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INTRODUCTION

Background

Stone Matrix Asphalt (SMA) has proven to be a rut resistant and cost effective surface layer material in Europe for the past twenty years. A number of SMA projects have been constructed in the U.S. since 1991 to evaluate its performance and these projects will continue to be monitored for several years. In order to observe the effects of various factors on the performance of SMA, laboratory studies have been carried out at the National Center for Asphalt Technology (NCAT). Previous work at NCAT has been reported in References 1, 2, and 3.

The variability of SMA mix properties have not been studied. Some evaluation needs to be made to evaluate the variability of optimum asphalt contents between different laboratories. This evaluation has been done for dense graded mixtures and found to be fairly high, therefore this data should be developed and evaluated for SMA.

One of the biggest problems observed so far with SMA has been draindown and the resultant fat spots. There are several draindown tests that have been used for SMA but all of them are subjective. A method is needed to quantitatively measure draindown and to relate this measured draindown to that measured in the field.

Most work to date on SMA has been with the Marshall Compactor but some work needs to be done with a Gyratory Machine since the new SHRP gyratory will eventually be used on SMA mixes. Some initial work with a gyratory machine has shown that the mixes close up more than with a Marshall hammer. Work needs to be done to compare the gyratory densities to that of the Marshall for SMA mixes. There has been much discussion about SMA mixtures having stone-on-stone contact. However, a method does not exist to actually determine quantitatively if stone-on-stone contact exists. A method is needed to do this.

Objective

The objectives of this SMA study were: 1) to find the interlaboratory average values and the standard deviations of voids in mineral aggregates (VMA), theoretical maximum density and optimum asphalt content, 2) to develop a draindown test and to evaluate the effects of various factors on draindown of asphalt in SMA mixes, 3) to develop a comparison of laboratory densities of SMA mixes prepared by a gyratory machine to those prepared by the mechanical Marshall hammer, and 4) to develop a method to evaluate stone-on- stone contact in SMA mixes.

Scope

The first part of the SMA round robin study was carried out with limestone aggregates and American cellulose fibers. Seven state, federal and contractor laboratories in addition to NCAT took part in this study. Preblended aggregates, asphalt cement, and fiber were sent to each of the participating agencies, They were requested to prepare mixtures at various asphalt contents and to compact using 50 blows with a Marshall hammer. After receiving all the data from each of the participating agencies, interlaboratory average and standard deviation values for voids in mineral aggregates, theoretical maximum density and optimum asphalt content (corresponding to three percent air voids) were calculated.

The first round robin test was conducted with a mix that had a relatively low optimum asphalt content. Therefore a second round robin test was conducted to evaluate an SMA mix with a higher optimum asphalt content. This phase of the study was carried out with Virginia traprock aggregates and American cellulose fibers. Twenty preblended aggregate samples, cellulose fibers, AC-20 asphalt cement, and wire baskets for draindown tests were sent to each of the eight participating agencies. Each agency was requested to prepare mixtures at various asphalt contents and to compact using 50 blows with a Marshall hammer, After receiving the data it was analyzed in the same way as that for the first round robin study and the results reported.

A detailed study was carried out to evaluate the draindown potential of SMA mixes with different kinds of fibers and fillers. A draindown test to quantify draindown was developed. Two types of fibers, European cellulose and mineral fiber, and one type of polymer, vestoplast, were used in various SMA mixtures and evaluated in the draindown test. In addition to these mixtures, a control mix was prepared without any fiber or polymer for comparison purposes. Two types of aggregates, gravel and limestone, with two types of fillers, baghouse fines and marble, were used. The percent passing the No. 4 Sieve was varied for each type of aggregate. The amount of draindown for each test was measured and the results analyzed to evaluate the effect of the various parameters on draindown.

The part of the study that intended to correlate the unit weight of specimens from the Marshall hammer and the gyratory machine was carried out with granite and limestone aggregates. Air void contents of specimens compacted in the gyratory machine were determined and the number of revolutions required to provide the same void level as that obtained with the Marshall hammer was established.

To evaluate stone-on-stone contact in SMA mixes, studies were carried out with gravel and limestone aggregates and 0.3 percent European cellulose fibers. Mixes were made by varying the percent of materials passing the No. 4 Sieve, starting at 50 percent and going down as low as 15 percent. The voids (VMA, VCA) were plotted against percent of material passing the No. 4 Sieve, and compared to VCA obtained from the dry rodded test of coarse aggregates to determine if stone-on-stone contact existed. Creep testing was carried out on each of these mixtures. Dense graded mixes were also tested for creep properties for comparison with the SMA mixtures. Plots of creep strain and creep modulus values were made.

TEST PLAN

The test plan used for the different parts of this study is presented in the following sections. A description of the test plan for each of the phases is given under the appropriate title below.

First Phase Round Robin

In this phase of the study granite from Buford, Georgia was used as the aggregate material. The specific gravity and absorption properties of the aggregate are shown in Table 1. The gradation of the aggregates used to prepare the SMA mixtures is given in Table 2.

An AC-20 asphalt cement from Chevron U.S. A Inc., Mobile, Alabama, was used in all the mixes for this study. The test properties, as supplied by the manufacturer, are given in Table 3.

Agricultural lime was used as the filler material and American cellulose was used as the fiber. A total of twenty preblended aggregate samples (blended to meet the gradation shown in Table 2) along with cellulose and asphalt cement were provided to each laboratory. The aggregates were mixed with 0.3 percent fiber and varying amounts of asphalt cement and compacted at 290/ F with 50 blows of a mechanical fixed base Marshall hammer. The mixes were made with asphalt contents varied at 0.5 percent increments and optimum asphalt content was chosen as that which produced 3.0 percent air voids. Rice gravities (ASTM D2041) were measured for the SMA mixtures at 6.0 percent asphalt content. Stability and flow tests were conducted, and the volumetric properties of the mixes were calculated. The data was analyzed to determine the variability of test results for theoretical maximum density, VMA, stability, flow, and optimum asphalt content.

Table 1. Specific Gravity and Absorption of Buford Granite

Property	Coarse Aggregate	Fine Aggregate
Apparent Specific Gravity	2.670	2.664
Bulk Specific Gravity	2.632	2.621
Absorption	0.61	0.60

Table 2. Gradation of Aggregates Used in the First Round Robin Study

Sieve Size	Percent Passing
1/2 inch	100
3/8 inch	65
No. 4	28
No. 8	24
No. 16	20
No. 30	17
No. 50	14
No. 100	12
No. 200	10

Table 3. Properties of the Asphalt Cement Used in the First and Second Round Robin Studies

Test	Test Results
Viscosity @ 140°F, poise	2083
Viscosity @ 275°F, cst	423
COC Flash Point, °F	600
Penetration @ 77°F, 0.1 mm	83
Thin Film Oven Test	
i) Weight Loss, %	0.01
ii) Viscosity @ 140°F, poise	6258
iii) Ductility @ 77°F, cm	150+
iv) Viscosity ratio	3
Specific Gravity @ 77°F	1.021
lbs/gallons @ 77°F	8.502

Second Phase Round Robin

The optimum asphalt content for SMA mixtures should be 6.0 percent or higher. In the first round robin study it was decided to conduct the average optimum asphalt content was below 6.0 percent so a second round robin test. This second round robin test used an aggregate that would provide a higher optimum asphalt content thus meeting the recommended criteria for SMA,

In this phase of the study a traprock being used on an SMA project in Maryland was selected as the aggregate. The specific gravity and absorption properties are shown in Table 4. The gradation of the aggregate used for the second round robin study is given in Table 5. For the binder an AC-20 asphalt cement from Chevron, Inc., U.S.A, Mobile, Alabama was used. The properties of this AC are shown in Table 3.

Agricultural lime and American cellulose were used as filler and fiber material respectively. Preblended aggregates, along with fiber and asphalt cement were sent to the different participating agencies. Cellulose at a rate of 0.3 percent by weight of total mixture was added to the aggregates prior to adding asphalt cement. The materials were mixed at 310°F and compacted at 290°F with 50 blows of a fixed base mechanical Marshall hammer. Mixes were made with different asphalt contents at 0.5 percent increments, starting at 5.5 percent and ending at 7.5 percent. For each asphalt content three samples were prepared. Rice gravity tests were conducted on two samples at 6.5 percent asphalt content, and the volumetric properties of the mixes were determined.

Table 4. Specific Gravity and Absorption of Traprock Used in Second Round Robin Test

Property	Coarse Aggregate	Fine Aggregate
Apparent Specific Gravity	3.05	3.03
Bulk Specific Gravity	3.00	2.98
Absorption	0.6	0.6

Table 5. Gradation of Aggregates Used in Second Round Robin Study

Sieve Size	Percent Passing
3/4 inch	100.0
1/2 inch	84.9
3/8 inch	64.2
No. 4	26.8
No. 8	14.3
No. 16	12.0
No. 30	11.7
No. 50	11.2
No. 100	10.3
No. 200	8.5

Each laboratory was requested to conduct a draindown test (developed in another this study) on the SMA mix at 7.0 percent asphalt with and without the 0.3 percent fibers. The results were reported.

Draindown Study

One of the problems that has been observed with SMA has been draindown of the asphalt cement resulting in fat spots. As part of this study a draindown test was developed and evaluated for its ability to simulate draindown in the field. Gravel and limestone aggregates were used in this part of the study. The gradations of the aggregates for the mixture evaluated are shown in Table 6. Two kinds of fibers and one polymer were investigated at two different proportions in the mixture. Baghouse fines and a marble filler were used in this investigation. The experimental plan is shown in Table 7. After the aggregates were batched to produce the required gradation the fibers were added and the resulting mix was kept in an oven at 315°F for four hours. Asphalt cement and aggregates were then mixed at 310°F for two minutes and transferred carefully into the wire mesh basket (Figure 1). The openings in the wire basket were 1/4 inch by 1/4 inch. The basket with the mix was placed into a preheated oven and maintained at 300°F for two hours. Pre-weighed papers were placed underneath the container to collect the asphalt cement drippings. The drippings were collected and weighed at 30 minute intervals for the two hour period. The cumulative weights were calculated and expressed as a percentage of the initial weight of the mix and the numbers were reported as percent draindown corresponding to the time of observation.

