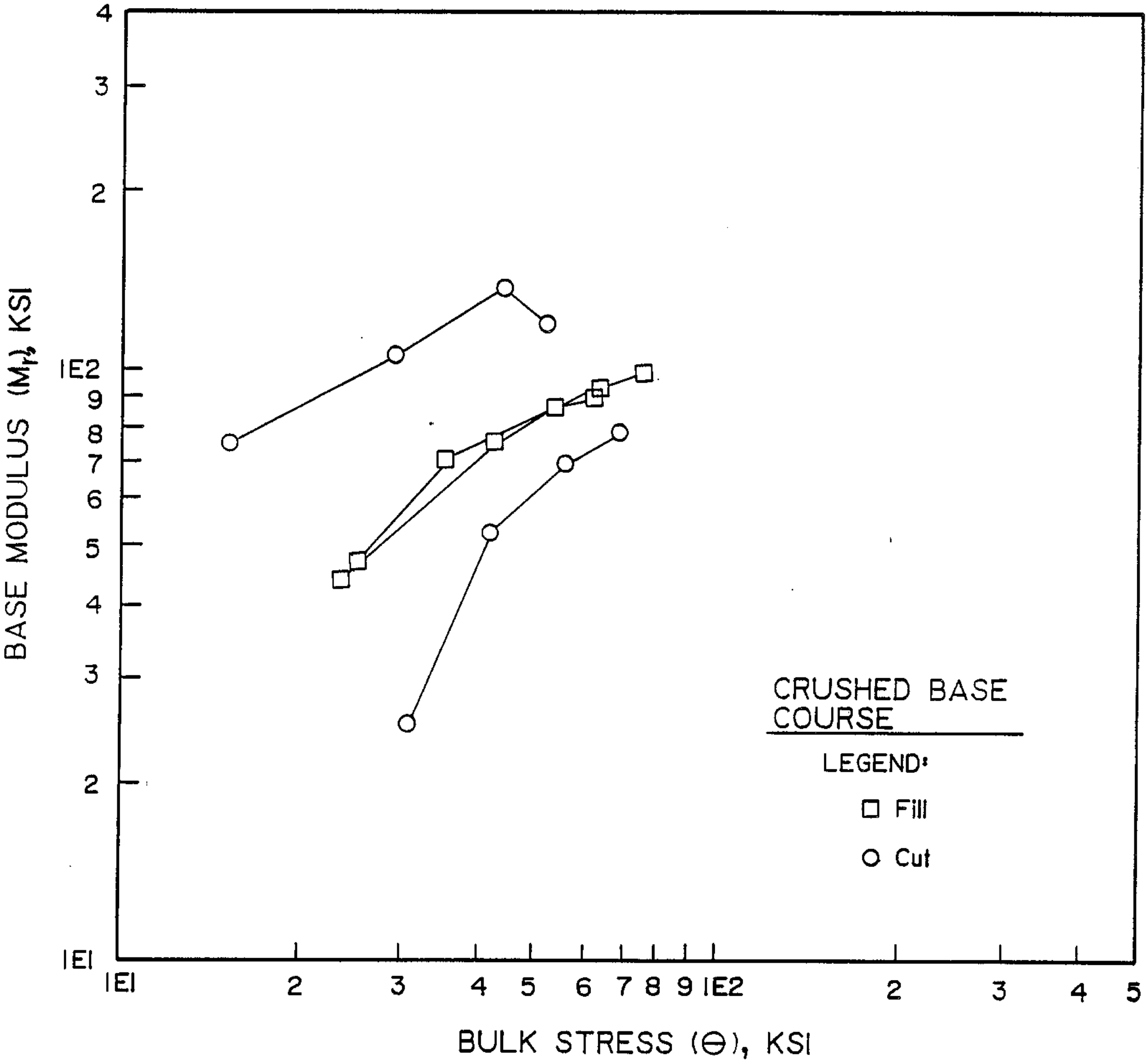

Figure 5 Back calculated crushed base course moduli from FWD deflections.

