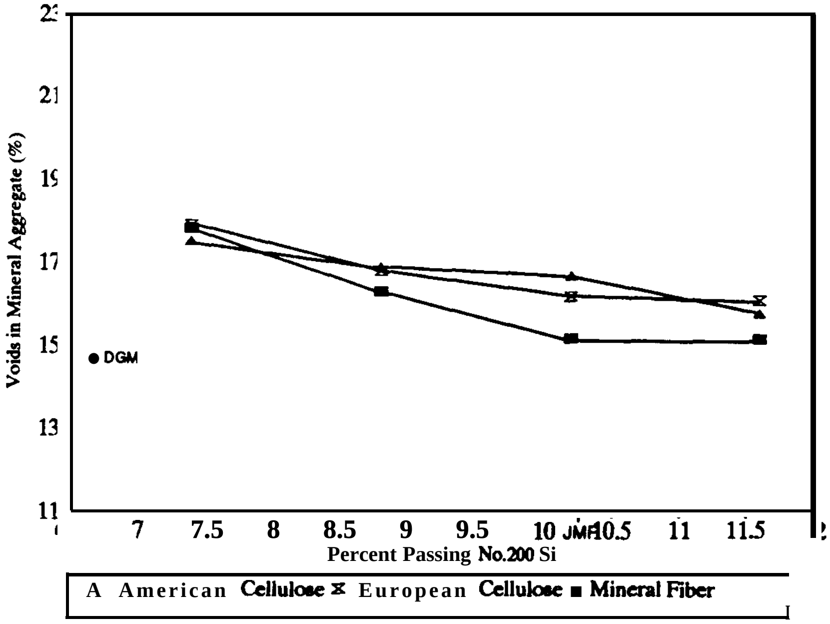

Figure 16a. VMA vs. percent passing No. 200 sieve for granite aggregate.

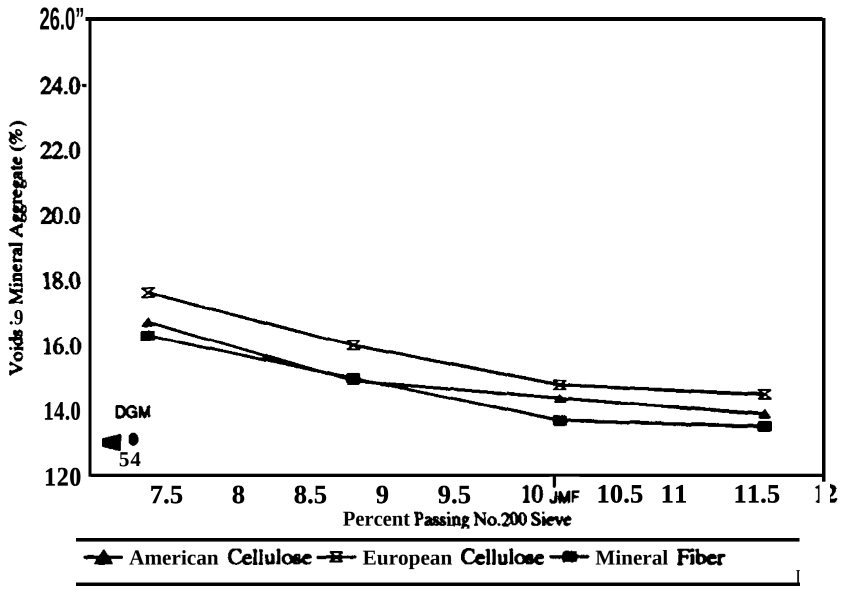

Figure 16b. VMA vs. percent passing No. 200 sieve for gravel aggregate.

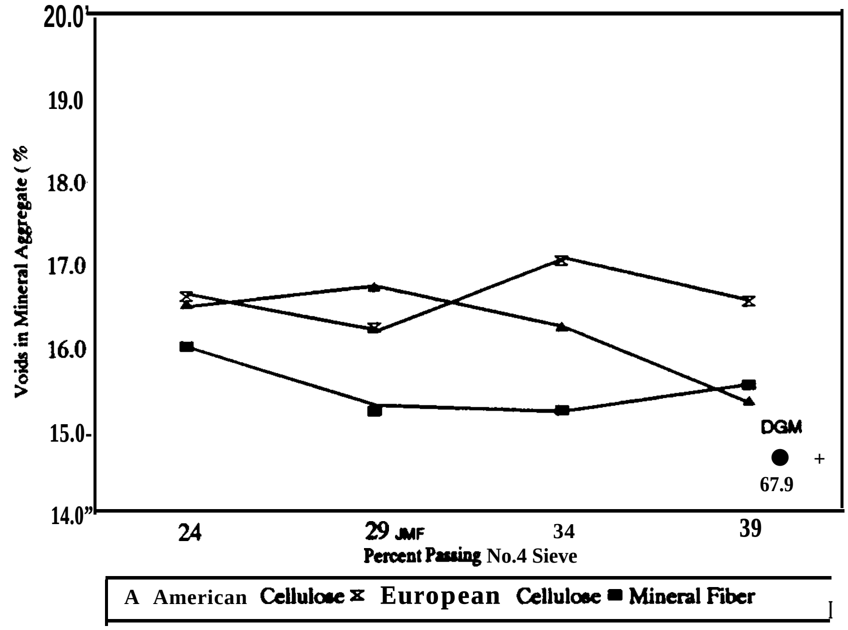

Figure 17a. VMA vs. percent passing No. 4 sieve for granite aggregate.

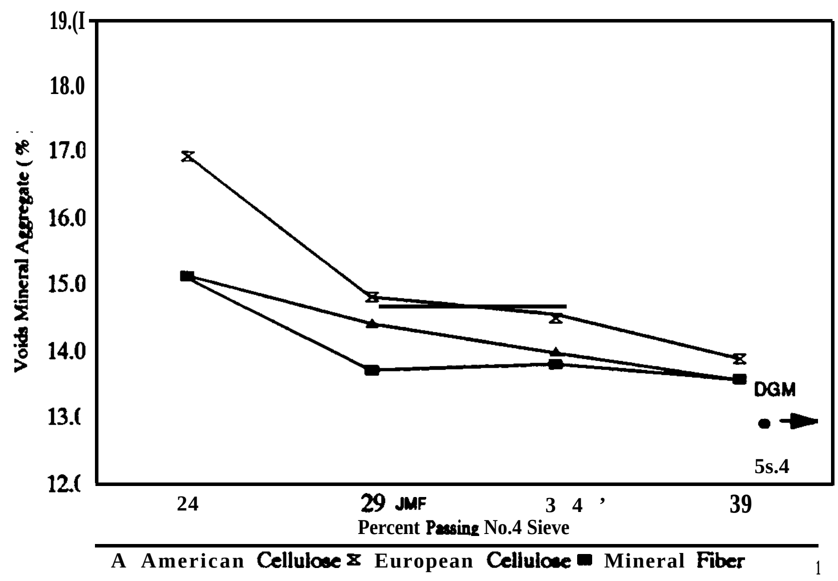

Figure 17b. VMA vs. percent passing No. 4 sieve for gravel aggregate.

GYRATORY SHEAR INDEX (GSI)

The Gyratory Shear Index (GSI) is a measure of the stability of an HMA mixture. The GSI has been shown to berelated to permanent deformation in dense graded mixtures and is likely related to permanent deformation for SMA mixtures. Typically, mixtures with values close to 1.0 are more likely to be stable than mixtures with GSI values greater than 1.0 (13). The GSI values for all mixtures evaluated in this study were 1.1 or below so there is no indication of instability problems (Tables 7-12).

GYRATORY ELASTO-PLASTIC INDEX (GEPI)

The GEPI is a measure of permanent deformation potential for dense graded mixtures. However, no criteria has been developed to predict the rutting potential for dense graded nor SMA mixes. Data has shown that higher GEPI values are an indication of lower mixture stability as shown in Tables 7-12. There is no general trend between GEPI and mixture proportions for the mixtures evaluated.

GYRATORY SHEAR STRESS

The Gyratory shear stress required to produce one degree angle is one important GTM property for evaluating the permanent deformation resistance. Previous work has indicated a relationship between rutting and shear stress to produce one degree angle for HMA (8). Higher shear stresses required to produce a one degree angle indicate a more stable mixture. Figures 18a and 18b show the trend for gyratory shear with changes in AC content. Higher AC contents slightly reduce the shear strength of the mix for both aggregates. This drop is to be expected but the only slight decrease indicates the high tolerance to changes in AC content for SMA mixtures.

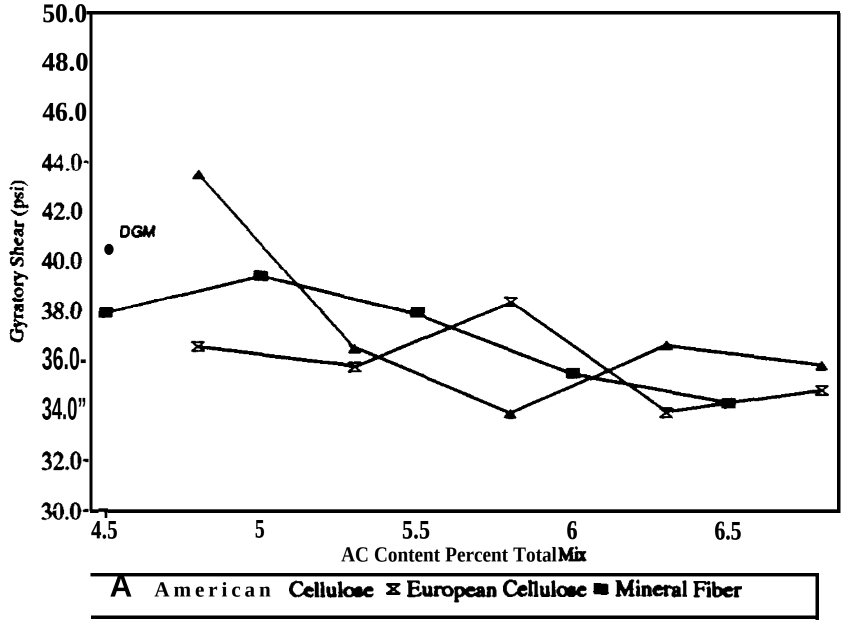

Figure 18a. Gyratory Shear vs. AC content for granite mixtures.

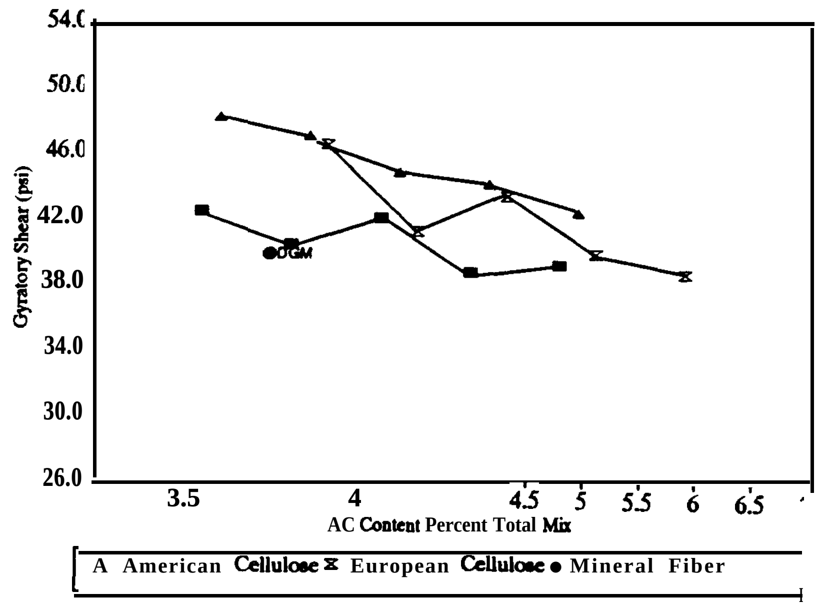

Figure 18b. Gyratory shear vs. AC content for gravel mixtures.

Figures 19a and 19b show the results for gyratory shear versus fiber content. An increase in fiber content appears to lower the shear strength for granite mixtures and has very little effect for gravel mixtures. Again the changes in shear stress are not sufficient to be of major concern. Hence the amount of fiber over the range investigated does not significantly affect shear strength of the SMA mixture.

Figures 20a and 20b show the results for gyratory shear versus percent passing the No. 4 sieve. The percent passing the No. 4 sieve appears to have little effect on the shear strength but a previous study (8) has shown that the SMA mixture becomes more sensitive to changes in the AC content at higher amounts passing the No. 4 sieve.

Figures 21a and 21b show the effect of percent passing the No. 200 sieve on shear strength. An increase in percent passing the No. 200 sieve for granite mixtures decreases the gyratory shear slightly while for gravel mixtures this increase in percent passing the No. 200 sieve increases the gyratory shear slightly. The reason for this difference in performance for the two aggregates is not clear.

MARSHALL STABILITY

The Marshall stability test, though extensively used to measure the stability of HMA, does not have a good correlation with the actual performance of HMA. However, it does help in evaluating the consistency and hence quality of dense graded mixtures (13). Figures 22a and 22b indicate that asphalt content has very little effect on the Marshall stability of SMA mixtures. The Marshall stability for SMA mixtures is significantly lower than that for dense graded mixtures. This is not an indication that dense graded mixtures are more stable than SMA mixtures but is an indication that Marshall stability may not be applicable for SMA. The quality of SMA mixtures is better controlled by the volumetric properties than by Marshall stability.