Table 6. Gradation of Aggregates Used in Draindown Study

Sieve Size	Percent Passing		
	Mix A	Mix B	Mix C
3/4 inch	100.0	100.0	100.0
1/2 inch	100.0	100.0	100.0
3/8 inch	75.0	65.0	60.0
No. 4	50.0	30.0	20.0
No. 8	39.9	24.9	17.5
No. 16	34.3	22.1	16.1
No. 30	30.0	20.0	15.0
No. 50	21.5	17.0	14.8
No. 100	15.1	13.9	13.3
No. 200	10.0	10.0	10.0

Table 7. Experimental Plan for Draindown Study

FIBER/POLYMER	**Aggregate**																							
	Gravel												Limestone											
	Gradation												**Gradation**											
	20% Fine				30% Fine				50% Fine				20% Fine				30% Fine				50% Fine			
	Filler												**Filler**											
	Bgf		Mar		Bgf		Mar		Bgf		Mar		Bgf		Mar		Bgf		Mar		Bgf		Mar	
	Asphalt Content, %												**Asphalt Content, %**											
	6	7	6	7	6	7	6	7	6	7	6	7	6	7	6	7	6	7	6	7	6	7	6	7
AC	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
E.1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
E.3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M.1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M.3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
P3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
P8	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Note: Bgf - Baghouse fines
Mar - Marble
AC - Asphalt cement without any additive (control)
E.1 - 0.1% (of mix) European cellulose fiber
E.3 - 0.3% (of mix) European cellulose fiber
M.1 - 0.1% (of mix) mineral fiber
M.3 - 0.3% (of mix) mineral fiber
P3 - 3.0% of binder polymer
P8 - 8.0% of binder polymer

Correlation of Properties of Marshall and COE GTM Specimens

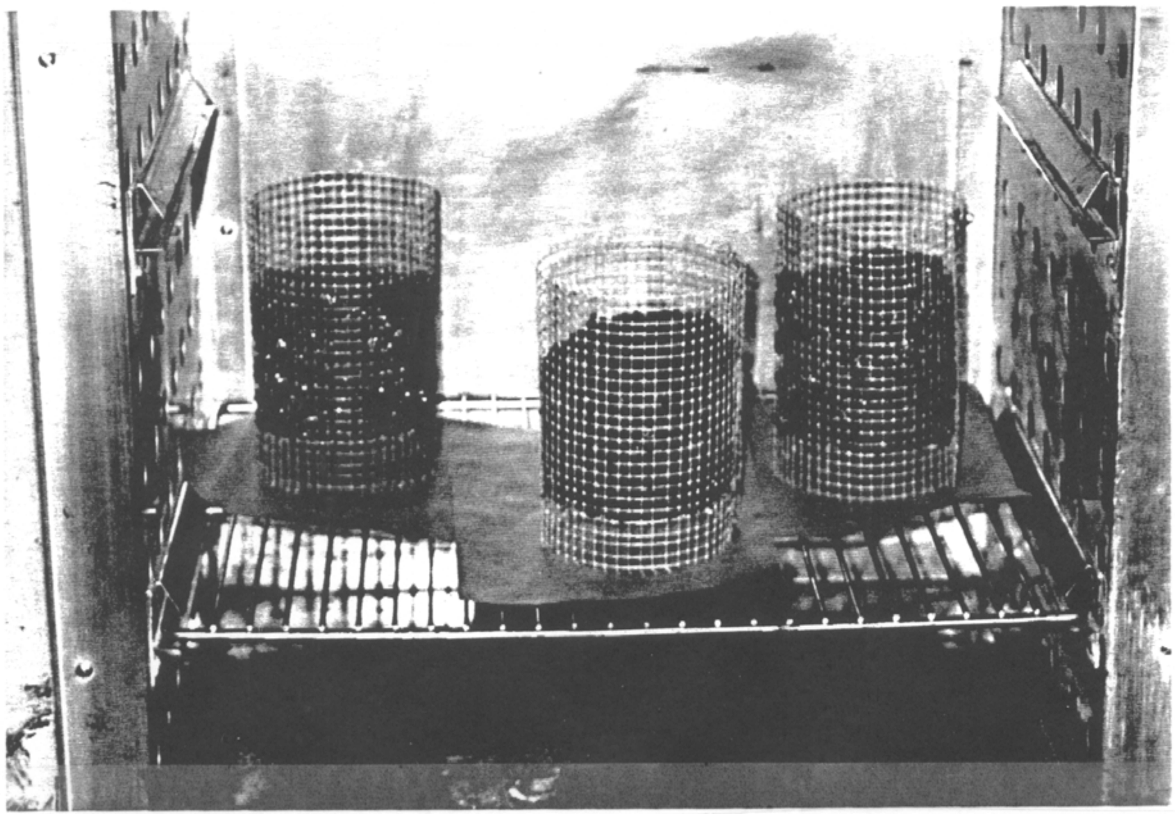

Figure 1. Typical Wire Mesh Baskets Used for Draindown Studies

Work has been performed on SMA with the Corps of Engineers Gyratory Machine and it is anticipated that the SHRP Gyratory will be used on some future work. There has been concern about the compaction effort required with the gyratory machine for SMA mixtures. For this reason a plan was developed to evaluate the number of gyrations needed to provide a density equal to that with 50-blow Marshall hammer.

The gravel and limestone aggregates were each blended to produce the gradation shown in Table 8 for this part of the study. European cellulose fiber was added to the aggregate at a rate of 0.3 percent by weight of total mix. Mix designs were performed using 50 blows with the mechanical Marshall hammer. Three samples were prepared for each asphalt content and optimum asphalt content was selected at 3.0 percent air voids. Volumetric properties of samples at various asphalt contents were determined. Using the optimum asphalt content obtained by the Marshall method of design, mixes were compacted with the COE GTM at various numbers of revolutions. The number of revolutions required to produce 3.0 percent air voids was determined from plots of air voids versus number of revolutions.

Evaluation of Stone-on-Stone Contact in SMA Mix

To obtain optimum resistance to rutting it is believed that stone-on-stone contact in the coarse aggregate portion of the SMA mixture is desired. In the past stone-on-stone contact has been very subjective and has only been evaluated by visual observation from cored samples. There is a need to develop a method to quantify the amount of stone-on-stone contact to ensure that it is sufficient to provide the desired properties.

Two types of aggregates, gravel and limestone, were used for this part of the study. Mixes were produced with various percentages of material passing the No. 4 Sieve. The percentages used were 50, 40, 30, 20, and 15. A dense mix with 66 percent passing the No. 4 Sieve was also prepared and evaluated for comparison to the SMA mixtures. The gradations, together with the corresponding mix designations are given in Table 9.

Table 8. Gradation of Aggregates and COE GTM

Sieve Size	Percent Passing
1/2 inch	100.0
3/8 inch	62.5
No. 4	25.0
No. 8	21.2
No. 16	19.1
No. 30	17.5
No. 50	15.9
No. 100	13.6
No. 200	10.0

Table 9. Gradation of Aggregates Used in Evaluation of Stone-on-Stone Contact in SMA

Sieve Size	Percent Passing					
	A	B	C	D	E	Dense
3/4 inch	100.0	100.0	100.0	100.0	100.0	100.0
1/2 inch	100.0	100.0	100.0	100.0	100.0	100.0
3/8 inch	75.0	70.0	65.0	60.0	57.5	85.0
No. 4	50.0	40.0	30.0	20.0	15.0	66.0
No. 8	39.9	32.4	24.9	17.5	14.7	50.0
No. 16	34.3	28.2	22.1	16.1	14.6	34.3
No. 30	30.0	25.0	20.0	15.0	14.5	24.0
No. 50	21.5	19.3	17.0	14.8	14.3	15.0
No. 100	15.1	14.5	13.9	13.3	12.4	9.0
No. 200	10.0	10.0	10.0	10.0	10.0	5.0

Samples were prepared using 0.3 percent European cellulose fiber and agricultural lime as the filler. Mix designs were performed with the mechanical Marshall compactor (50 blows), by preparing and compacting samples with asphalt content varied at 0.5 percent increments. Three samples were made at each asphalt content. The optimum asphalt content was chosen as that asphalt content which produced 3.0 percent air voids. Voids in mineral aggregates (VMA) and voids in coarse aggregates (VCA) were calculated for the compacted samples. Voids in coarse aggregates (VCA) were calculated by replacing percent of aggregates in mix (used in VMA calculations) by percent of coarse aggregates in the calculations. To measure the VCA with no fine aggregates, the coarse aggregate was placed in a container and dry rodded to maximum density in accordance with ASTM C29. The aggregates were rodded when the container was filled to one-third, two-thirds and full. The VCA in the dry rodded condition represents the condition at which stone-on-stone contact exists. The VMA and VCA at the optimum asphalt content were then plotted against the percent fines and compared to the VCA for a mix without any fine aggregates. The point at which the VCA in the mixture is equal to the VCA in the dry rodded condition is the point at which it is assumed that stone-on-stone contact exists.

Evaluation of Creep Properties of SMA Mixes with Various Percentages of Material Passing the 4.75 (No. 4) Sieve

Gravel and limestone aggregates were used for this part of the study. The gradations in Table 9 were used in the evaluation of stone-on-stone contact, and to evaluate creep properties of the mix. To observe the change in creep properties with time another SMA mix (designated as F) was used with 25 percent passing the No. 4 Sieve (Table 8). The optimum asphalt content for mixtures A - E was obtained from the evaluation of stone-on-stone contact phase of the study. Mixes were compacted using 50 blows with the mechanical Marshall hammer. Three samples of each mixture with various percentages of material passing the No. 4 Sieve were mixed with asphalt cement and compacted using 50 blows with the mechanical Marshall hammer. Dynamic creep tests were performed for one hour on mixes designated as A, B, C, D, E, and the dense mix. Strain and modulus values were plotted against percent passing the No. 4 Sieve for mixes A, B, C, D, E, and the dense mix.

TEST RESULTS AND ANALYSIS

Round Robin Studies

Several laboratories participated in the first and second round robin studies but some had to be excluded from the analysis due to hammer type used. For the analysis eight laboratories participated in the first study and nine in the second.