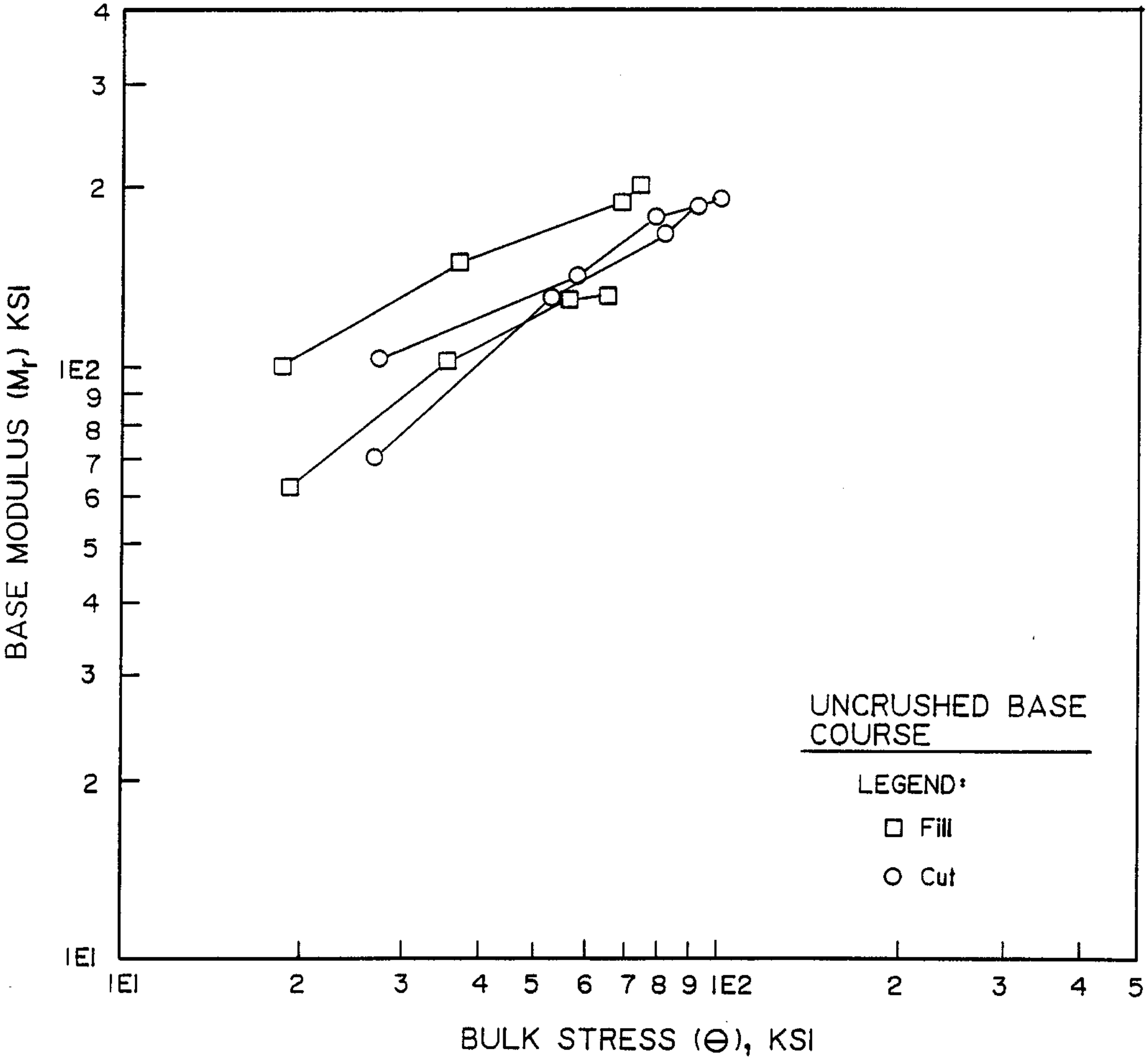

Figure 6 Back calculated uncrushed base course moduli from FWD deflections.