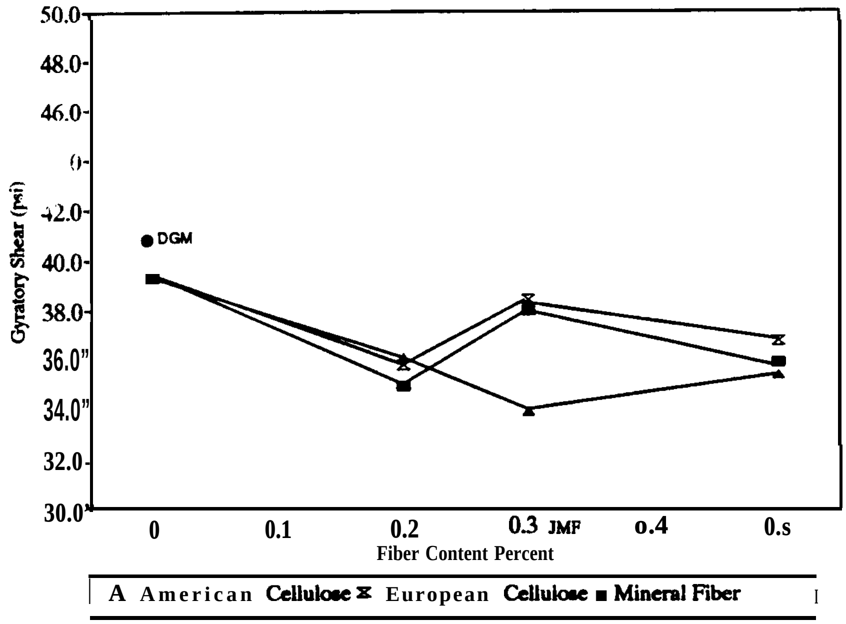

Figure 19a. Gyratory shear vs. Fiber content for granite mixtures.

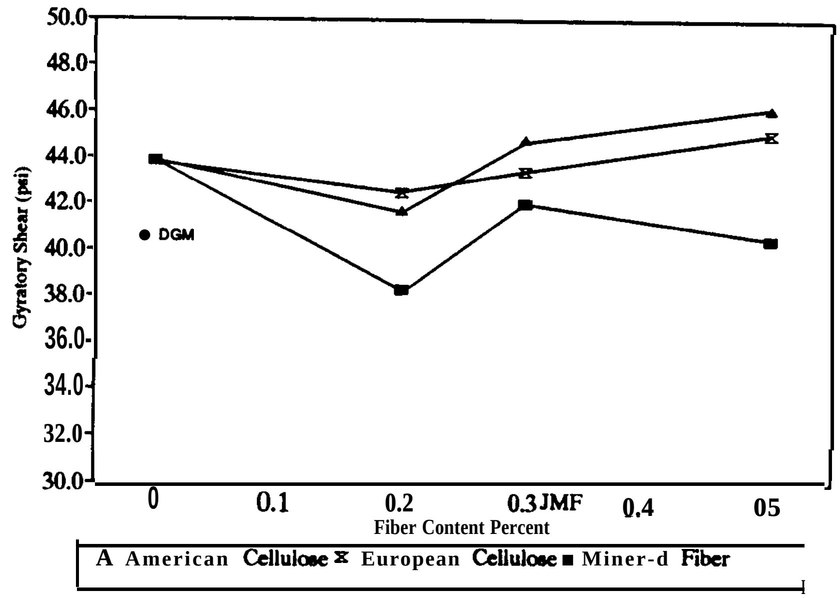

Figure 19b. Gyratory shear vs. Fiber content for gravel mixtures.

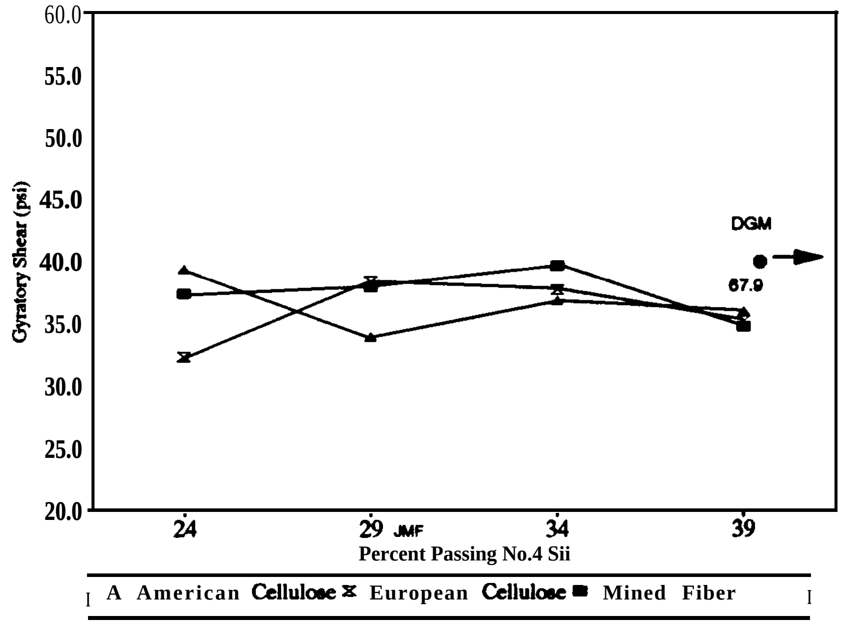

Figure 20a. Shear stress vs. percent passing No. 4 sieve for granite mixtures.

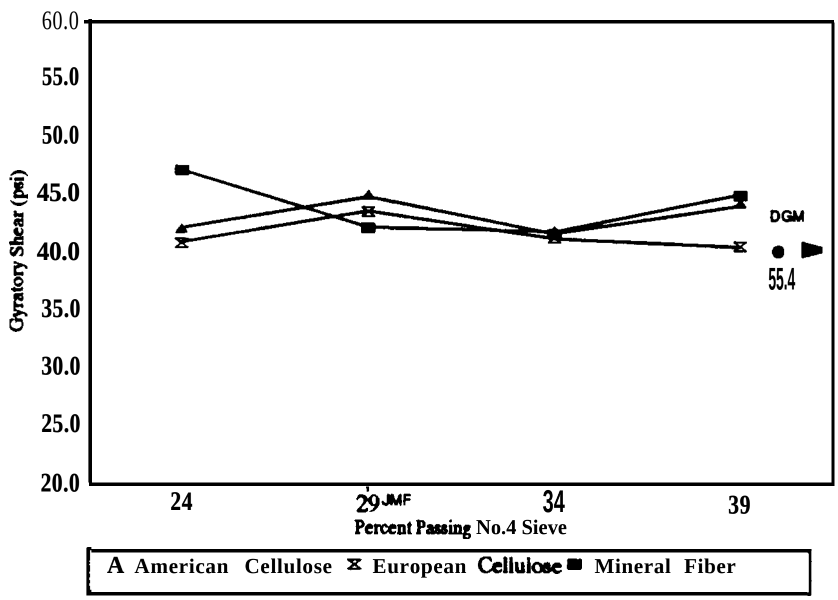

Figure 20b. Shear stress vs. percent passing No. 4 sieve for gravei mixtures.

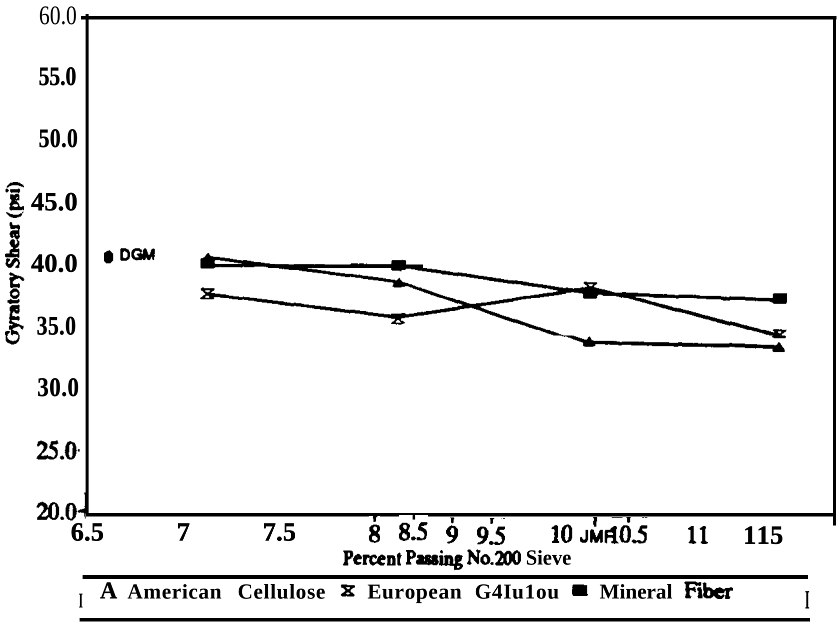

Figure 21a. Shear stress vs. percent passing No. 200 sieve for granite mixtures.

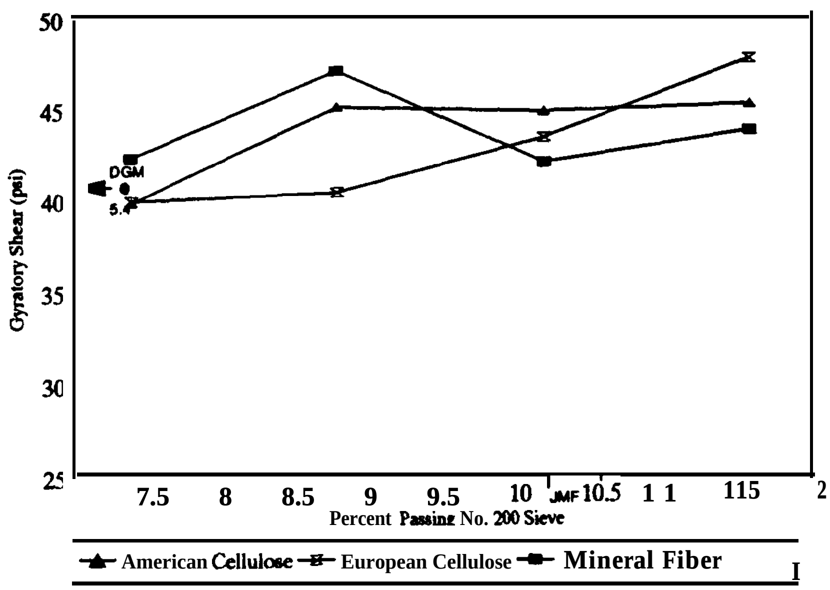

Figure 21 b. Shear stress vs. percent passing No. 200 sieve for gravel mixtures.

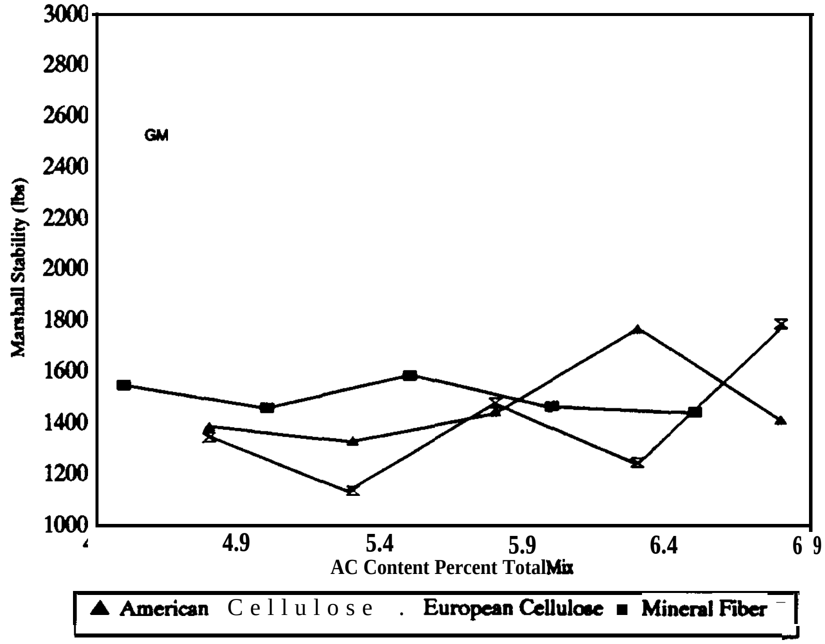

Figure 22a. **Stability** vs. AC content for granite mixtures.

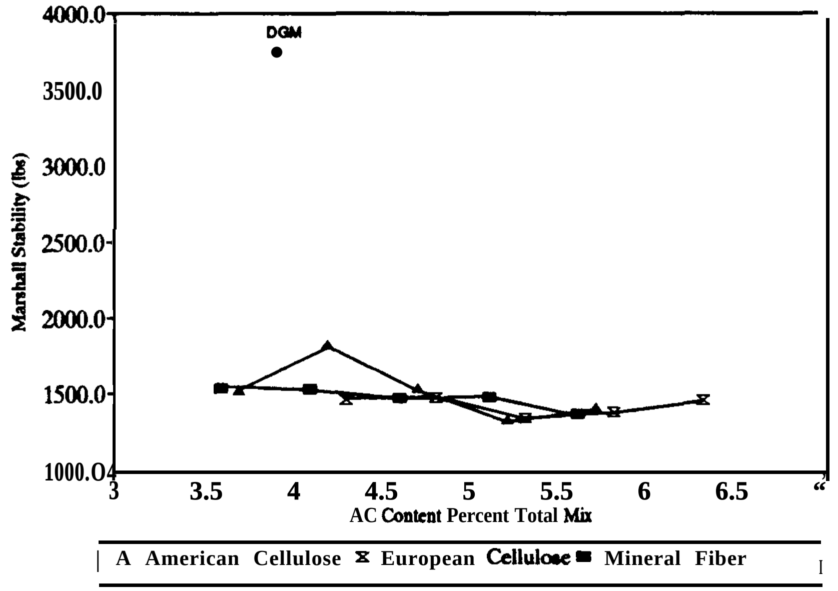

Figure 22b. **Stability** vs. AC content for gravei mixtures.

The relationship between fiber content and Marshall stability is shown in Figures 23a and 23b. These figures show that the Marshall stability for SMA mixtures is insensitive to fiber content.

Figures 24a and 24b show the effect of percent passing the No. 4 sieve on Marshall stability. The trend indicates that the Marshall stability for the SMA mixtures increases with increasing percent passing the No. 4 sieve.