The results obtained from these two studies are shown in Tables 10 and 11. The results of the two round robin studies are compared to that for a dense mix round robin study shown in Table 12 (4). The variability of optimum asphalt content of SMA mixes is observed to be greater than that for the dense graded mix (Table 12). The variability in Theoretical Maximum Density (TMD) is found to be the same for SMA and dense graded mixture for the first round robin study but higher for SMA mixes in the second round robin study. The variabilities measured for the mixtures in the two SMA round robin tests were very similar. There is some difference in the values for the Theoretical Maximum Density and flow.

The high variability for selected optimum asphalt content for SMA mixtures indicates that the selected asphalt content for a given SMA aggregate mixture will be less precise than that for dense graded mixtures. This could present a significant problem if SMA mixtures were overly sensitive to asphalt content. Past experience has shown that SMA mixture quality is not affected as much by changes in asphalt content as dense mixes. Although the precision for selecting the optimum asphalt content for SMA should me improved, it should not be a major problem. It is most important that SMA mixtures be monitored during production to ensure that the air voids in the laboratory compacted mixture be controlled within the desired range.

Table 10. Summary of Results from First Round Robin Study SMA MIX

Agency	Max Spec Gravity (6.0% AC)		Unit Weight lb/ft^3	Opt AC % (VTM=3%)	VMA %	Stability (140°F) lb	Flow (140°F) 0.01 inch
	Test 1	Test 2					
Asphalt Institute	2.421*	---	148.3	5.2	14.8	1800	10
FHWA R&D	2.432	---	148.6	5.2	14.7	2350	13
Georgia DOT	2.426	---	146.2	5.9	16.0	1650	10
Marylan d DOT	2.429	2.417	148.5	5.2	15.0	1880	11
Michigan DOT	2.430	---	150.0	4.7	14.0	2300	9
Missouri HTD	2.416	2.419	149.7	4.5	13.5	1900	10
NCAT	2.426	---	147.2	5.9	16.1	1615	12
Virginia DOT	2.434	---	147.8	5.8	16.4	1610	11

Note: --- Not available
* Back calculated

As noted earlier the variabilities of the Marshall stability values for SMA and dense graded mixtures are significantly different. The variability of the dense mix is considerably higher. A review of the data from the dense mix round robin shows that the average stability was approximately 2500 pounds which is approximately 50 percent higher than that for SMA. Calculating the variability in terms of coefficient of variation indicates that the percent variability for SMA mixtures is approximately the same as for dense graded mixtures.

The percent draindown values evaluated in the second round robin study and the corresponding statistics for mixes with and without cellulose fibers are given in Tables 11 and 12. Percent draindown in an SMA mix with 7.0 percent AC without cellulose is observed to be approximately 70 times more than that in the same SMA mix with 0.3 percent cellulose. Even though the variability of the draindown is high, there appears to be a significant difference between the test results with and without cellulose.

The draindown test appears to be a simple, fast procedure that can be used to evaluate draindown potential of various mixtures. This test can be used effectively for research, mix design, and quality control. After this test has been verified to be correlated to actual draindown in the field it can be used in the laboratory to evaluate a number of materials and mixtures to provide guidance for specifying materials. It can be used during the mix design to evaluate the potential for draindown in the designed mix and to evaluate the effect of material variations on draindown. This test can be used for quality control during construction to indicate when the SMA mix is approaching the threshold at which draindown occurs. The test may indicate an approaching problem prior to it actually showing up in the SMA mixture on the roadway.

Table 11. Summary of Optimum Asphalt Content and Void Results from Second Round Robin Study SMA Mix

Agency	Max Spec Gravity (6.5% AC)	Unit Weight lb/ft^3	Opt AC %	VMA (%)	Stability (140°F) lb	Flow (140°F) 0.01 inch	Percent Draindown (7.0% AC)	
							Without Cellulose	With 0.3% Cellulose
Asphalt Institute	2.658	159.5	7.0	20.6	1218	9.3	6.70	0.03
FHWA, TA	2.660	160.8	6.6	19.7	1830	7.9	6.25	0.04
FHWA R&D	2.648	160.1	6.4	19.4	1677	9.8	5.01	0.00
Georgia DOT	2.660*	160.3	6.9	20.2	1300	8.7	1.32	0.05
Kentucky DOH	2.653	160.8	6.4	19.5	1850	8.5	2.41	0.01
Maryland DOT	2.648	161.5	6.1	18.4	1400	9.8	5.20	0.02
Michigan DOT	2.676	163.5	5.9	18.3	1552	71.	5.30	0.23
Missouri HTD	2.664	158.0	7.3	21.2	1098	13.4	9.60	0.05
NCAT	2.667	159.1	7.3	21.0	1729	12.0	9.70	0.27

Note: --- Not available
* Back calculated

Table 12. Variability of Results from Round Robin Studies

Project	Opt. AC		Max Specific Gravity		Bulk Specific Gravity		VMA (Opt. AC)		Stability (140°F) lb		Flow (140°F) 0.01 inch		Percent Draindown			
													Without Cellulose		With 0.3% Cellulose	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
SMA Round Robin No. 1	5.3	0.534	2.426	0.006	2.377	0.0200	15.06	1.04	1888	293	11	1.3	---	---	---	---
SMA Round Robin No. 2	6.65	0.502	2.657	0.014	2.572	0.0226	19.81	10.4	1517	275	10	2.0	5.7	2.82 cv=49.5 %	0.08	0.10 cv=125 %
Dense Mix Round Robin	---	0.34	---	0.006	---	0.0220	---	1.13	---	437	---	2.1	---	---	---	---

Note: Opt. AC - Optimum Asphalt Content
Std Dev - Standard Deviation
CV - Coefficient of Variation (%)
--- - Not available

Plots of optimum asphalt content, theoretical maximum specific gravity, VMA, stability and flow of SMA mixes obtained from different agencies in the first round robin study are shown in Figures 2 through 6. No obvious outliers are observed in any of the plots. The optimum asphalt content values ranged from 4.5 to 5.9 percent. A plot of stability versus VMA is shown in Figure 7. It is observed that as VMA of a mix increased, the stability tended to decrease. This indicates that a part of the variability in the stability test is actually due to differences in density of the mixture being evaluated. As suspected the mixture with higher density had higher measured stability values.

The results from the second round robin study are shown in Figures 8 through 15. No obvious outliers are observed in these plots, however the draindown tests do show some significant scatter and possible outliers. The optimum asphalt content ranged from 4.9 to 7.0 percent. As shown in Figure 13 the stability values are observed to decrease with an increase in VMA again indicating that differences in density between labs affected the measured stability.

Draindown Study

The results of the draindown tests with different aggregates, gradations, fillers, fibers, and polymer are shown in Appendix A. Only a summary of the data is provided in the text of the report for the convenience of the reader. A typical plot of cumulative draindown versus time is shown in Figure 16. Note that most of the draindown occurs within the first hour which may allow the test to be standardized at one hour. Also notice that the amount of draindown for the samples shown in Figure 16 is increased by a factor of approximately 5 when increasing the asphalt content from 6.0 percent to 7.0 percent. Plots of average cumulative draindown against time for different variables in SMA mixtures are shown in Figures 17 through 21.

Figure 17 shows that the SMA mixtures using the baghouse fines had much less draindown than the mixtures using marble dust. The likely reason for this difference is the smaller particle sizes for the baghouse fines. The smaller particles provide more surface area for a given weight and thus tend to stiffen the binder more than the coarser fines. This clearly shows the importance of size of material passing the No. 200 Sieve on draindown. The size of the material passing the No. 200 sieve then must be controlled to ensure that draindown does not become a problem.

Figure 18 shows the effect of asphalt content on draindown for various SMA mixtures. An asphalt content of six percent is approximately optimum for most of the SMA mixtures shown and seven percent asphalt content is on the high side. The data shows that a one percent increase in asphalt content resulted in a significant increase in draindown. This higher amount of draindown at 7.0 percent AC is caused by draindown of filler material and AC at the higher asphalt content. It appears that for a given mixture there is a threshold asphalt content at which there is very little or no draindown. Once this threshold is exceeded, draindown occurs. In the design process steps should be taken to produce a mixture with a high threshold asphalt content for draindown and to produce a mixture that is not sensitive to draindown when minor mixture variations occur.

The type and amount of stabilizer material significantly affects the draindown of SMA (Figure 19). For the additives evaluated in this study it appears that 0.3 percent mineral fiber and 0.3 percent European cellulose fiber produced the least draindown. The mixtures with no additive and 0.3 percent (binder wt.) vestoplast produced the most draindown. The mixtures containing eight percent vestoplast (binder wt.), 0.1 percent European cellulose fiber, and 0.1 percent mineral fiber produced intermediate draindown. The data indicates that stabilizer type and amount of stabilizer significantly affect draindown results. For this study all draindown tests were conducted at 300°F. In the future this test needs to be conducted at the mix temperature anticipated in the field to better evaluate the true draindown potential of the various mixtures.