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 below:

$$M_R = K_1 \Theta^n$$

where: M_R = Resilient Modulus
= Bulk stress
K_1,n = constants

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 T-180 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 seconds. Note that 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. While the laboratory values were approximately half those

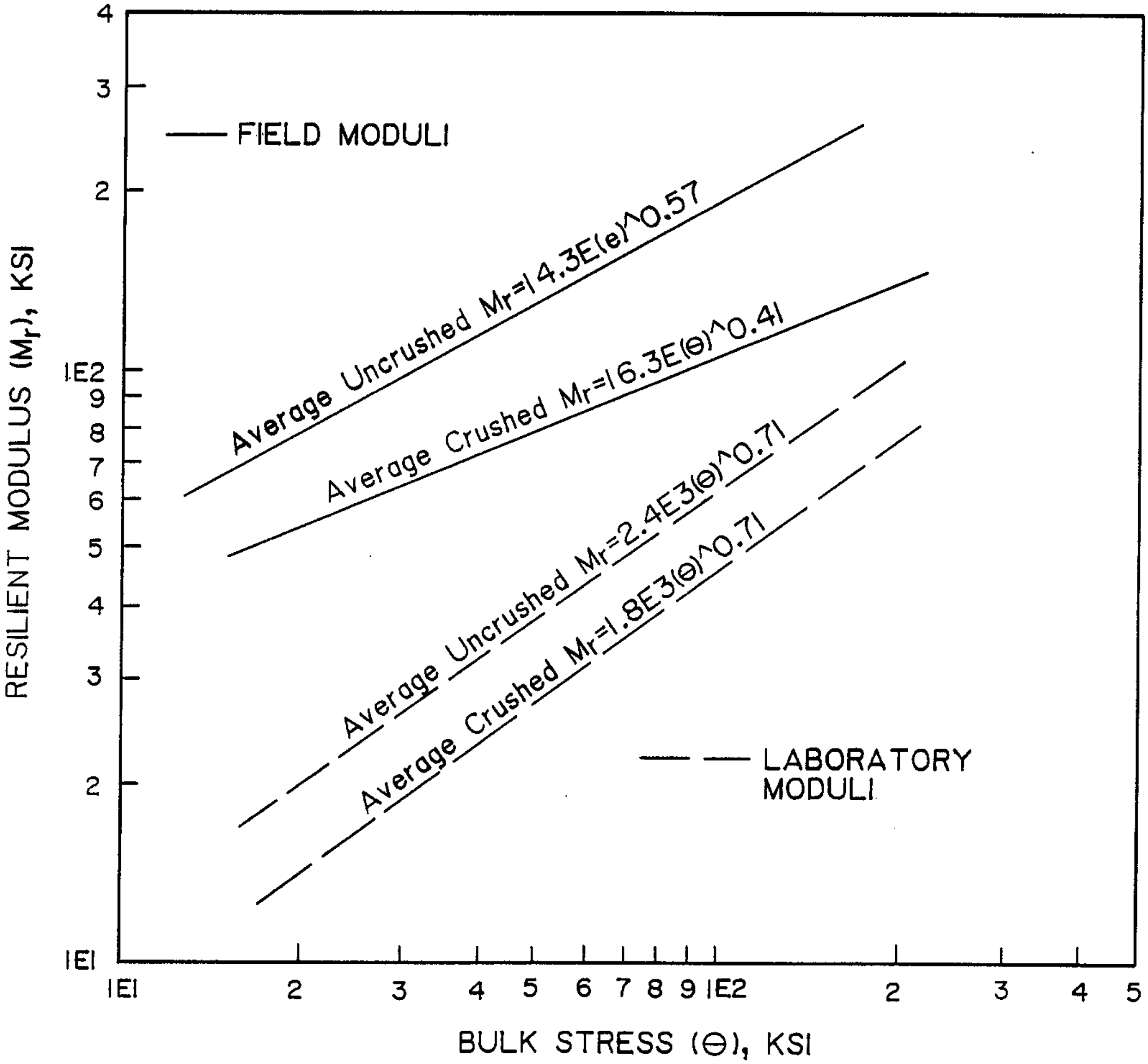

Figure 7 Comparison of laboratory measured base course moduli to back calculated moduli from FWD deflections.

determined in the field, the uncrushed material still performed better than the crushed material. These results are rather surprising in light of past and present research involving crushed and uncrushed gravels. This may be attributable to the fact that the maximum size of the uncrushed material is 2 inches while the maximum size of the crushed base is only 1 inch.