Figures 25a and 25b show the effect of percent passing the No. 200 sieve on Marshall stability. As expected, an increase in percent passing the No. 200 sieve generally slightly increases the stability of SMA mixtures.

In summary, the Marshall stability is not very sensitive to changes in SMA mixture components. The Marshall stability value was always lower for SMA than for the control dense graded mixtures. The Marshall stability is not a good prediction of performance for SMA just as it is not with dense graded mixtures but very low stabilities may still be an indication of mixture problems as it is with dense graded mixtures.

FLOW

The flow value is a general indication of potential for permanent deformation in dense graded mixtures. A high flow value (greater than 16) usually is considered as an indication that the mixture may be unstable under traffic. Figures 26a and 26b show that asphalt content has very little effect on flow for SMA. This again shows that SMA mixture properties are not highly sensitive to changes in asphalt content. The flow of SMA mixtures is always higher than that for dense graded mixtures which may be an indication that the SMA mixtures are more flexible.

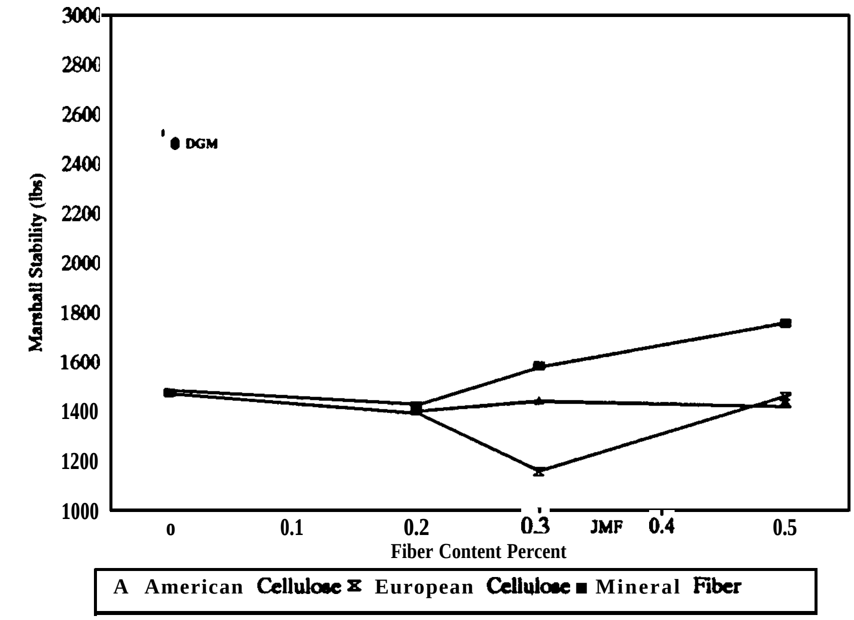

Figure 23a. Stability vs. Fiber content for granite mixtures.

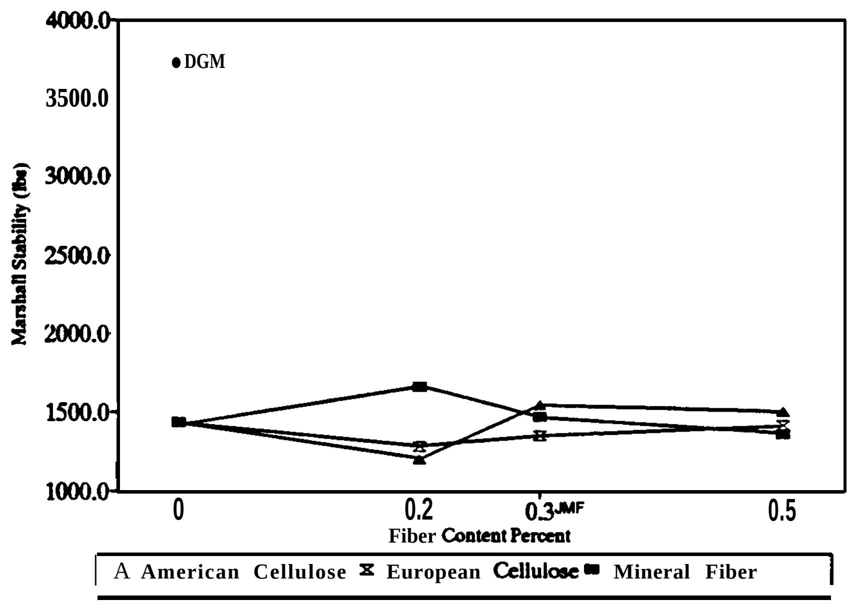

Figure 23b. Stability vs. Fiber content for gravel mixtures.

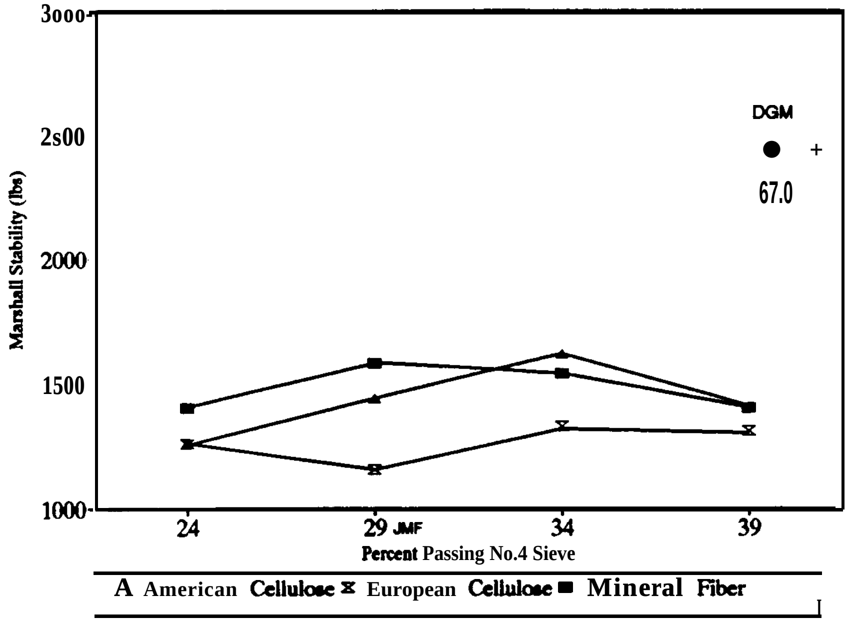

Figure 24a. Stability vs. percent passing the No. 4 sieve for granite mixtures.

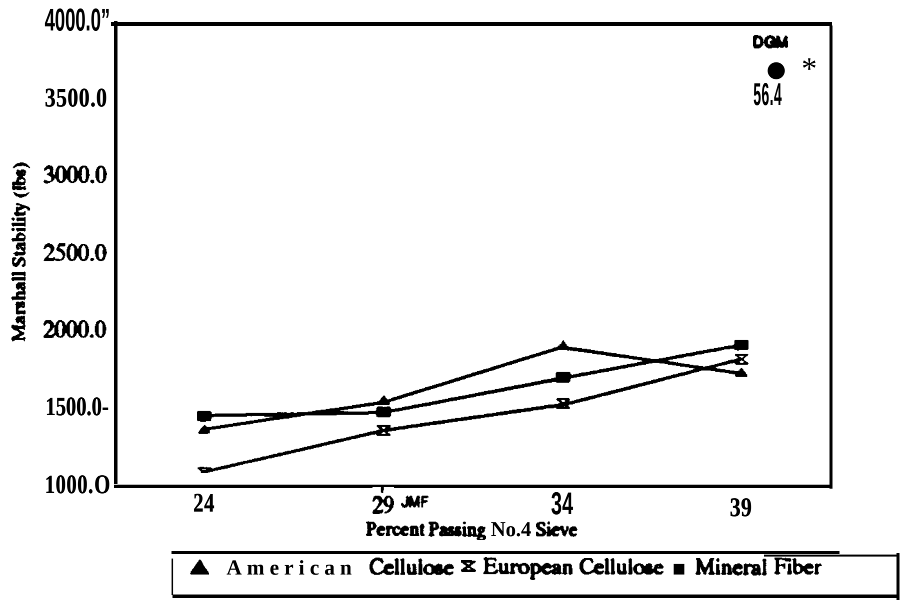

Figure 24b. Stability vs. percent passing the No. 4 sieve for gravel mixtures.

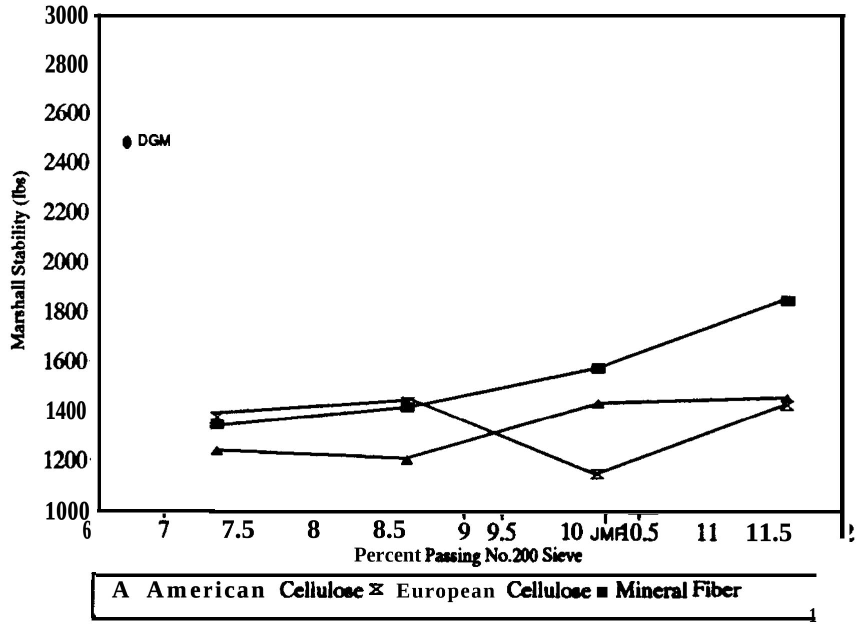

Figure 25a. Stability vs. percent passing No. 200 sieve for granite mixtures.

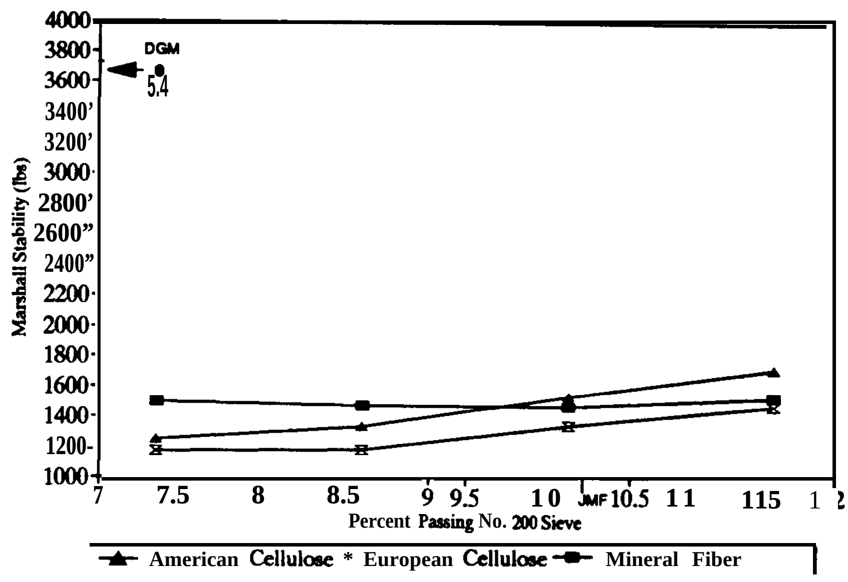

Figure 25b. Stability vs. percent passing No. 200 sieve for gravel mixtures.

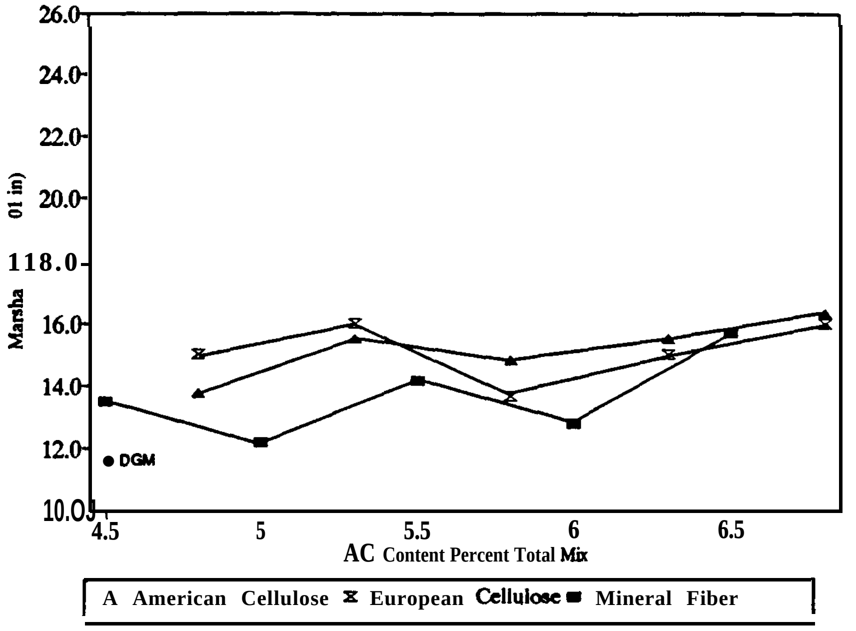

Figure 26a. Flow vs. AC content for granite mixtures.