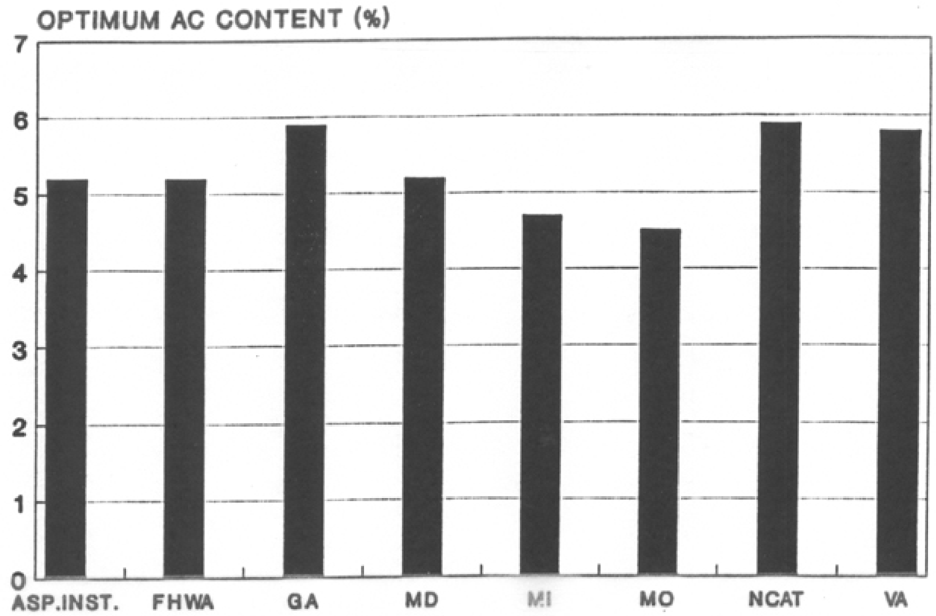

Figure 2. Optimum Asphalt Contents of SMA Mix from First Round Robin Study

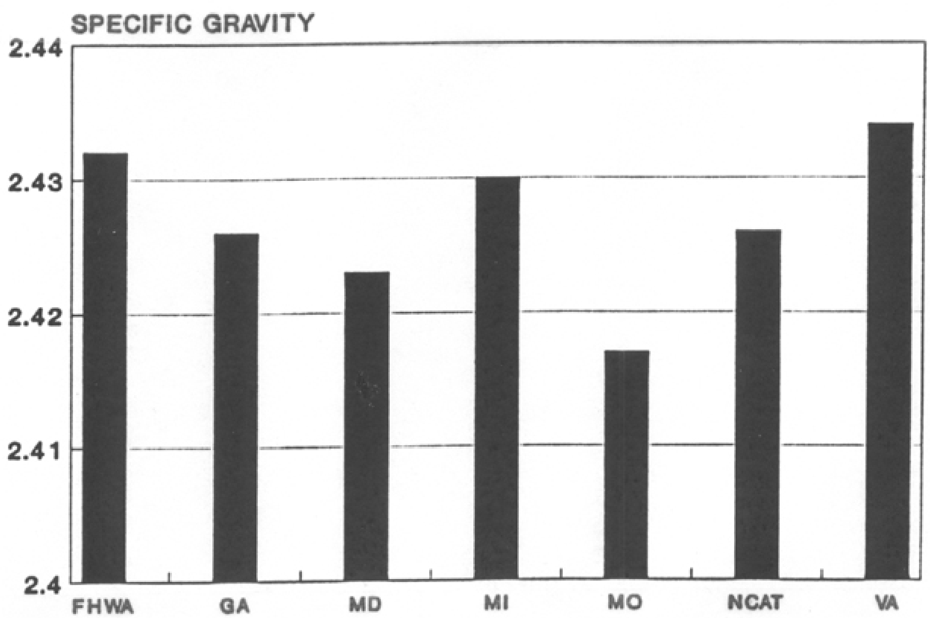

Figure 3. Theoretical Maximum Specific Gravity (@ 6 Percent AC) of SMA Mix from First Round Robin Study