Laboratory resilient modulus tests were also run on samples prepared at 1.5 percent over 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 indicating a higher reduction of 27%, than the crushed, which only indicated a reduction of 16%. This seems 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). Since these percentages are based on one test each over optimum, and further research should be considered to evaluate the effects of moisture of 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 repetitions. Two tests on both the crushed and uncrushed bases were run at optimum

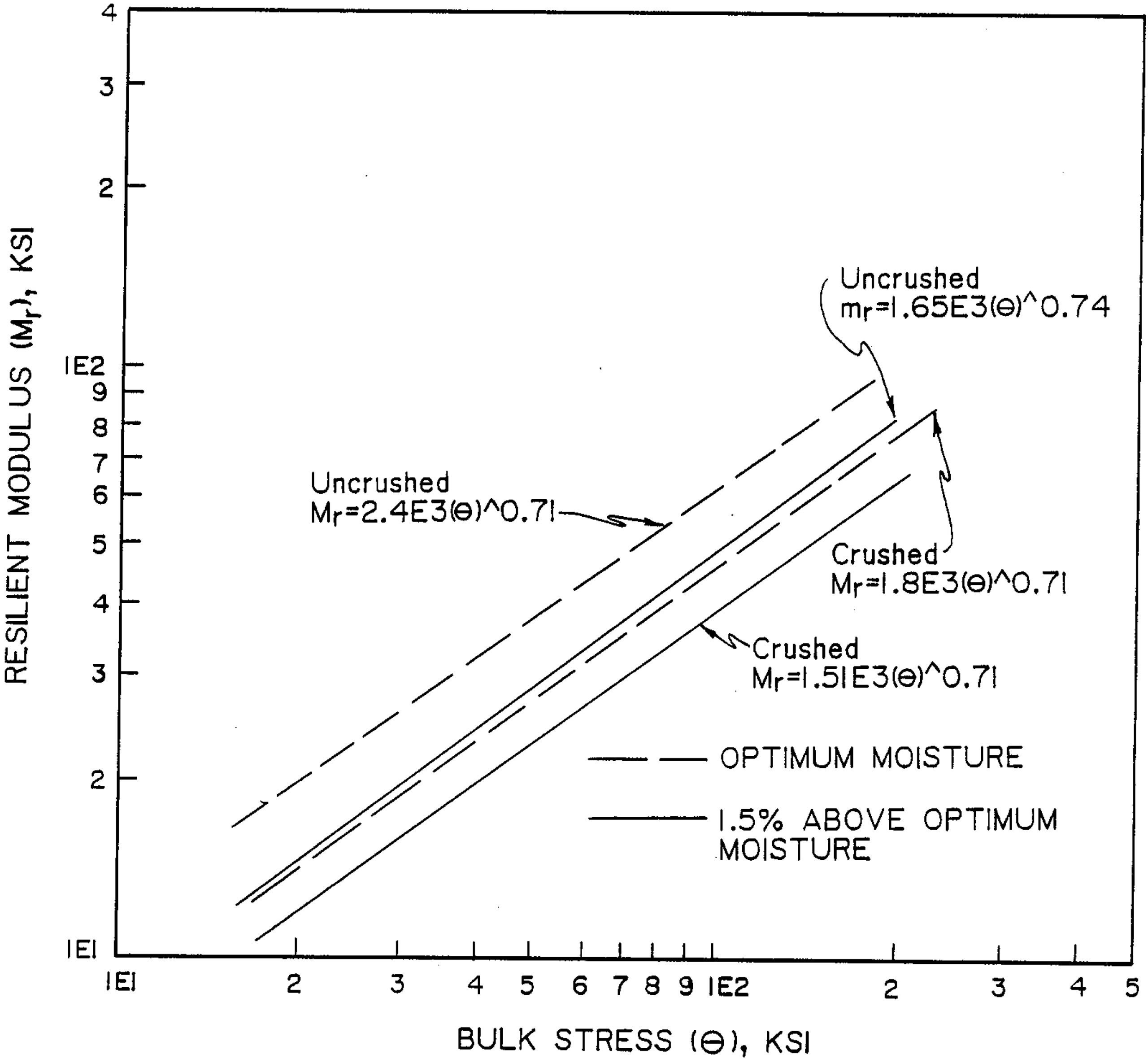

Figure 8 Comparison of laboratory measured base course moduli tested at optimum moisture content and 1.5 percent above optimum.