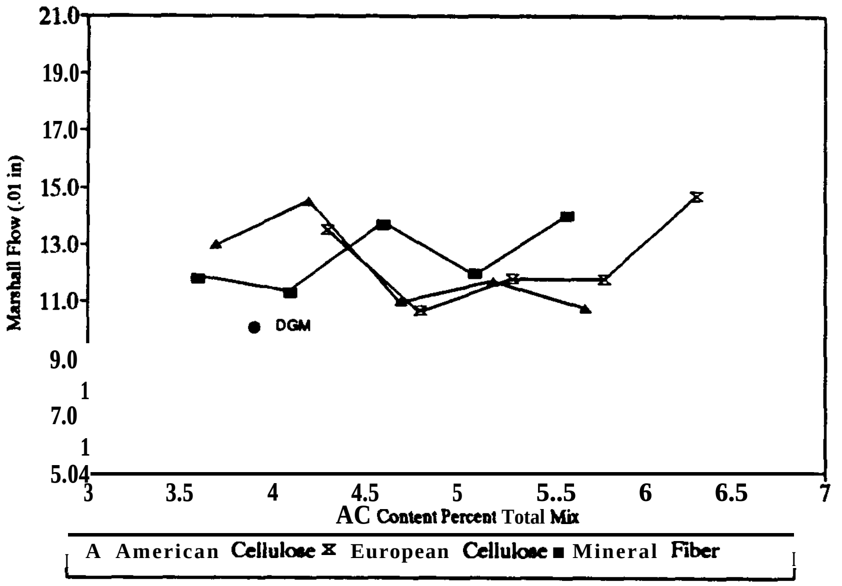

Figure 26b. Flow vs. AC content for gravel mixtures.

Figures 27a and 27b show the effect of fiber content on flow. The flow appears to decrease slightly at higher fiber content; however, there is a lot of scatter in the data resulting in no obvious trend being identified.

Figures 28a and 28b show the effect of percent passing the No. 4 sieve on flow. The trend indicates a reduction in flow for higher percents passing the No. 4 sieve. In all cases, the flow for the SMA mixtures is higher than that for the dense graded mixtures. The flow approaches that for dense graded mixtures as the percent passing the No. 4 sieve increases.

Figures 29a and 29b show the effect of percent passing the No. 200 sieve on flow. For the granite mixtures, the flow appears to increase to a point and then decrease with increasing amount of percent passing the No. 200 sieve. The trend for the gravel SMA mixtures was downward for increasing amounts of material passing the No. 200 sieve. As expected, an increase in percentage passing the No. 200 sieve tends to stiffen the binder generally resulting in a lower measured flow.

INDIRECT TENSILE STRENGTH

The indirect tensile test was measured at 77°F at a loading rate of 2 inches per minute. An increase in asphalt content resulted in a gradual increase in tensile strength (Figures 30a and 30b). Tensile strength is mostly a measure of the strength of the asphalt cement and an increase in the amount of asphalt cement may provide more cross sectional area of asphalt cement and therefore a higher measured strength. The tensile strength values of the SMA mixtures are always lower than that for the dense graded mixtures.

Figures 3 la and 3 lb show the effect of fiber content on indirect tensile strength. The trend in tensile strength is downward for increasing fiber content for the granite mixture, but no trend is apparent for the gravel mixtures. It seems logical that the addition of fiber would

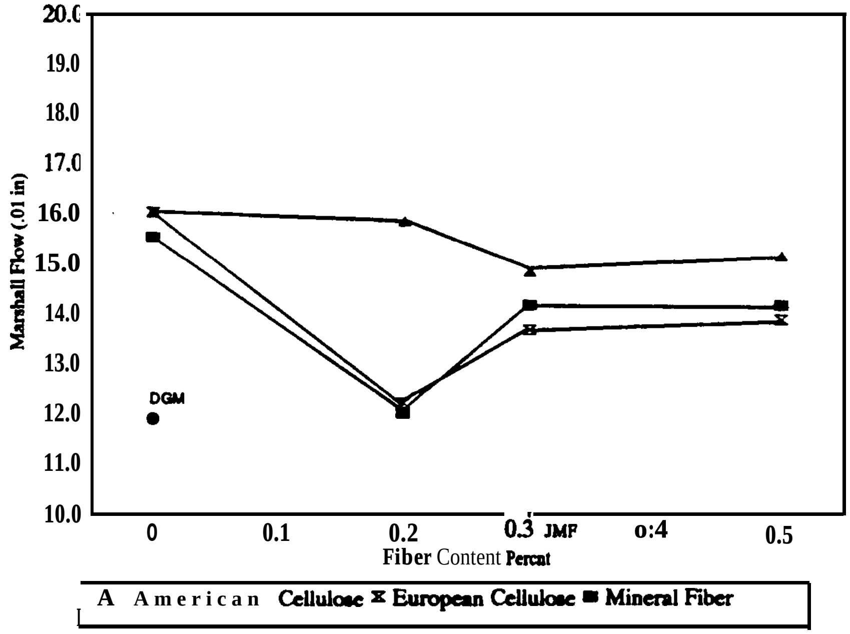

Figure 27a. Flow vs. Fiber content for granite mixtures.

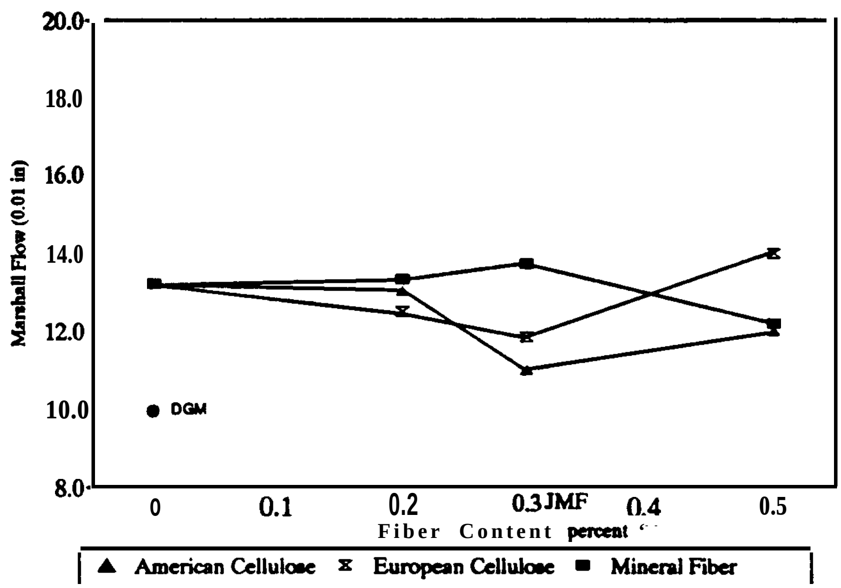

Figure 27b. Flow vs. Fiber content for gravel mixtures.

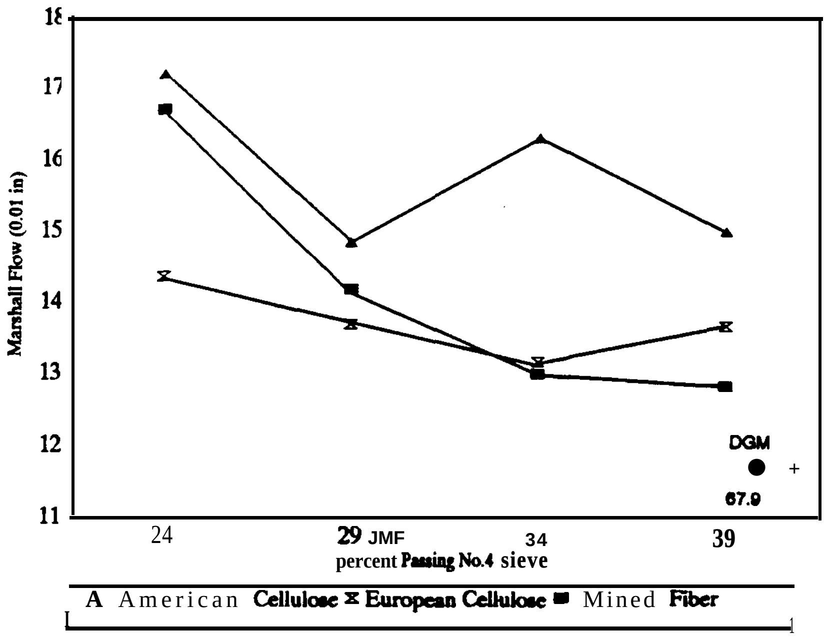

Figure 28a. Flow vs. percent passing No. 4 sieve for granite **mixtures.**

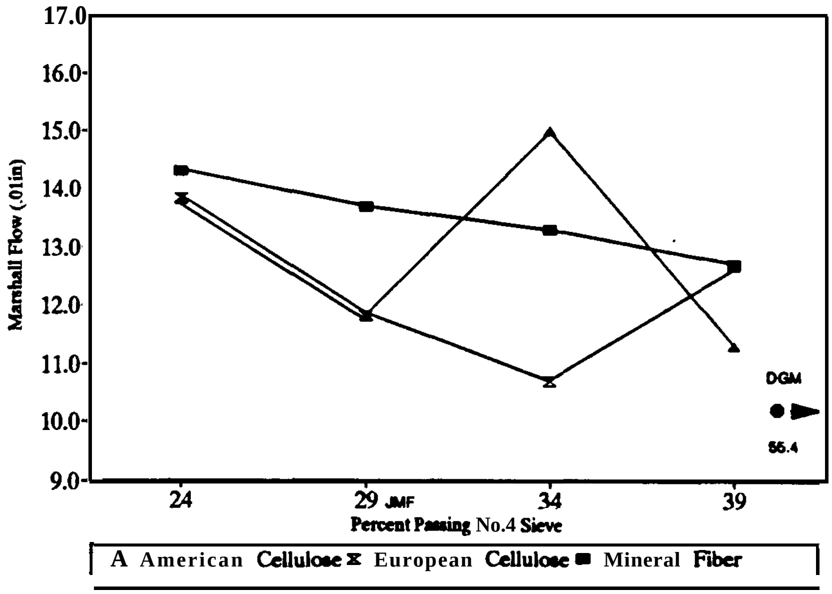

Figure 28b. Flow vs. percent passing No. 4 sieve for gravel mixtures

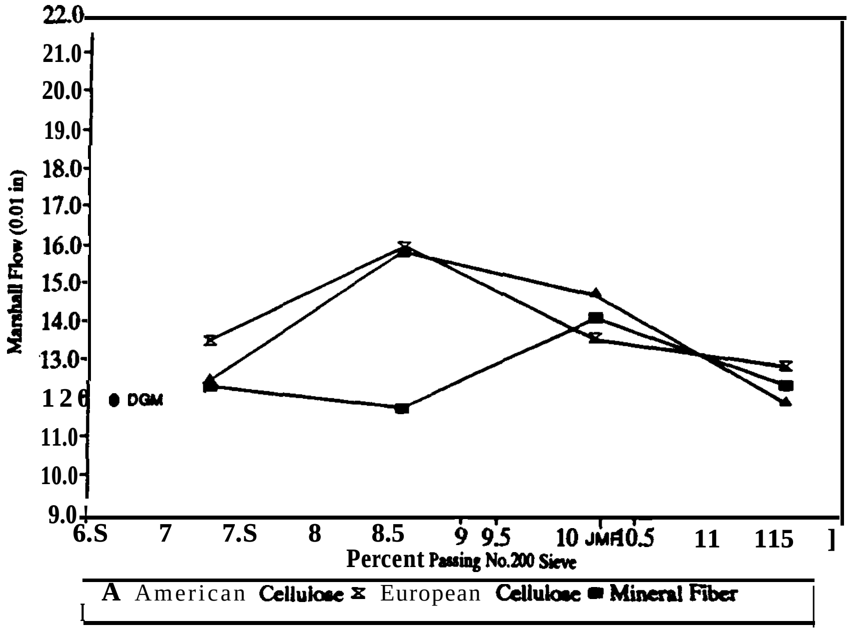

Figure 29a. Flow vs. Percent passing No. 200 sieve for granite mixtures.

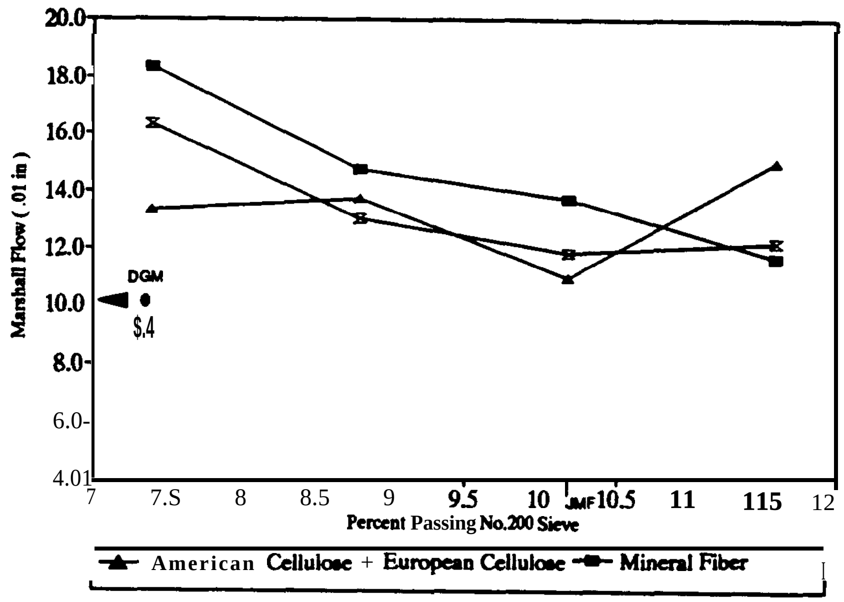

Figure 29b. Marshall Flow vs. percent passing No. 200 sieve for gravel mixtures

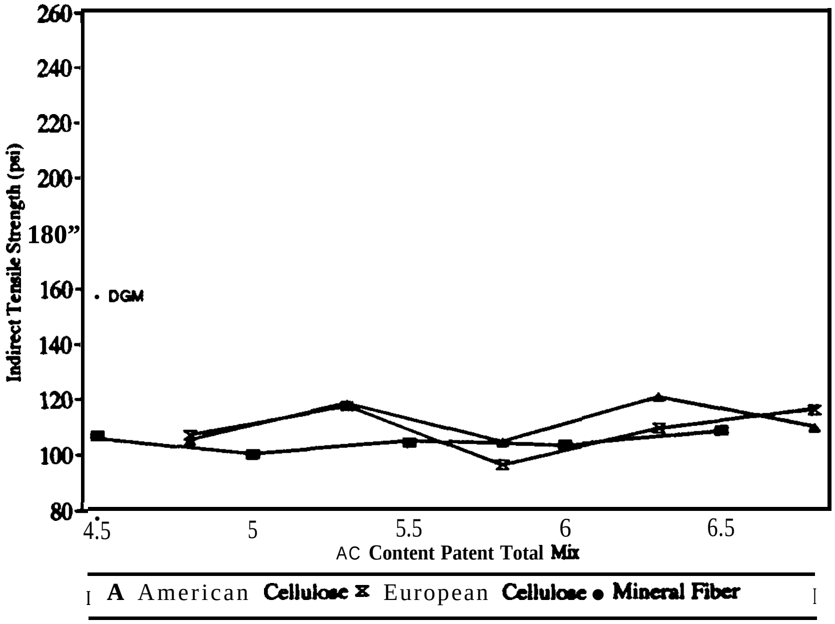

Figure 30a. Indirect tensile strength vs. AC content.