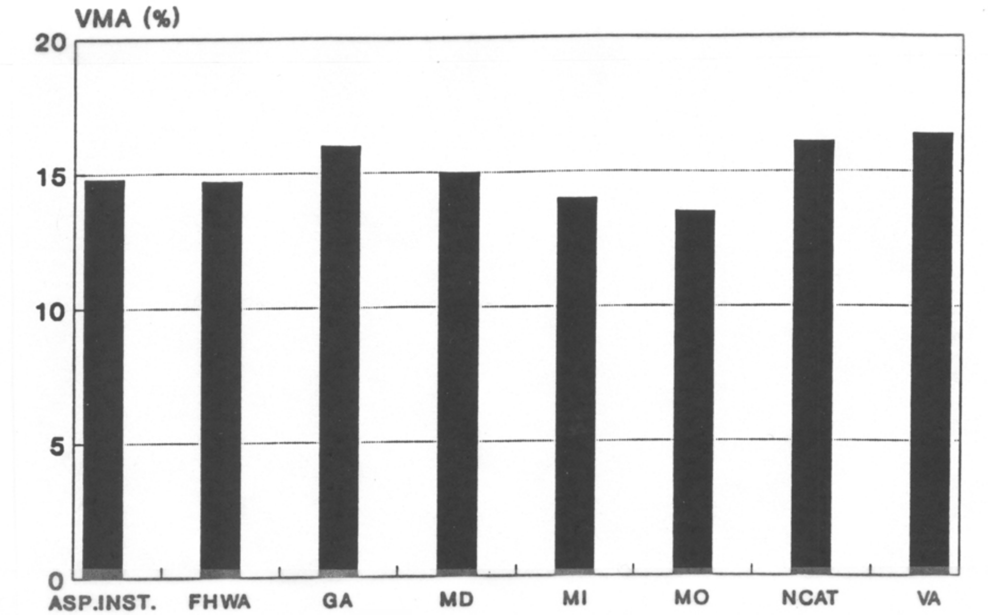

Figure 4. VMA (3 Percent voids) of SMA Mix from First Round Robin Study

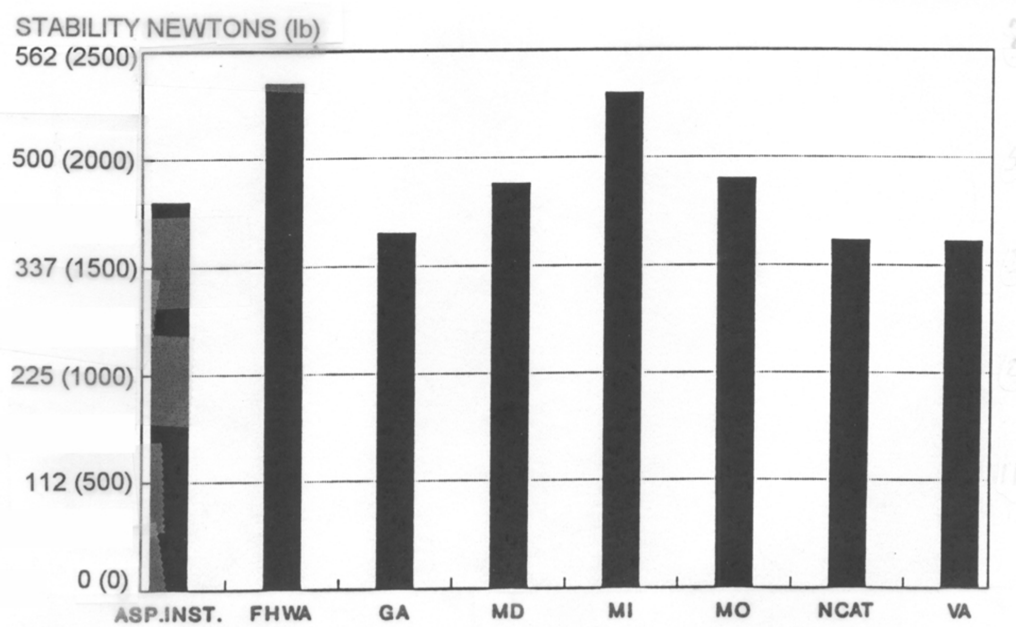

Figure 5. Stability (3 Percent voids) of SMA Mix from First Round Robin Study

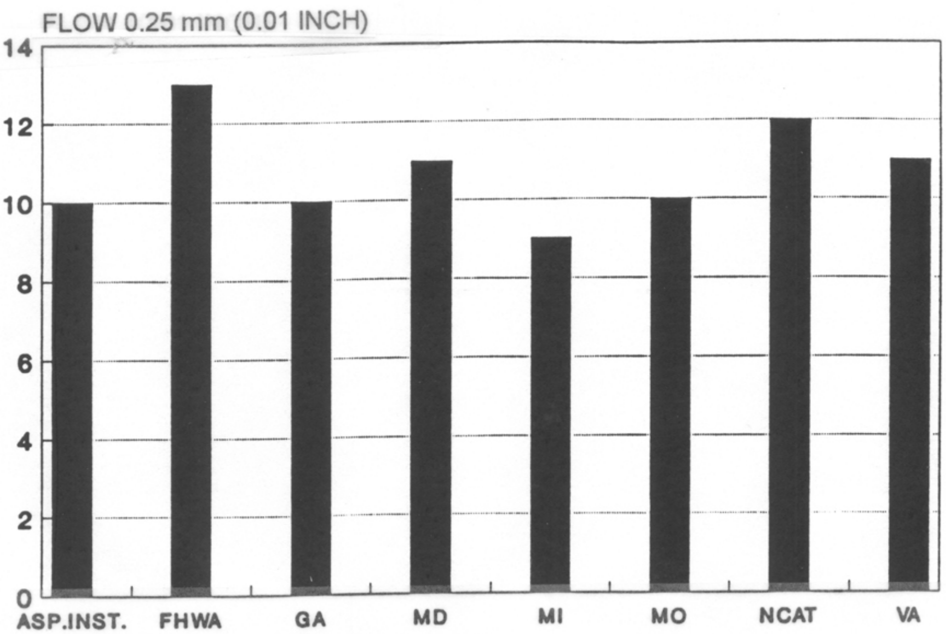

Figure 6. Flow (3 Percent voids) of SMA Mix from First Round Robin Study

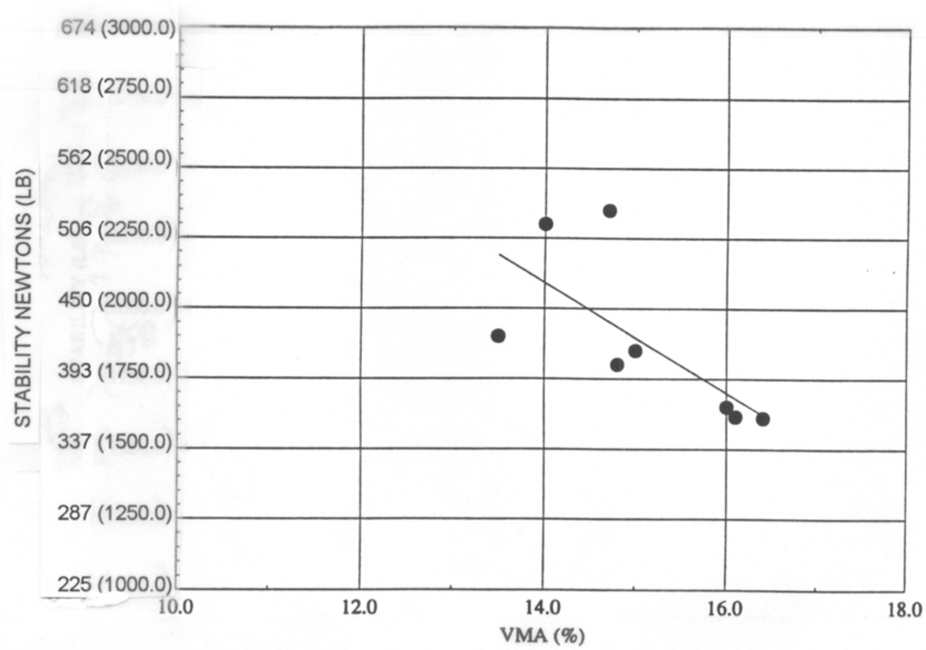

Figure 7. Plot of Stability versus VMA of SMA Mix from First Round Robin Study

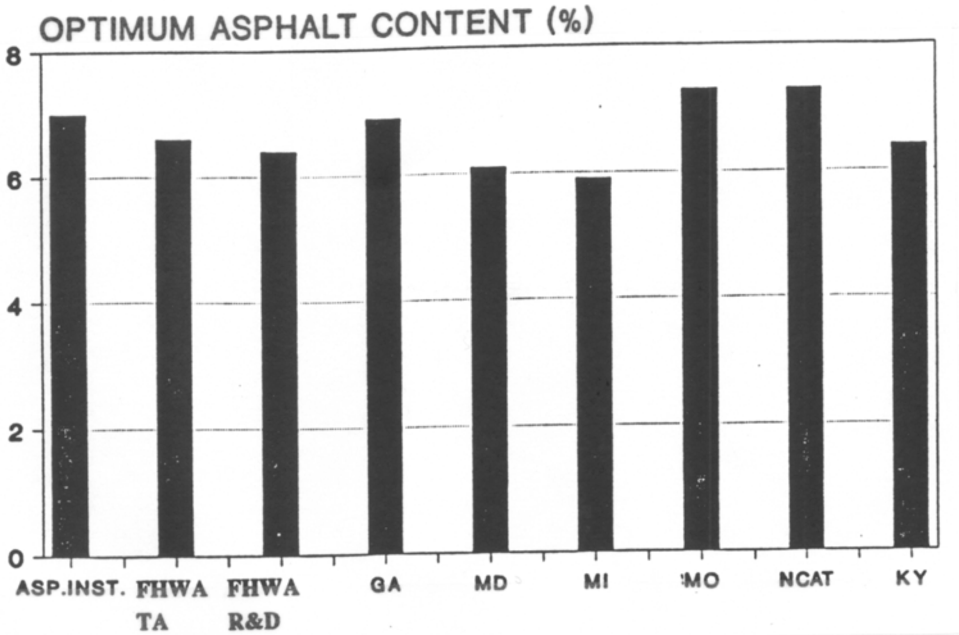

Figure 8. Optimum Asphalt Contents of SMA Mix from Second Round Robin Study

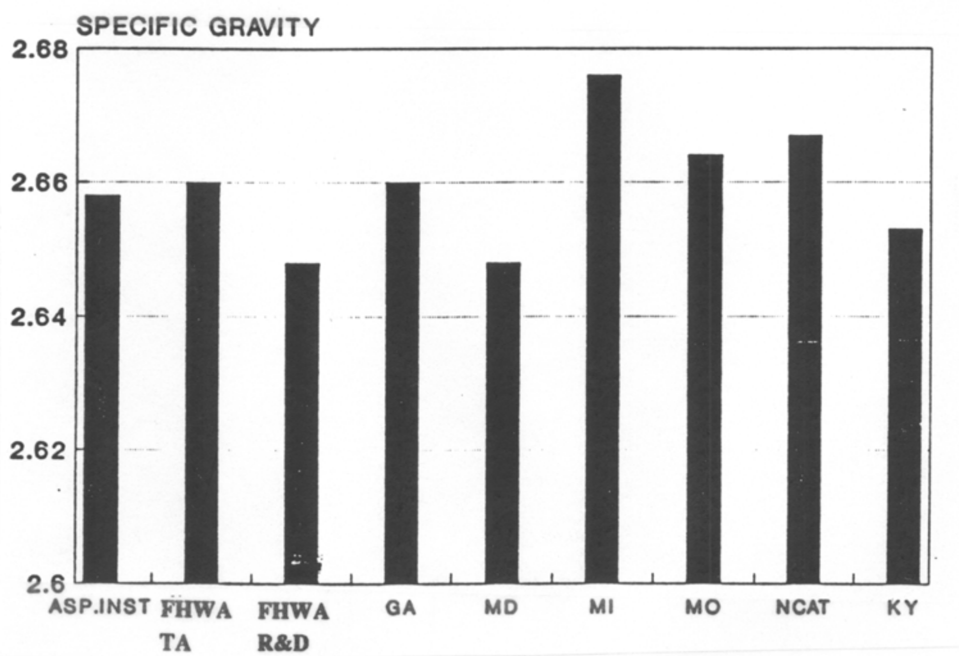

Figure 9. Theoretical Maximum Specific Gravity (@ 6.5 Percent AC) of SMA Mix from Second Round Robin Study