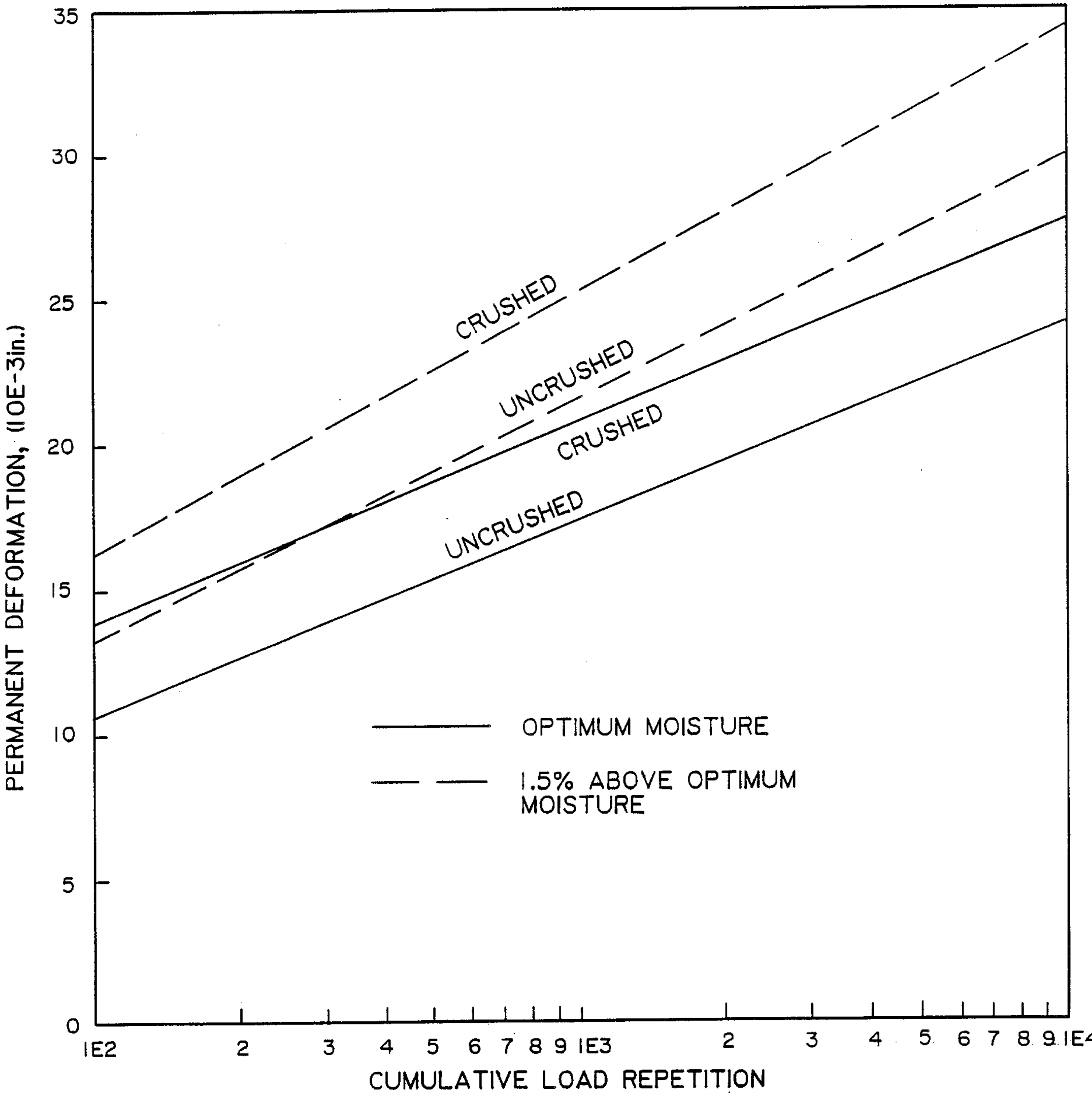

Figure 9 Results of laboratory measured base course permanent deformations at optimum moisture content and 1.5 percent above optimum.