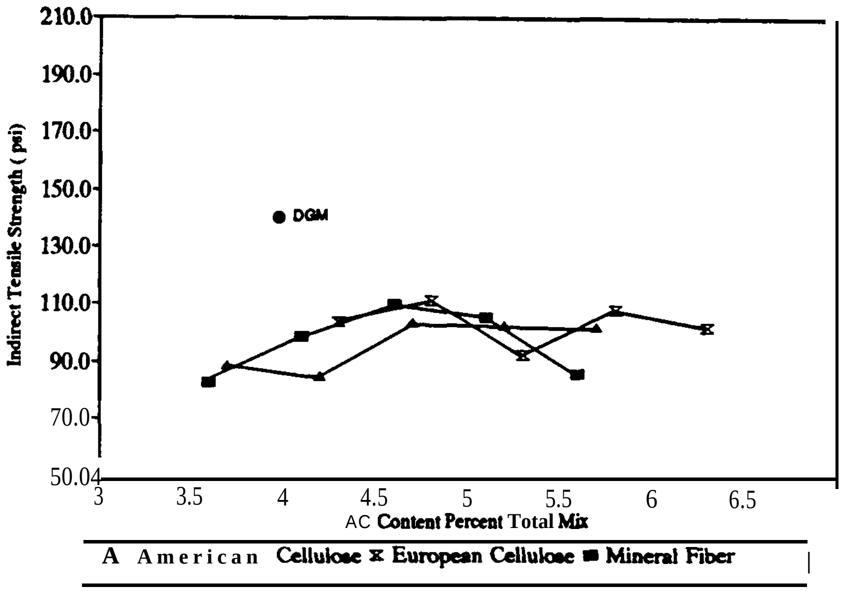

Figure 30b. Indirect tensile strength vs. AC content for gravel mixtures.

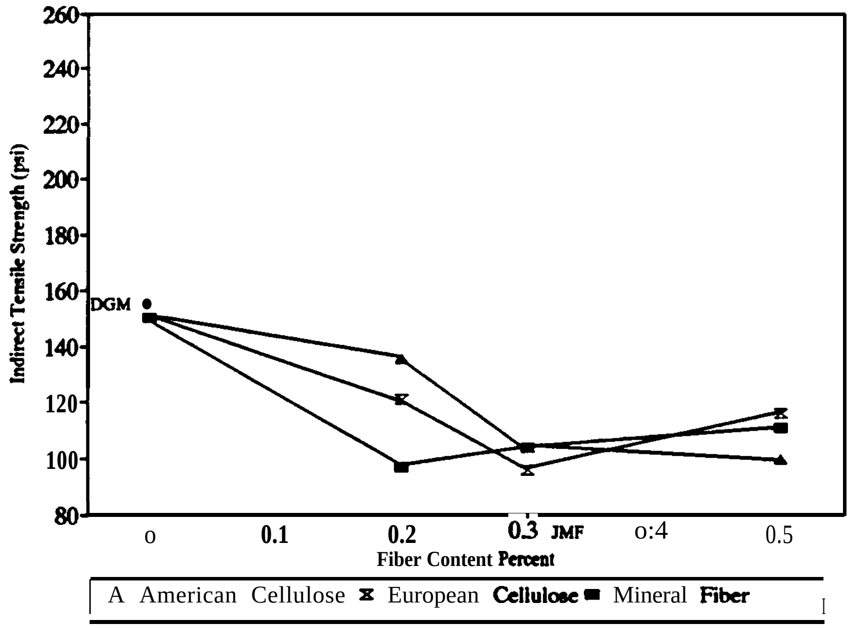

Figure 31a. Indirect tensile strength vs. Fiber content for granite mixtures.

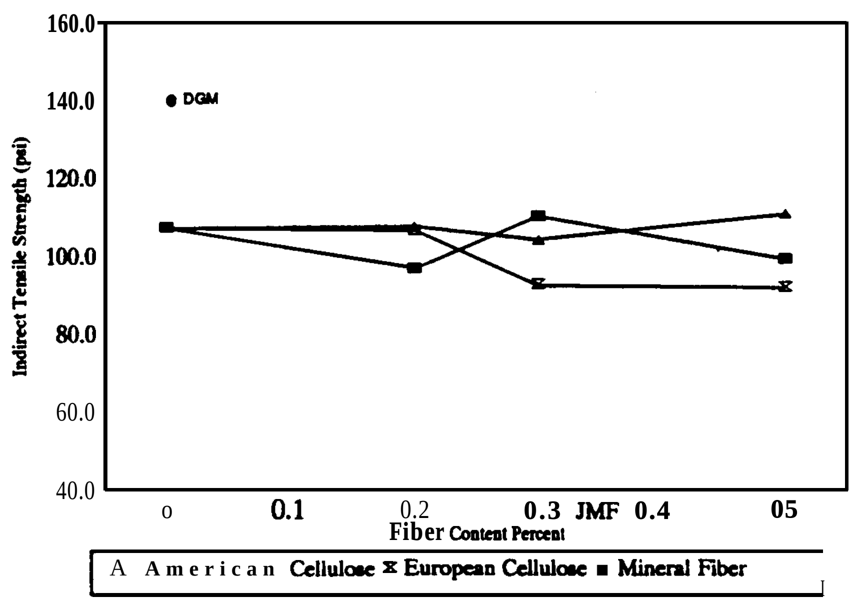

Figure 31 b. Indirect tensile strength vs. Fiber content for gravel mixtures.

increase the tensile strength but loss in density due to the increase in some fibers may have offset any reinforcing benefits of the fibers. There was not a loss in density when the mineral fibers were used however, the abrasion and possible partial breakdown of the fibers may have affected the results.

Figures 32a and 32b show the effect of percent passing the No. 4 sieve on tensile strength. There is considerable scatter in the data, but the trend indicates an increase in tensile strength with increasing amounts passing the No. 4 sieve. The tensile strength approaches that of the dense graded mixture as the percent passing the No. 4 sieve increases.

Figures 33a and 33b show the effect of percent passing the No. 200 sieve on tensile strength. The results indicate a slight increase in tensile strength for increasing amounts of material passing the No. 200 sieve. The material passing the No. 200 sieve likely stiffens the asphalt cement resulting in a higher measured strength.

RESILIENT MODULUS

There is no good correlation between M_R and rutting, but high M_R at low temperatures may result in low temperature cracking (13). The results of M_R testing for 40°, 77° and 104° F are provided in Tables 7-12.. The data does not show any significant trends, primarily due to the high variability, but the following general trends were observed. The variability of M_R for dense graded mixtures is high but appears to be even higher for SMA mixtures which may be caused by the larger stone content in the mixture. The SMA mixtures with granite aggregate typically had M_R values approximately equal to that of the dense graded mixtures. The SMA mixtures with gravel aggregate typically had M_R values lower than that of the dense graded mixtures.

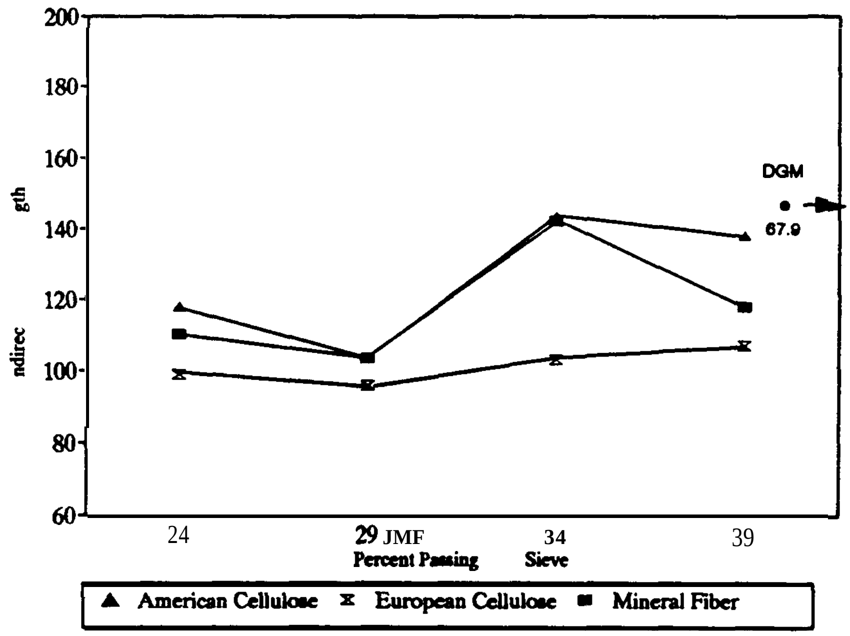

Figure 32a. indirect tensile strength vs. percent passing No. 4 sieve for granite mixtures

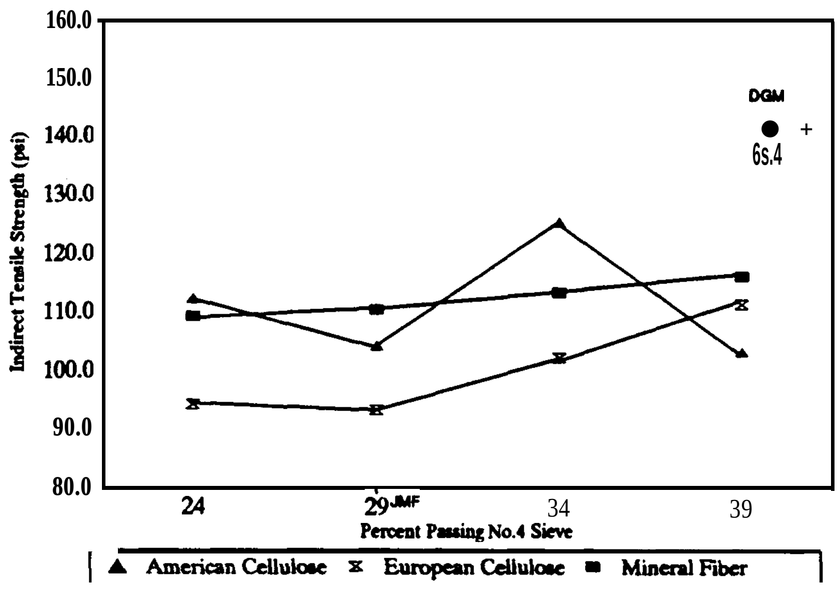

Figure 32b. Indirect tensile strength vs. percent passing No. 4 sieve for gravel mixtures.

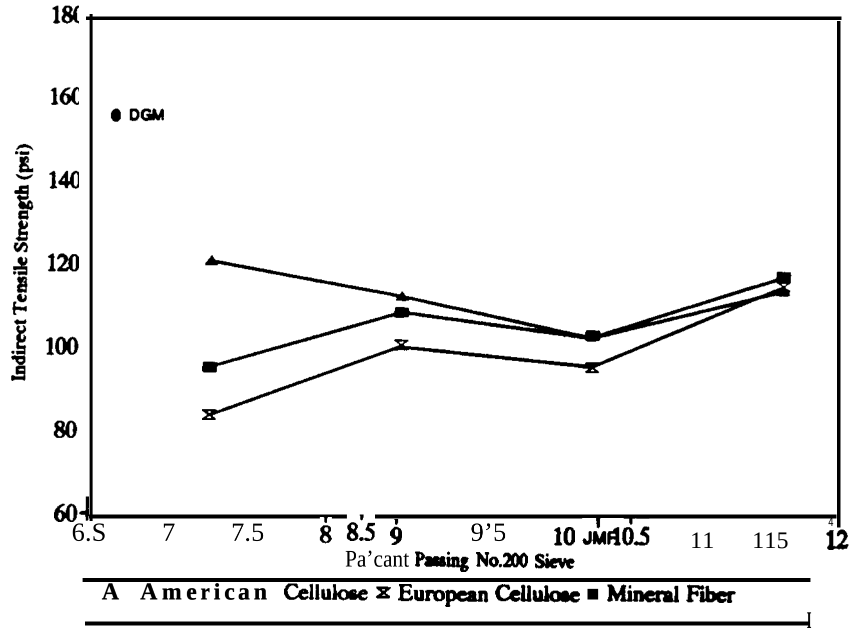

Figure 33a. Indirect tensile strength vs. percent passing No. 200 sieve for granite mixtures.