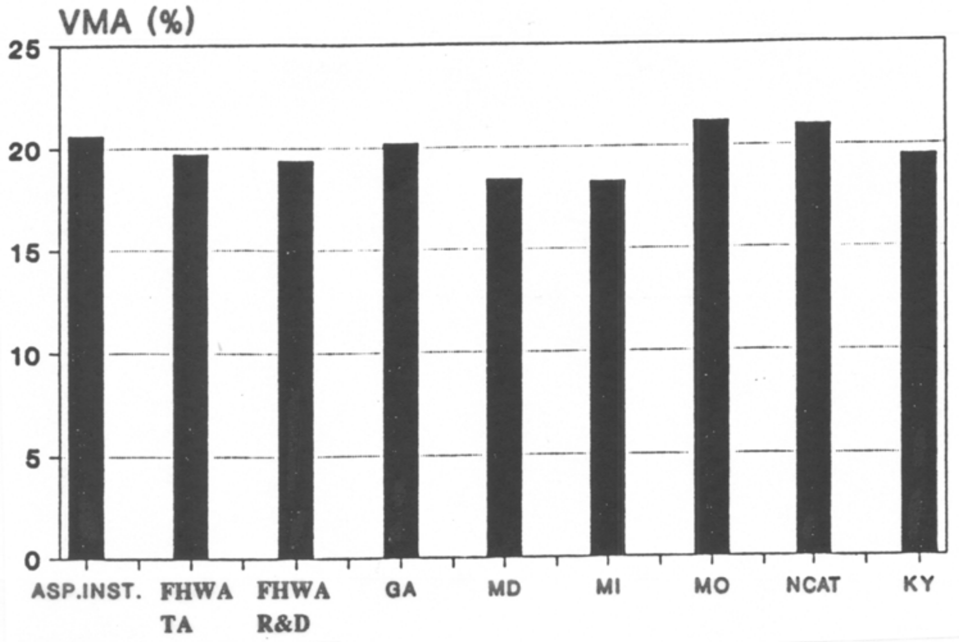

Figure 10. VMA (3 Percent voids) of SMA Mix from Second Round Robin Study

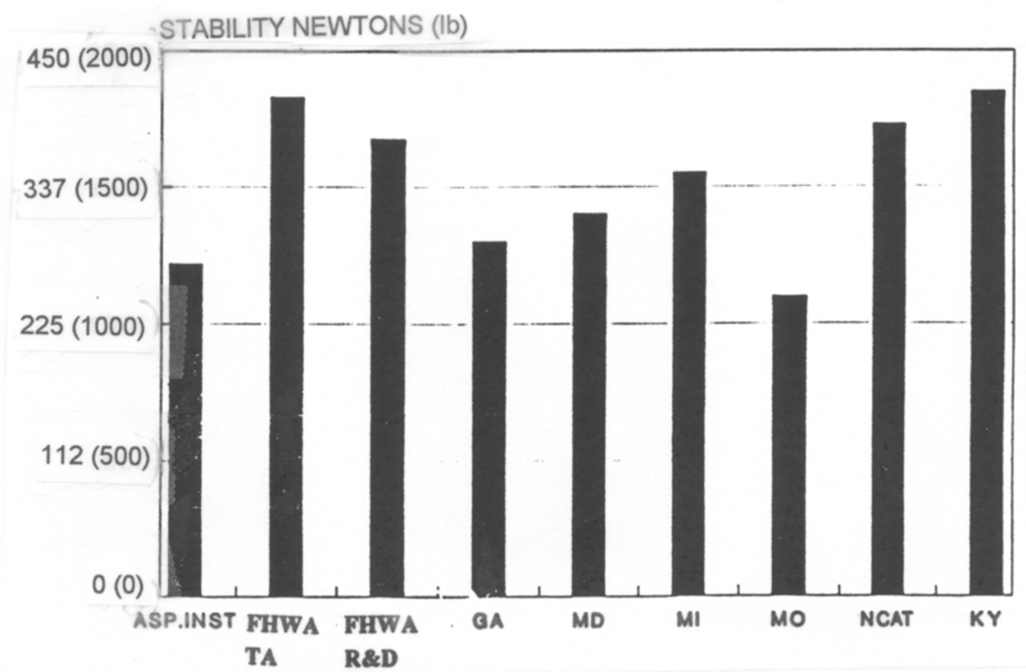

Figure 11. Stability (3 Percent voids) of SMA Mix from Second Round Robin Study

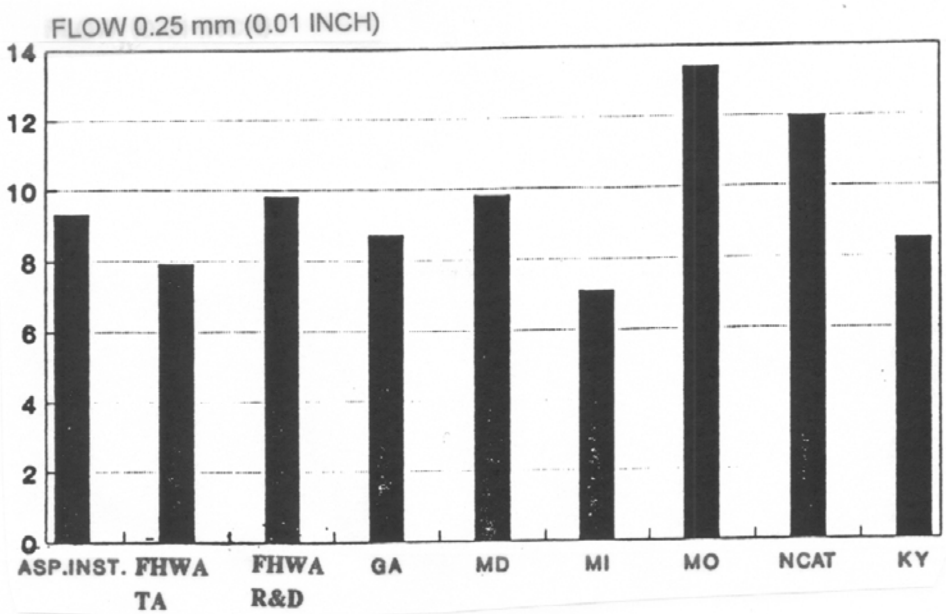

Figure 12. Flow (3 Percent voids) of SMA Mix from Second Round Robin Study

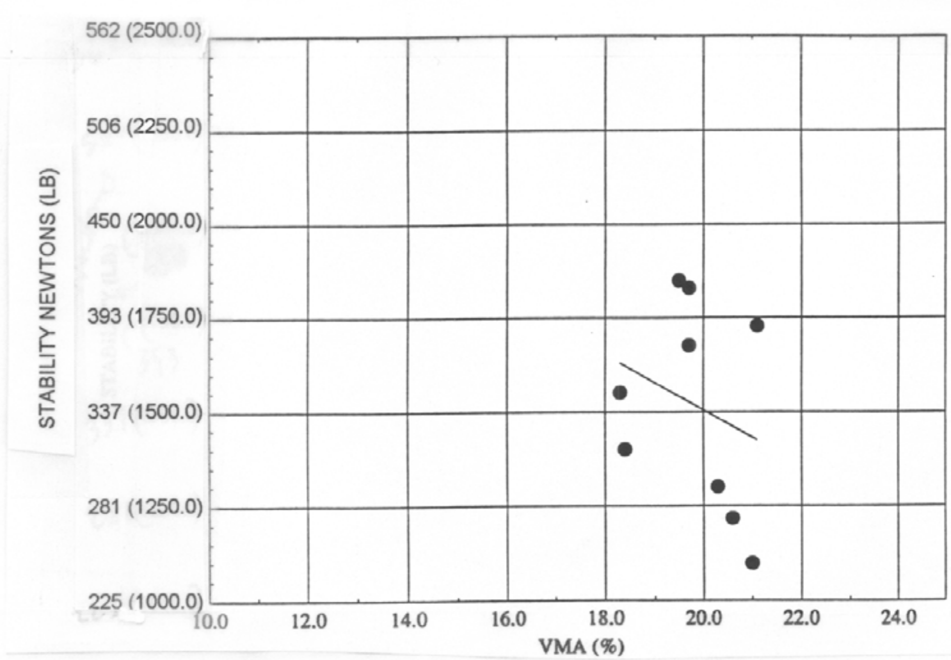

Figure 13. Plot of Stability versus VMA of SMA Mix from Second Round Robin Study

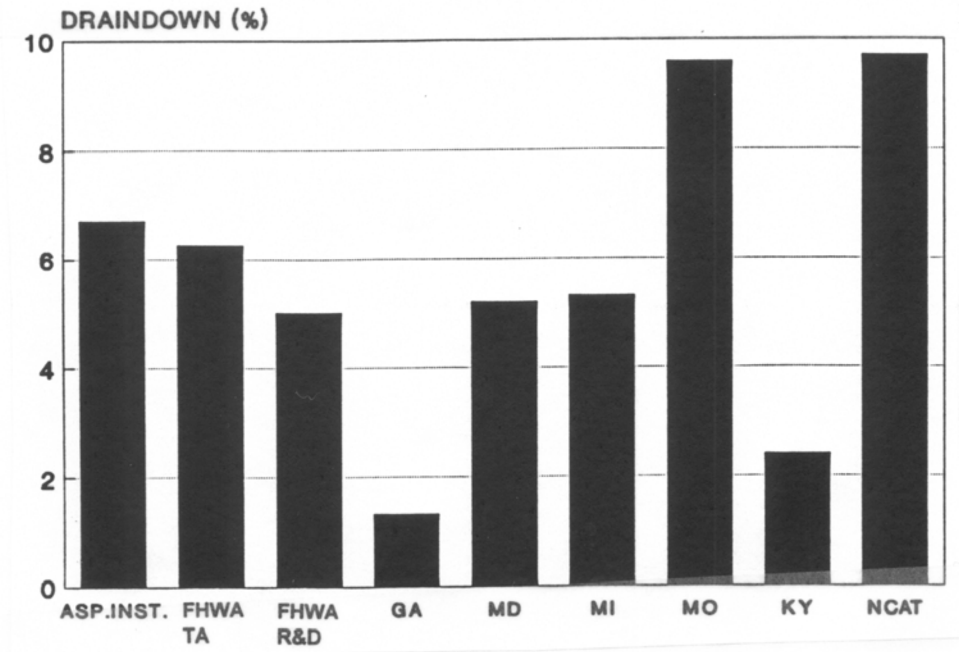

Figure 14. Percent Draindown of SMA Mix without Cellulose

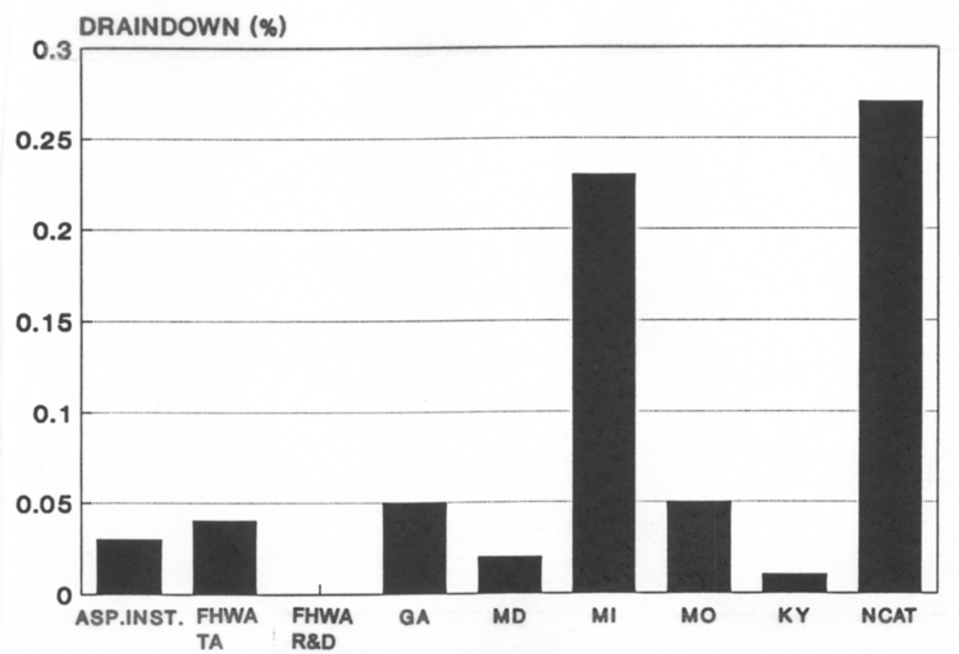

Figure 15. Percent Draindown of SMA Mix with 0.3 Percent Cellulose

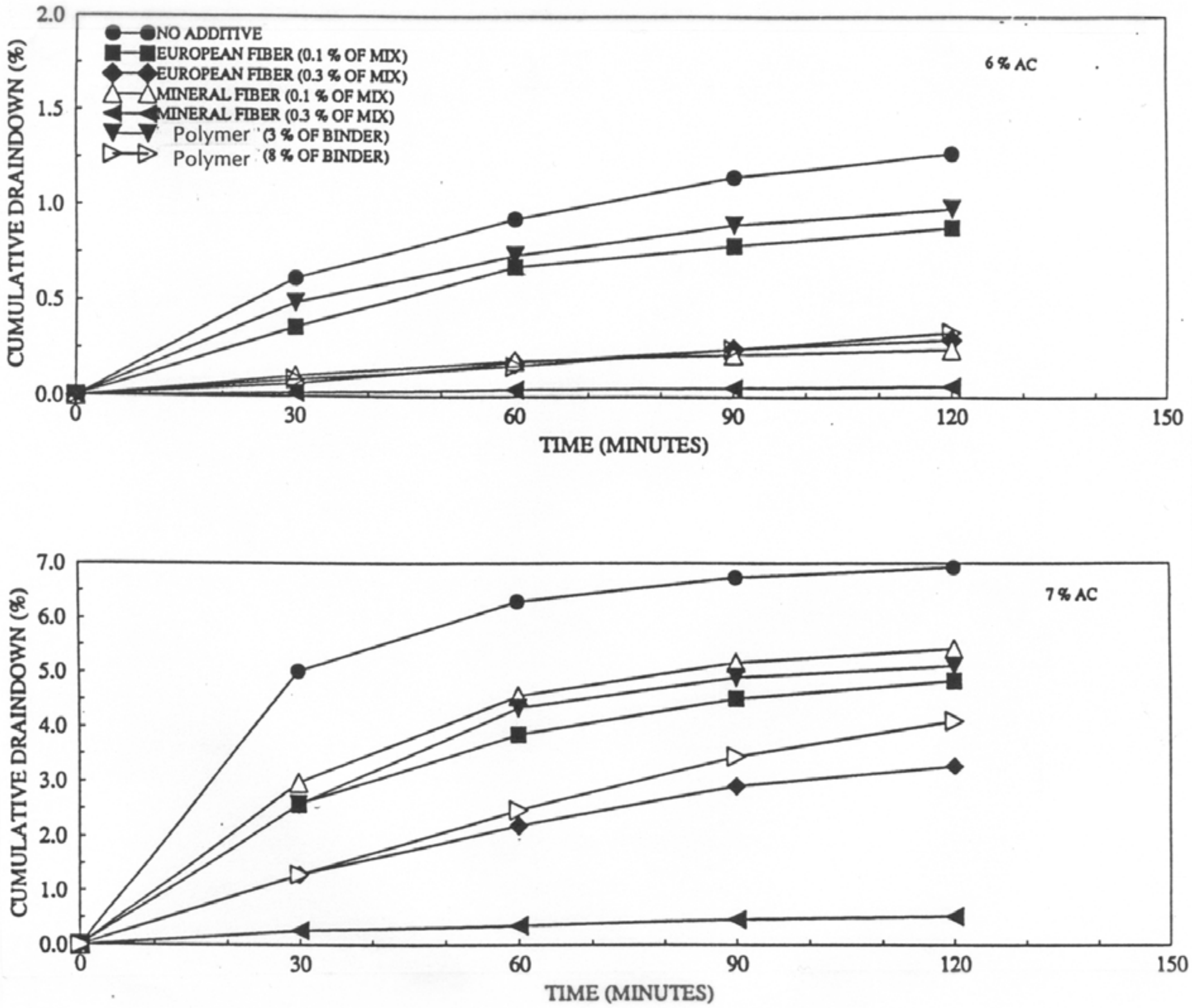

Figure 16. A Typical Draindown versus Time Plot for Mixtures Using Gravel Aggregates, Baghouse Fines, and 20 percent Passing the No. 4 Sieve