moisture and one at 1.5 percent moisture above optimum. Figure 9 shows the results of the average of two tests at optimum as well as the one above optimum for both the crushed and uncrushed bases. Again the uncrushed base performed better yielding smaller permanent deformations than the crushed. Both the crushed and uncrushed showed about the same percentage increase in permanent deformation upon saturation. Again this is based on one test of each material and 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 inches of asphalt concrete, 6 inches of base course, 12 inches of subbase over a combined embankment and subgrade was selected for analysis (Table 6). The average laboratory AC moduli and the average field back-calculated moduli for the base course for each section were used as shown in Table 7. For the summer months the subbase moduli were made equal to the combined back-calculated 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

Table 6

LAYER THICKNESSES USED IN ANALYSIS OF PAVEMENT LIFE

Layer	Thickness (Inches)
Asphalt Concrete (AC)	3.0
Base Course	6.0
Subbase	12.0
Subgrade	--

Table 7

MATERIALS PROPERTIES USED IN ANALYSIS OF PAVEMENT LIFE

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

Table 8

RESULTS OF ANALYSIS OF PAVEMENT LIFE

	Uncrushed Base				Crushed Base			
Month	AC Modulus (ksi)	Strain (10^{-6})	Allowable Repetitions (X1000)	Annual** N_i/N_f	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

during the winter. The fatigue curve recommended in Volume II of the proposed AASHTO "Guide for Design of Pavement Structures" (4) was used to determine fatigue life:

$$\mathrm{Log}_{10} N_f = 15.988 - 3.291 \log_{10} \left[\frac{\epsilon_t}{10^{-6}} \right] - 0.854 \log \left[\frac{S_{mix}}{10^3} \right]$$

where:

N_f = the number of allowable load repetitions

ϵ_t = the strain in the bottom of the AC layer

S_m = the AC modulus

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

Results

The analysis as presented in Table 8, shows that with 3.0 inches of asphalt, the pavement with the uncrushed base would have a life of 12.3 years, while 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 over that of the crushed base. However, as constructed with 3.1 inches of asphalt concrete over the uncrushed base and 4.0 inches over the crushed base, the asphalt pavement with the crushed base has a longer life than with an uncrushed base, by as much as 31%.

DISCUSSION

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 lots of the gradations on Figure 3, shows that the uncrushed base plots closer to a straight line. The crushed base line has a slight curve upward. The straighter plot and the larger maximum size explains the higher density. The higher density apparently results in the uncrushed base being stiffer and having a higher resilient modulus. This in turn leads to better performance. It also is interesting to note that the uncrushed base has 1 percent more passing the No. 200 sieve and the 0.02 mm than the crushed base. 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 a 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 percent 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 inches, 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 inch, 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 above optimum, but still showed a higher modulus than the base when saturated.

3. Both the crushed and the uncrushed base showed about the same percentage increase in permanent deformation at 1.5 percent above optimum moisture content.

4. In back calculating the base modulus from the FWD readings, the ELMOD program using the method of equivalent layers gave consistantly higher moduli than the MODCOMP2 program using elastic layer analysis.

5. The back-calculated field moduli were approximately two to three times as high 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 back calculated moduli for the base courses, indicated that with the same asphalt thickness the asphalt pavement over the uncrushed base would have a 54 percent longer life than the pavement 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 being stiffer and having a higher resilient modulus. This in turn leads to better performance for 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 report is based on one sample each of the crushed and uncrushed base course. Also, the springtime damage to the asphalt concrete as shown in the pavement life analysis is significant. Further testing is recommended to provide a statistical verification of the results presented in this report.

4. The permanent deformation results presented in this report are based on one sample each of crushed and uncrushed base course. 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. While the uncrushed base course was shown to perform better than the crushed base, the general use of uncrushed base courses should not be implemented until more complete testing is performed, both in the laboratory and with 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 non-urban where there is no horizontal forces on the pavement structure due to stopping and starting.

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