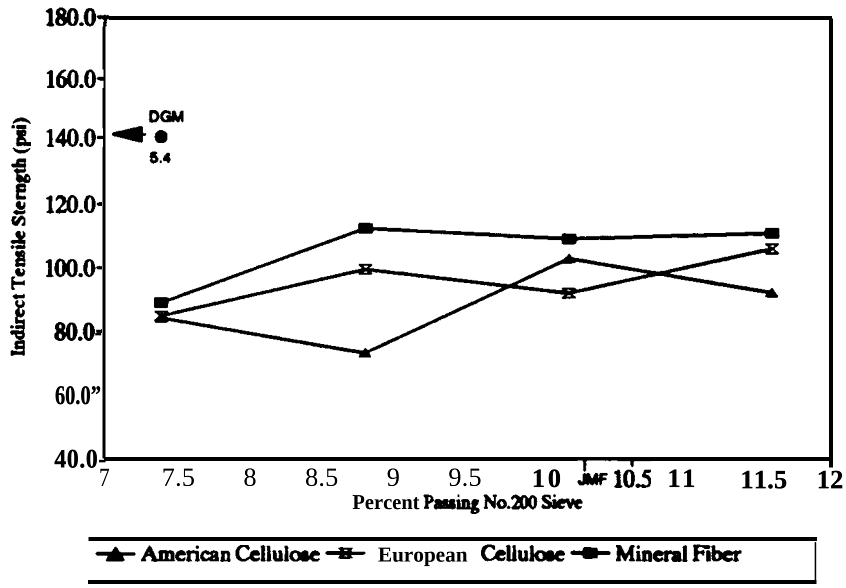

Figure 33b. Indirect tensile strength vs. percent passing No. 200 sieve for gravel mixtures.

STATIC CREEP

The static creep test was conducted on all the mixtures evaluated using the standard Marshall size samples. The tests were conducted with an applied stress of 120 psi, a confining pressure of 20 psi, and a temperature of 140°F. The creep stiffness is determined by dividing the normal stress by the creep strain. The total time of loading was one hour with 15 minutes allowed for rebound. The results are shown in Figures 34a-37b.

The static creep data for the granite-mineral fiber mixtures is not included in this report. The data was obviously in error and was discarded.

The creep was approximately equal for the SMA mixtures containing each of the three fibers and for the dense graded mixture. As expected, the creep typically increased slightly for increased asphalt content, however the increase was not great. Typically an increase in fiber content slightly increased the creep. The creep decreased with an increase in the percent passing the No. 4 sieve to a point then began to increase with an additional increase in the percent passing the No. 4 sieve (Figure 36a and 36b). This indicates that there might be an optimum percentage passing the No. 4 sieve.

PERMANENT DEFORMATION
("DYNAMIC CREEP")

The permanent deformation test was conducted on all mixtures using the standard Marshall size samples. The test applied 120 psi normal load and 20 psi confining pressure and was conducted at 140°F. This load was applied at one cycle per second at a temperature of 140°F. The load was applied for 0.1 second and removed for 0.9 second for each cycle. The permanent deformation modulus was determined by dividing the normal stress by the permanent strain. The total time of loading was one hour. The results are provided in Figures 38a-41b. The data shows that there is

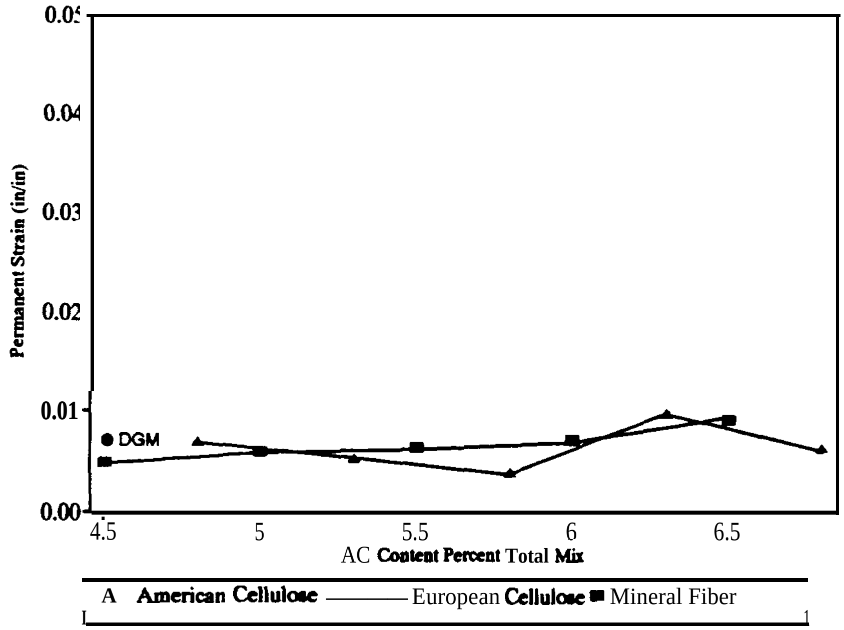

Figure 34a. Permanent Strain vs. AC content for granite mixtures (Static Creep).

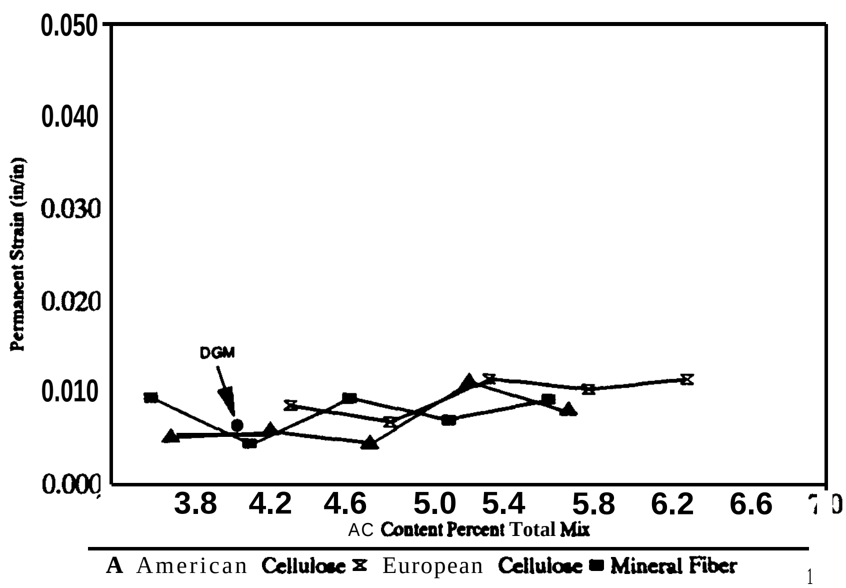

Figure 34b. Permanent Strain vs. AC content for gravel mixtures (Static Creep).

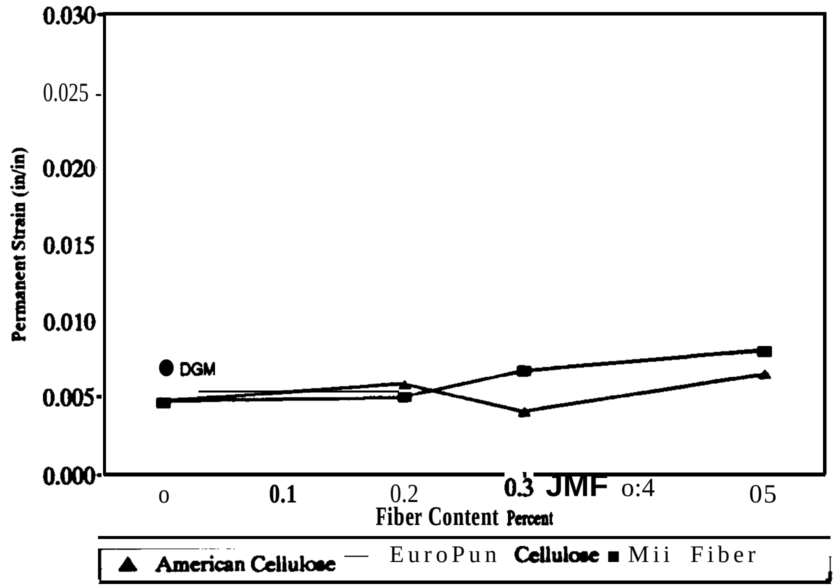

Figure 35a. Permanent Strain vs. Fiber content for granite mixtures (Static Creep).

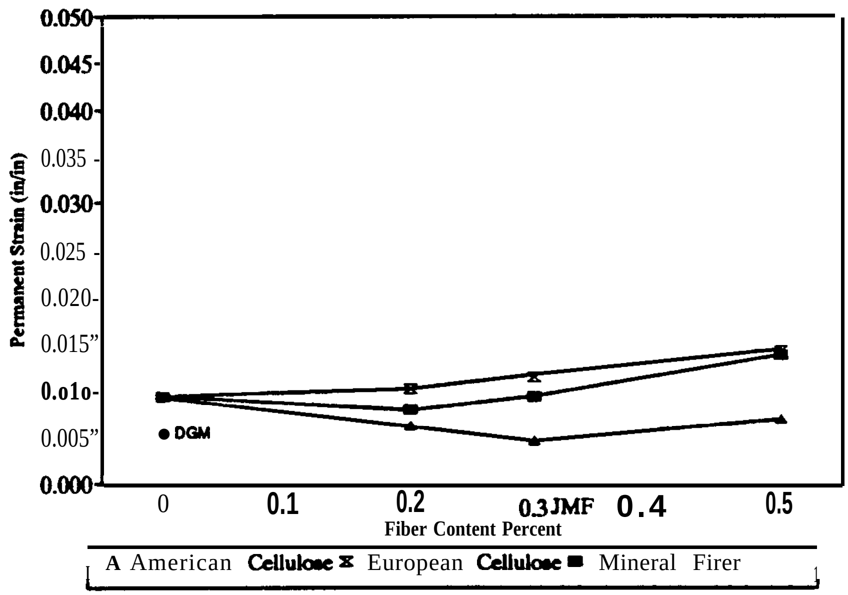

Figure 35b. Permanent Strain vs. Fiber content for gravel mixtures (Static Confined Creep).

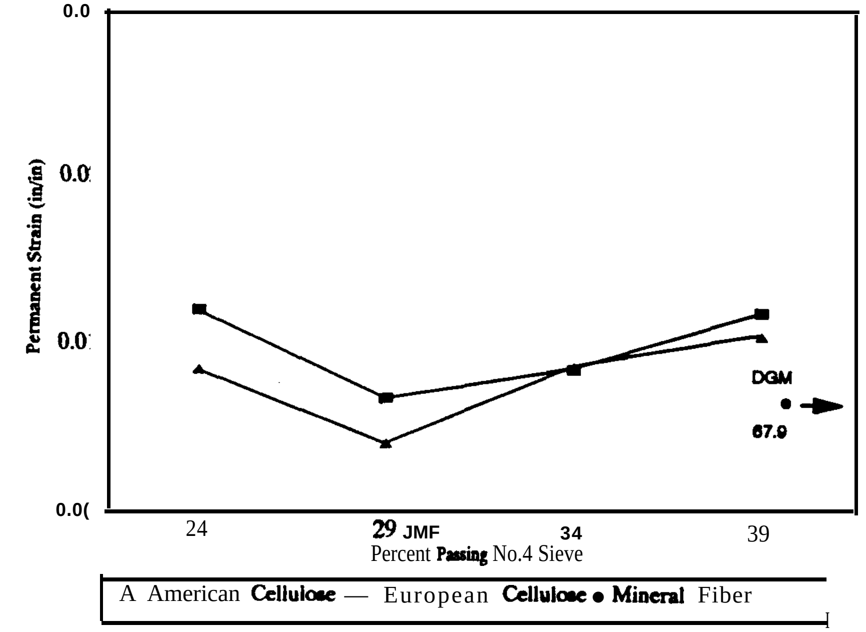

Figure 36a. Permanent Strain vs. percent passing No. 4 sieve for granite mixtures (Static Confined Creep).

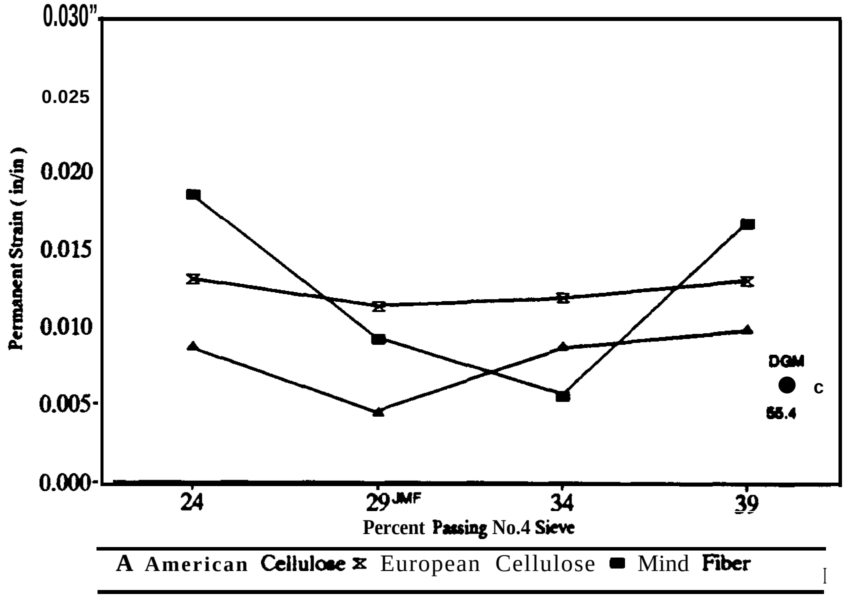

Figure 36b. Permanent Strain vs. percent passing No. 4 sieve for gravel mixtures (Static Confined Creep).