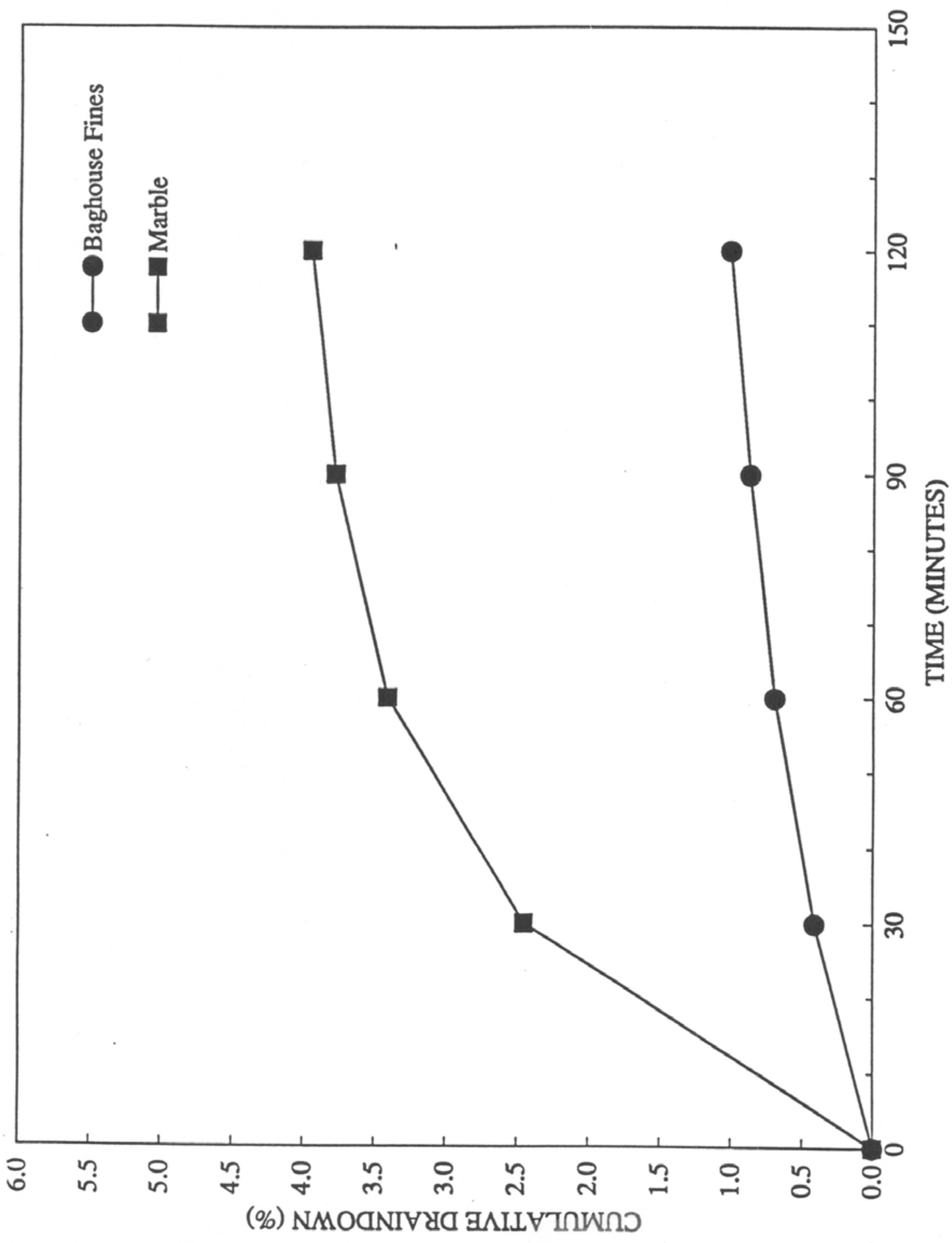

Figure 17. Draindown versus Time for Mixes with Different Types of Fillers

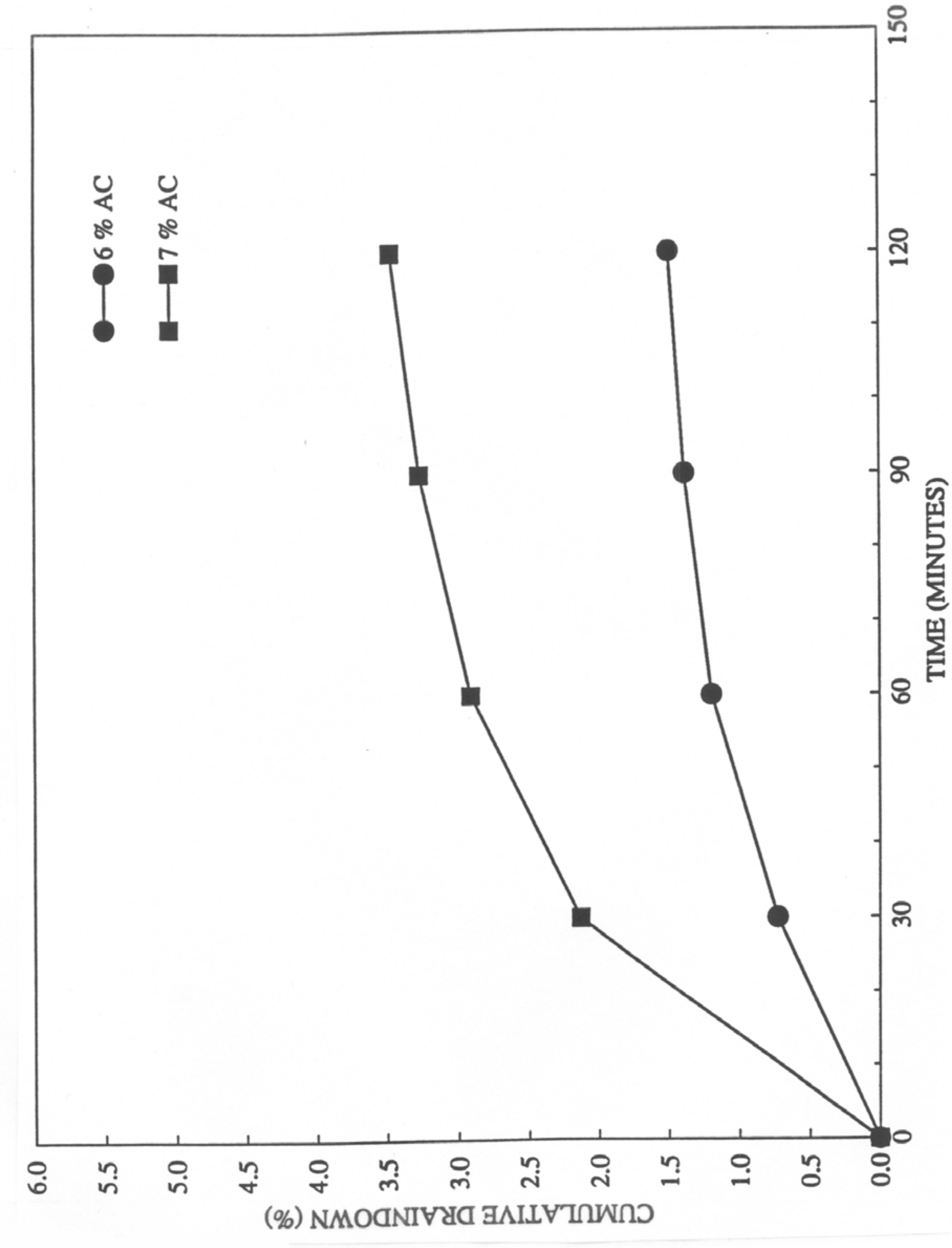

Figure 18. Draindown versus Time for Mixes with Different Asphalt Contents

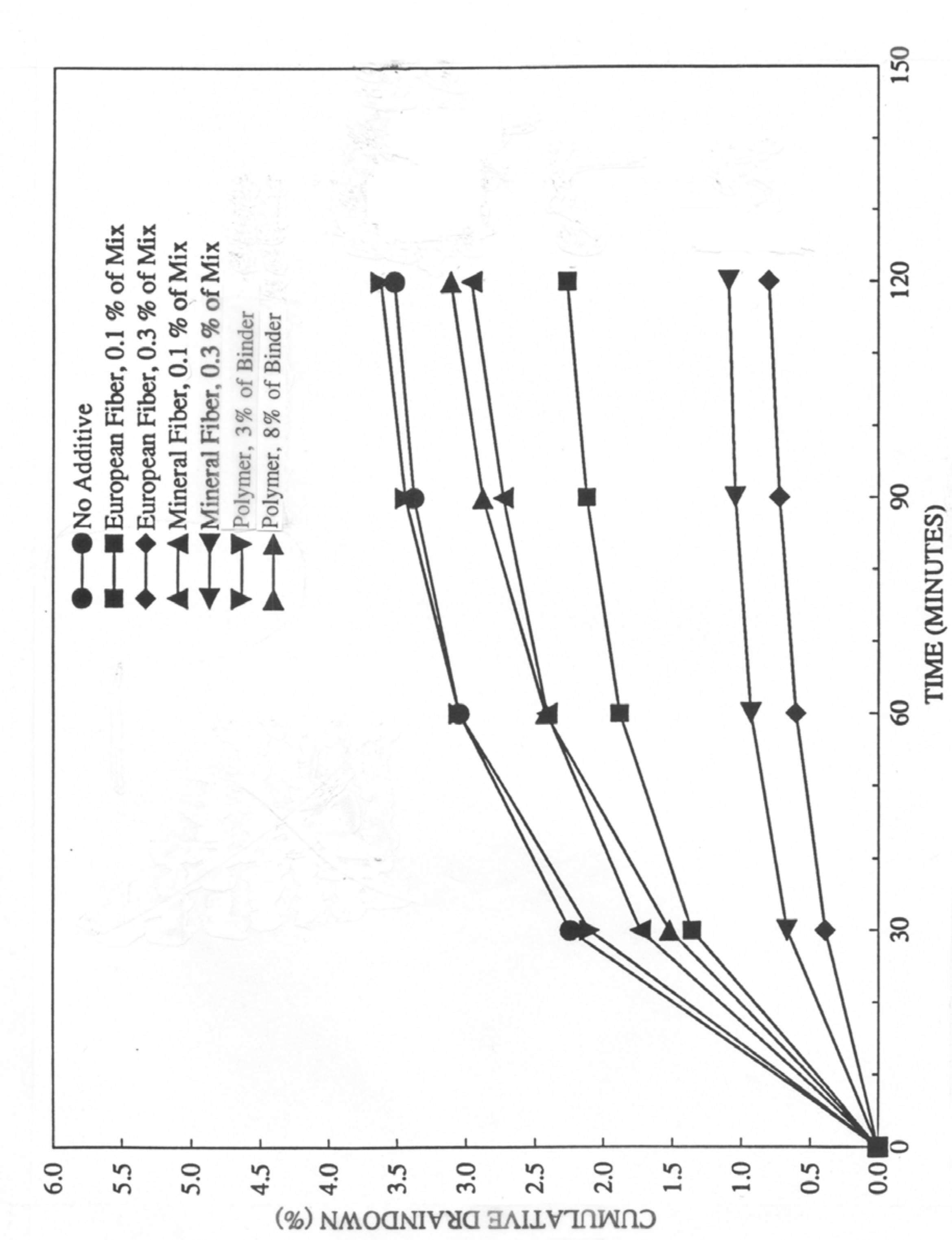

Figure 19. Draindown versus Time for Mixes with Different Types of Additives

Figure 20 shows that the amount of material passing the No. 4 Sieve affects draindown. The mixtures with 20 percent passing the No. 4 Sieve had significantly more draindown than the mixes with 50 percent passing the No. 4 Sieve. Mixes with 30 percent passing the No. 4 Sieve had an intermediate amount of draindown. The freer mixes have more surface area and lower optimum asphalt content and therefore should have less draindown. Probably the biggest reason for differences in draindown is the size of the internal voids. With the coarser mixes the internal voids of the uncompacted mix are larger resulting in more draindown. The mix with 50 percent passing the No. 4 Sieve under normal circumstances would not experience draindown and the data appears to confirm this fact.

Figure 21 shows the effect of aggregate type on draindown. The amount of draindown for the two aggregates investigated was approximately equal and this would be expected for other aggregates. Hence it appears based on this limited study that aggregate type may have little effect on draindown.

As is evident from the results of the draindown tests, significant differences seem to exist between results obtained from mixes with different material combinations. An Analysis of Variance was conducted on the obtained results to test the effects of different factors on draindown As is evident from the results of the draindown tests, significant differences seem to exist between results obtained from mixes with different material combinations. An Analysis of Variance was conducted on the obtained results to test the effects of different factors on draindown values. The summary of results are shown in Tables 13 and 14 and detailed data is provided in Appendix B. If a significance level of 0.05 is considered it is seen that all the different factors, filler type, percent fines, asphalt content and fiber type, have significant effects on draindown as shown in Figures 