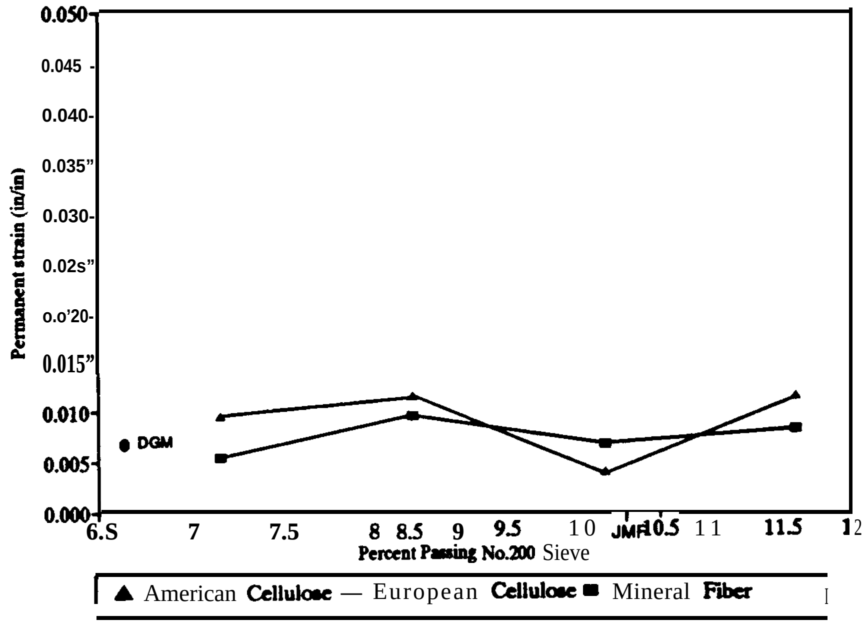

Figure 37a. Permanent Strain vs. percent passing the No. 200 sieve for granite mixtures (Static Confined Creep).

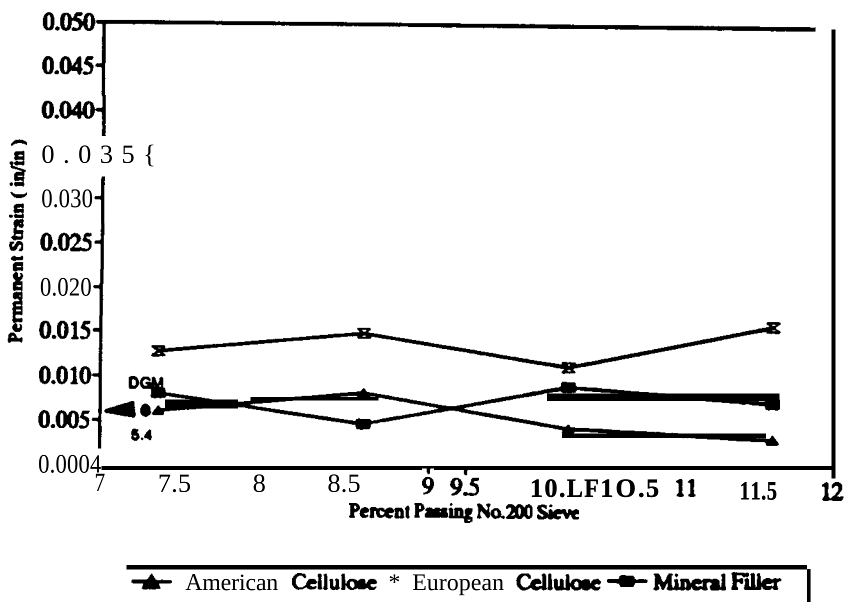

Figure 37b. Permanent Strain vs. percent passing No. 200 sieve for gravel mixtures (Static Confined Creep).

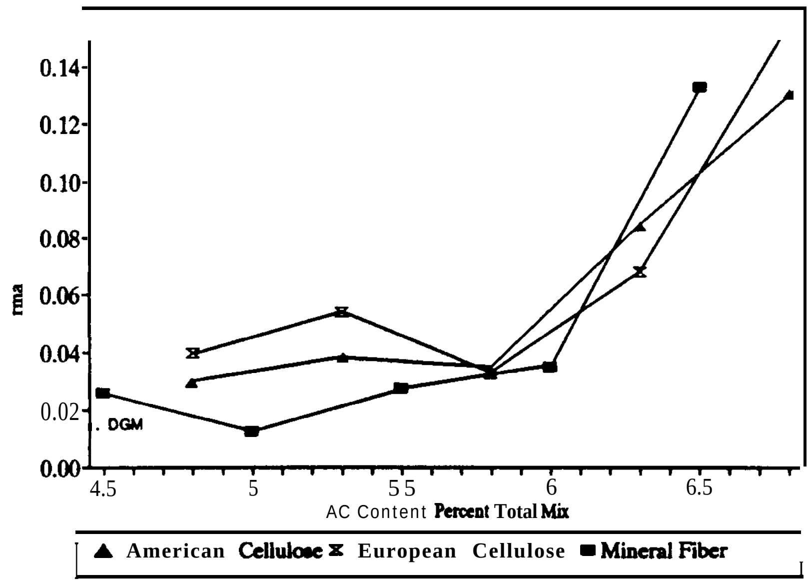

Figure 38a. Permanent Strain vs. AC content for granite mixtures (Dynamic Creep).

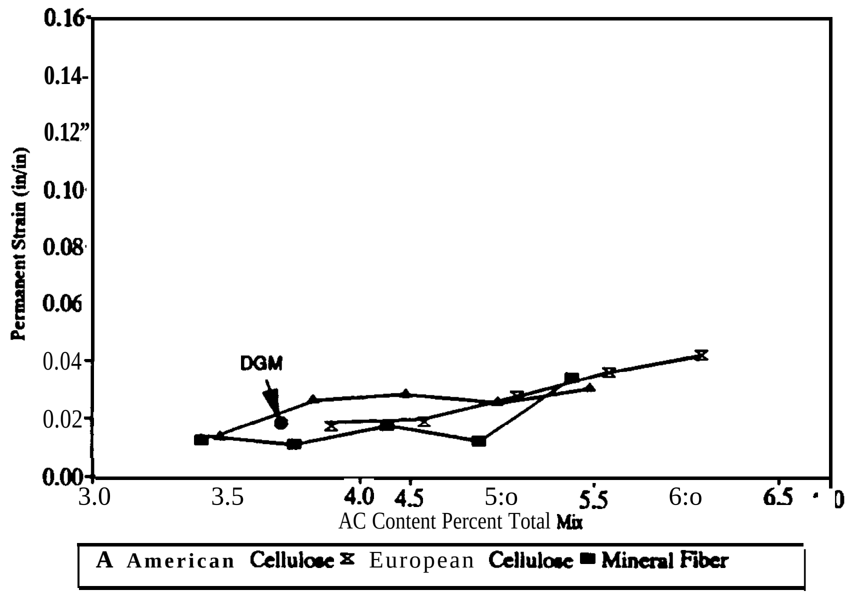

Figure 38b. Permanent Strain vs. AC content for gravel mixtures (Dynamic Creep).

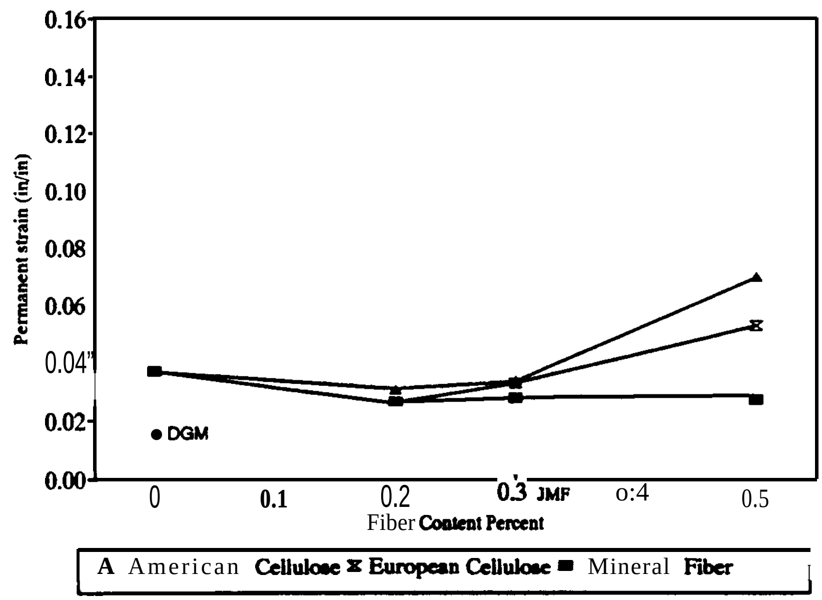

Figure 39a. Permanent Strain vs. Fiber content for granite mixtures (Dynamic creep).

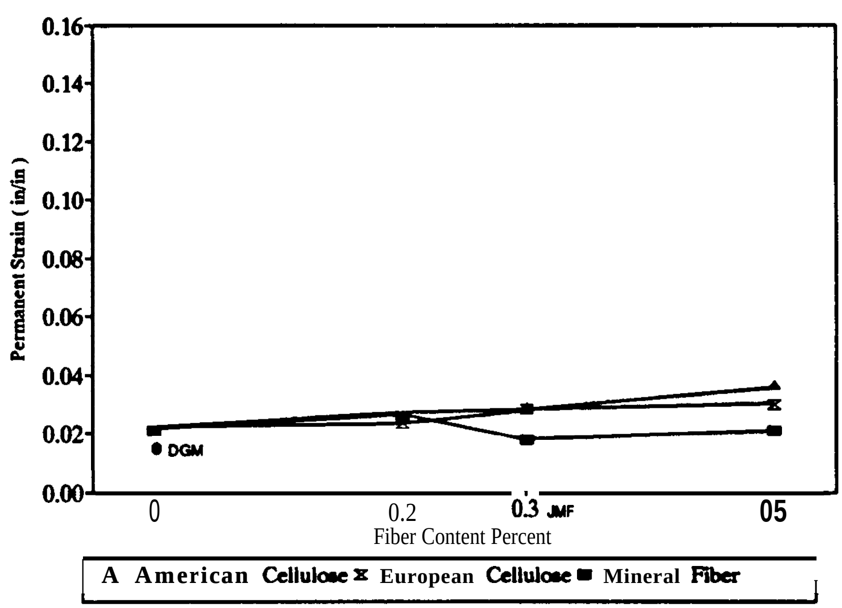

Figure 39b. Permanent Strain vs. Fiber content for gravel mixtures (Dynamic Creep).

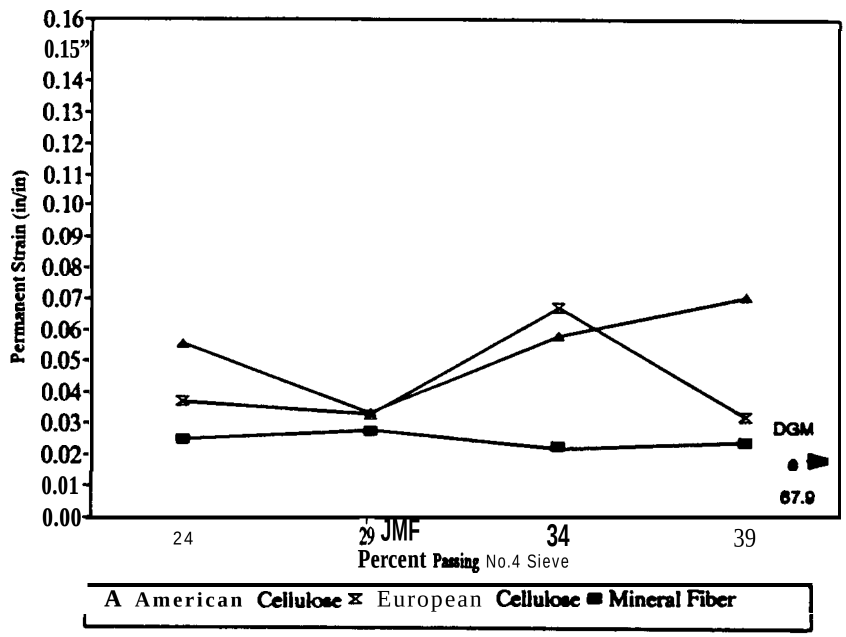

Figure 40a. Permanent Strain vs. percent passing No. 4 sieve for granite mixtures (Dynamic Creep).

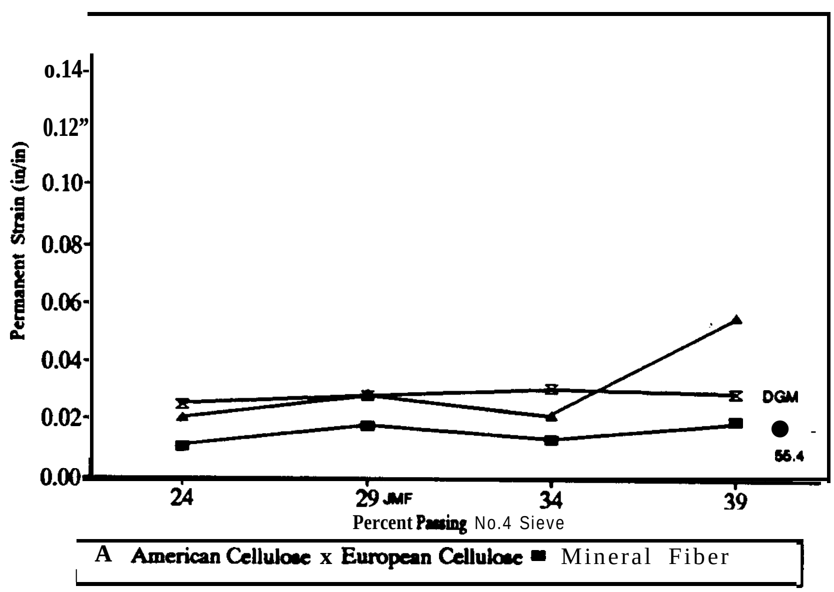

Figure 40b. Permanent Strain vs. percent passing No. 4 sieve for gravel mixtures (Dynamic Creep)

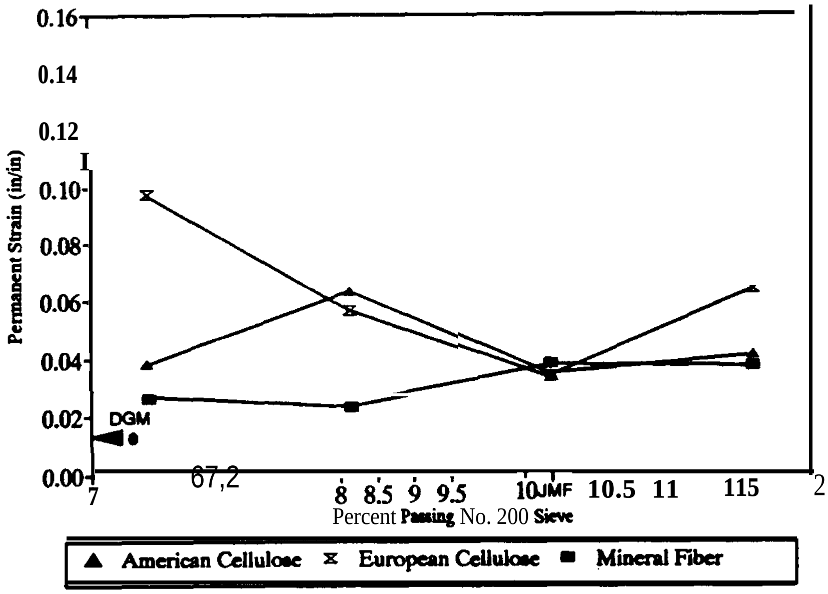

Figure 41a. Permanent Strain vs. percent passing No. 200 sieve for granite mixtures (Dynamic Confined Creep).

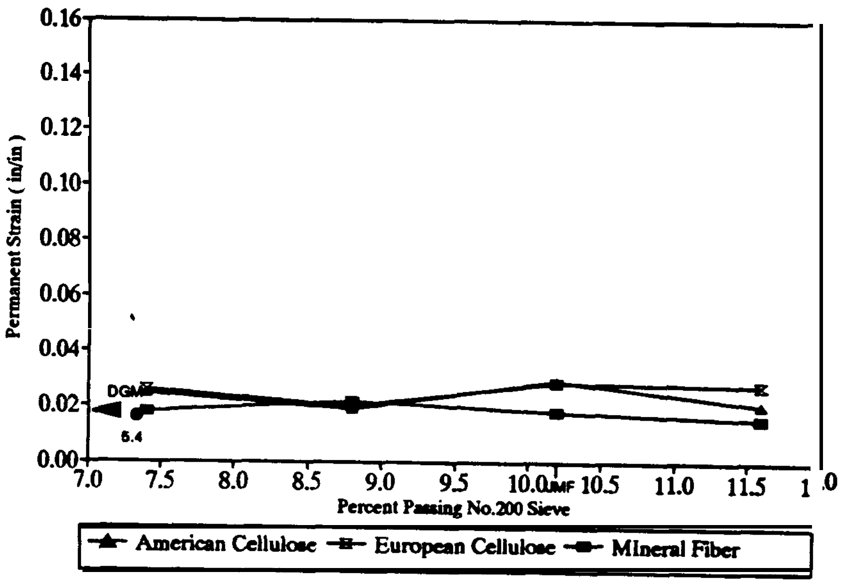

Figure 41b. Permanent Strain vs. percent passing No. 200 sieve for gravel mixtures (Dynamic Creep).

no significant difference in the test results for the three fibers. The measured creep in the SMA mixture is normally approximately equal or slightly higher than that of the dense graded mixture.

The data for the SMA granite mixtures (Figure 38a) shows that increasing asphalt content above 5.8 percent significantly increases the measured creep of the samples. There is a gradual increase in creep for increasing asphalt content for the SMA mixtures containing gravel (Figure 38b). Based on the VMA test results the gravel mixture likely had more stone-on-stone contact than the granite mixture. For this reason the gravel SMA mixture was likely less sensitive to increases in asphalt content. Only one of the gravel mixtures had an asphalt content above 6 percent which may not be high enough to see a significant increase in creep.

An increase in fiber content above 0.3 percent (Figures 39a and 39b) generally resulted in a slight increase in permanent deformation. An increase in the percent passing the No. 4 sieve also resulted in very little change in permanent deformation (Figures 40a and 40b). There is no clear trend in the effect of increasing the percent passing the No. 200 sieve on permanent deformation (Figures 41a and 41b)

EFFECT OF CHANGES IN AGGREGATE TYPE

As stated earlier, a silicious gravel and granite were used in the SMA mixtures evaluated. A comparison of the test results for granite and gravel SMA mixtures is shown in Table 13 for mixtures containing 24 percent and 29 percent passing the No. 4 sieve. These two gradations are typical of those being used for SMA.

The results indicate that the two aggregates have different VMA values. The gradation of the 2 aggregates may have to be different to meet the required VMA specifications if VMA is specified for SMA. For example, if the VMA requirement is set at 16 then the granite aggregate could have as high as 29 percent passing the No. 4 sieve and meet the requirements, however, the gravel aggregate could have no more than 24 percent or possibly lower passing the No. 4 sieve.

Table 13. Comparison of SMA mixtures with silicious Gravel and Granite aggregates.

	Amerioan Cellulose		European Cellulose		Mineral Fiber	
	Gravel	Granite	Gravel	Granite	Gravel	Granite
29% passing No. 4 sieve						
Asphalt Content	4.7	5.0	5.3	5.8	4.6	5.5
Air Voids	3.6	3.5	2.7	3.0	3.3	2.5
VMA	14.4	16.7	14.8	16.2	13.7	15.2
Stability	1544	1437	1346	1153	1472	1579
Flow	11	15	12	14	14	14
Tensile Strength	104	104	93	96	110	104
M_R@40	1197	1506	1914	2131	1902	2058
M_R@77	196	374	235	305	245	316
M_R@104	63	151	56	73	62	105
Static Creep Modulus	26667	36386	10619	-	13043	32894
Dynamic Creep Modulus	4110	3818	4211	3828	6678	4409
Shear Strength	44.8	33.85	43.4	38.33	42.0	37.9
24% passing No. 4 sieve						
Asphalt Content	5.0	5.7	5.9	5.5	5.0	5.8
Air Voids	3.7	3.5	3.4	4.3	3.7	2.6
VMA	15.1	16.5	16.9	16.6	15.1	16.0
Stability	1351	1260	1075	1259	1435	1400
Flow	14	17	14	14	14	17
Tensile Strength	112	118	94	99	109	110
M_R@40	1557	2463	1404	1803	1900	1258
M_R@77	230	342	201	405	253	354
M_R@104	51	81	46	86	60	63
Static Creep Modulus	13793	18415	9231	—	6486	10294
Dynamic Creep Modulus	5797	2693	4790	3129	11215	5233
Shear Strength	41.9	39.3	40.7	32.2	46.9	37.3

The aggregate type does not appear to affect the Marshall Stability for these mixtures, but it does appear to affect the flow (average flow for gravel equals 13 and for granite equals 15). This higher flow for granite aggregate is likely the result of higher optimum asphalt contents for the granite mixture. The average optimum asphalt content for the gravel SMA mixture is 5.2 percent and for the granite SMA mixture the average is 5.7 percent. So the gradation and aggregate type have a significant effect on the optimum asphalt content and ultimately on the durability. Both of these mixtures fail to meet the desired 6.0 percent minimum asphalt content. This could have been met by decreasing the void requirements to 3.0 percent and/or by decreasing the percent passing the No. 4 sieve.

The aggregate type does not have a significant effect on tensile strength. This is probably affected more by asphalt cement type than aggregate type. The data appears to indicate that the tensile strength is lower for mixtures with European cellulose but there is not sufficient data for a detailed statistical analysis.

The resilient modulus is almost always higher for the granite aggregate than for the gravel. The percent difference appears to be largest at 77°F and 104°F. It is not clear why the resilient modulus for granite aggregate is larger than that for gravel. It was assumed that the resilient modulus and indirect tensile strength would show similar results; however, the aggregate type appears to affect resilient modulus but not tensile strength.

In most cases, the static creep modulus is higher for the granite (10294-38386 psi) than for the gravel mixtures (6486-26667 psi). However, the dynamic creep modulus is higher for the gravel mixtures (4110- 11215 psi) than for the granite mixtures (2693-5233 psi). It is not clear why the two types of creep tests provide different results. However, past work has indicated that mixtures with slightly high AC have a tendency to perform better than slightly lean mixes in the static creep test. The granite mixture generally had the higher AC.

The shear strength measured during compaction with the gyratory machine is always higher for the gravel mixture (40.7-46.9 psi) than for the granite mixture (32.2-39.3 psi) which also compares with the results with the dynamic creep modulus.

The results indicate that the mixes with 24 percent passing the No. 4 sieve on the average have higher VMAs, lower stabilities, higher flows, higher tensile strengths, similar resilient moduli, lower static creep moduli, similar dynamic creep moduli, and similar shear strengths when compared with mixtures having 29 percent passing.

CONCLUSIONS

Theprirnary purpose of this report was to develop a database of information on SMA mixtures. Gradation, asphalt content, aggregate type, fiber type, and fiber quantity were varied to help evaluate the effect of these variables on the laboratory properties of SMA. This study was intended to provide information that would validate the recipes now used in Europe for production of SMA and provide data to indicate why these recipes are successful.

Field studies have shown SMA mixtures to provide excellent performance so a laboratory study to verify the performance of SMA is not needed. However, there is a need to determine which laboratory tests are able to predict the quality of SMA. That was the goal of this study.

SMA mixtures did not perform as well as the dense graded mixtures on many of the tests. For example stability was lower, flow was higher, and resilient modulus was lower for SMA. This does not mean that SMA will not perform as well as a dense graded mix but means that the tests are either not applicable to SMA or the limits for the test results should be adjusted. Some of the tests did show SMA to perform equal to or better in some cases than the dense graded mixtures. These tests which include gyratory shear, confined creep, and permanent deformation (dynamic creep) will likely be more accurate in predicting the performance of SMA,

Most of the mixtures evaluated in this study would not meet the present requirements for SMA because of the low optimum asphalt content, When this study began most SMA projects were being constructed with a mixture having more than 30 percent of the aggregate passing the No. 4 sieve. This study showed for the two aggregates investigated that the percent passing should be below 30 percent and maybe below 25 percent. The results are still applicable in evaluating the effect of changes in mixture proportions on properties of SMA mixtures.

The following specific conclusions can be made from these test results.

1. SMA mixtures using mineral fiber will typically have lower optimum asphalt content and lower VMA than SMA mixtures containing cellulose. All the SMA mixtures had higher VMA values than the dense graded mixtures. This is necessary for SMA so that a sufficiently high asphalt content can be added to provide for improved durability.
2. Increasing the fiber content of SMA mixtures results in a slight increase in VMA which allows for a slightly higher optimum asphalt content.
3. Changing the percent passing the No. 200 sieve or No. 4 sieve for the SMA mixtures results in a significant change in VMA. This indicates that close control of gradation is necessary during production to insure a satisfactory product. Increasing the percent passing the No. 200 sieve will fill the voids in the mastic to a point and then begin to push the aggregate apart. Increasing the percent passing the No. 4 sieve will fill the voids in the coarse aggregate matrix to a point and then begin to increase the voids in the coarse aggregate.
4. The shear strength of SMA mixtures only decreases slightly with increasing asphalt content. This indicates some tolerance for SMA to AC changes. The shear strength of the SMA mixtures ranged from slightly lower to slightly higher than that for the dense graded mixtures.
5. The Marshall stability of SMA mixtures was always significantly lower than that for dense graded mixtures. This indicates that the Marshall stability requirements should be lowered for SMA or the test should be deleted from the specifications. The stability of SMA mixtures increased with increasing amounts of materials passing the No. 4 and No. 200 sieve. This lower Marshall stability for SMA does not indicate a lack of stability in SMA

mixtures but instead indicates a lack of the Marshall stability test to actually measure the mixture stability.

6. The measured flow was higher for SMA mixtures than for dense graded mixtures. This is an indication that the SMA mixture is more flexible than dense graded mixtures.

7. The indirect tensile strength of SMA mixtures was always lower than that for dense graded mixtures. The tensile strength of the mixture is not as important as the tensile strain at failure. Future work should evaluate the tensile strain at failure to better evaluate the potential of SMA mixtures to provide good performance. The strain at failure was not measured in this study.

8. The resilient modulus of SMA mixtures was typically lower than that for dense graded mixtures. This simply means that SMA is not as stiff in tension as a dense graded mixture. Ideally mixtures should be flexible in tension and stiff in compression or shear. The variability of the resilient modulus values for SMA was high.

9. The permanent deformation of the SMA determined from the static creep test had values approximately equal to that of the dense graded mixtures.

10. The dynamic permanent deformation tests showed that the SMA mixtures usually had slightly higher permanent strain values than the dense graded mixtures. However, previous studies have shown that SMA mixtures are less sensitive to a small decrease in air voids thus SMA is less affected by variations in mixture proportions.

11. Generally speaking, all three fibers produced SMA mixtures that should provide satisfactory performance. Changes in aggregate gradation, fiber type and fiber content did not greatly affect the mechanical properties when the optimum asphalt content for each mixture was used. Some of these changes would likely affect the draindown of asphalt cement during construction, but draindown was not evaluated in this study.

12. SMA mixtures have proven to provide good performance in Europe and have shown promise in the U.S. The data developed within this report indicates the range of test results to expect with standard U.S. tests for SMA mixtures. These results should be helpful in setting criteria for SMA mixtures or for identifying areas where new tests may be needed. The data in this report can not be used to compare performance of SMA mixtures to that of dense graded mixtures but can be used to help establish tests to be specified and criteria for these tests. The comparison of performance for SMA and dense graded mixtures must be done in the field for a significant amount of time.

RECOMMENDATIONS

This study looked at the effect of fibers, gradation, asphalt content, and aggregate type on the mechanical properties of SMA mixtures. The fibers have very little effect on the mechanical properties however, the primary purpose of the fibers is to prevent draindown of these rich asphalt mixtures during construction. Additional work needs to be performed to evaluate the effect of various types of fibers and polymers on asphalt cement draindown.

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