17-21. This is true for both types of aggregates used. Tables 15 and 16 show the groupings of the different variables obtained from Duncan's Multiple Range test. For both types of aggregates the mixes with marble filler experience higher draindown values than those mixes with baghouse fine filler. For both types of aggregates draindown decreases with an increase in the percent passing the No. 4 Sieve. This is expected since the high surface area of the fine aggregates helps in reducing flow of asphalt cement in mixes. With respect to effects of fiber in both cases the mixes with 0.3 percent European cellulose and 0.3 percent mineral fiber show the lowest amount of draindown.

The data show under the test conditions for this study that SMA mixtures tend to have more draindown when: the asphalt content is higher, when the filler is coarser (marble versus baghouse fines), when the percent passing the No. 4 Sieve is lower, when a polymer is used instead of a fiber. The amount of draindown is obviously affected by temperature and amount of material passing the No. 200 Sieve but these items were not evaluated in this study. There was no difference in draindown for the two aggregates used.

Based on the results of this study the draindown test appears to be a good way to quantify the draindown in the laboratory which should be related to the draindown that would be observed in the field. Additional work is needed to finalize this draindown procedure but it does appear to have the potential of being a very good test for mix design and control of SMA mixture. A correlation needs to be developed between laboratory draindown and draindown experienced in the field. To do this some method must be developed to quantify the amount of draindown in the field. The draindown test in the laboratory also needs to be conducted at the expected field mixture temperature. It is also suggested that this test be conducted at temperatures above and below that anticipated for mix production to evaluate the sensitivity to temperature changes which may occur due to normal production variation or due to modifications in mixing temperature.

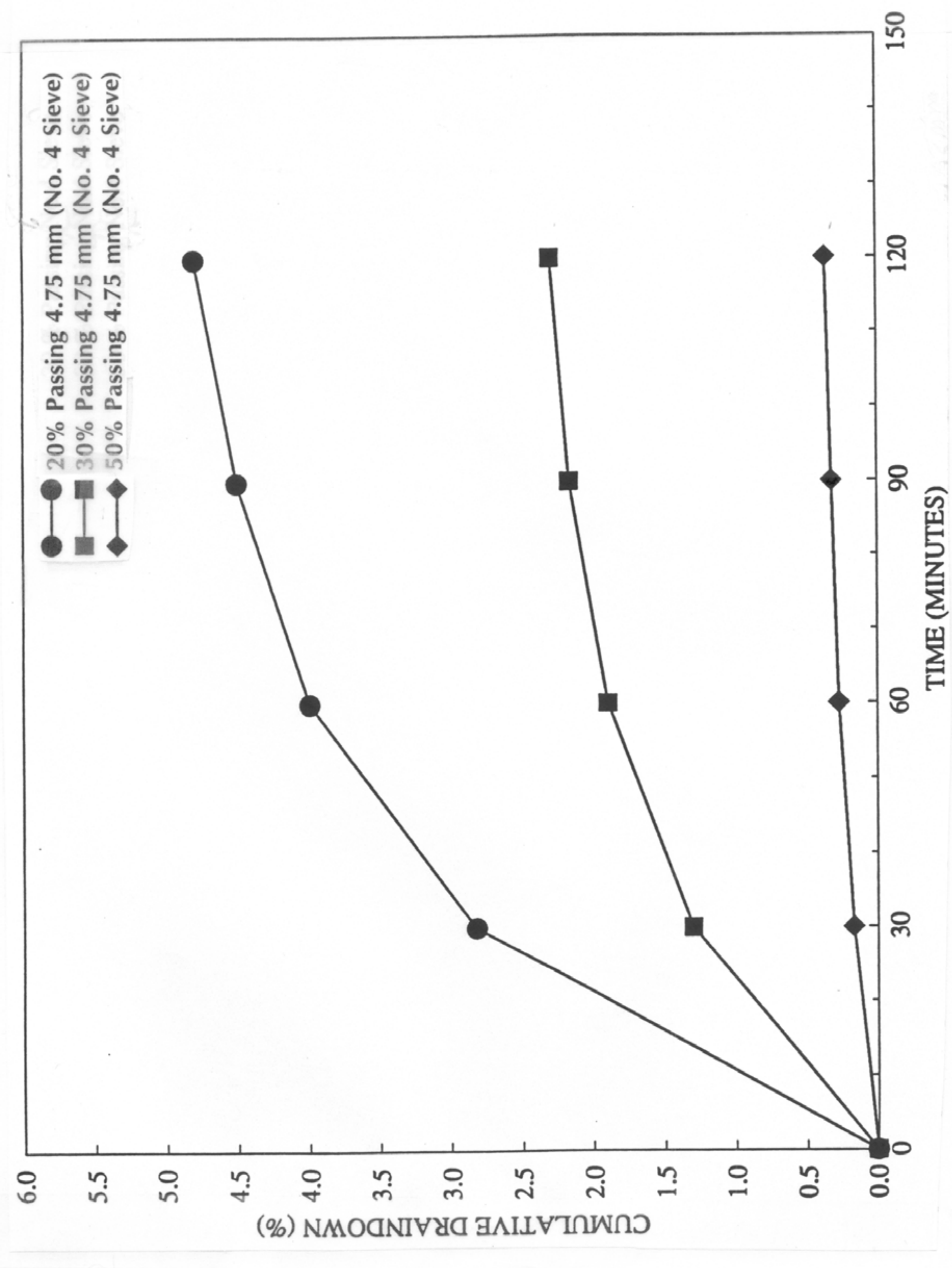

Figure 20. Draindown versus Time for Mixes with Different Percentages of Material Passing 4.75 mm (No. 4) Sieve

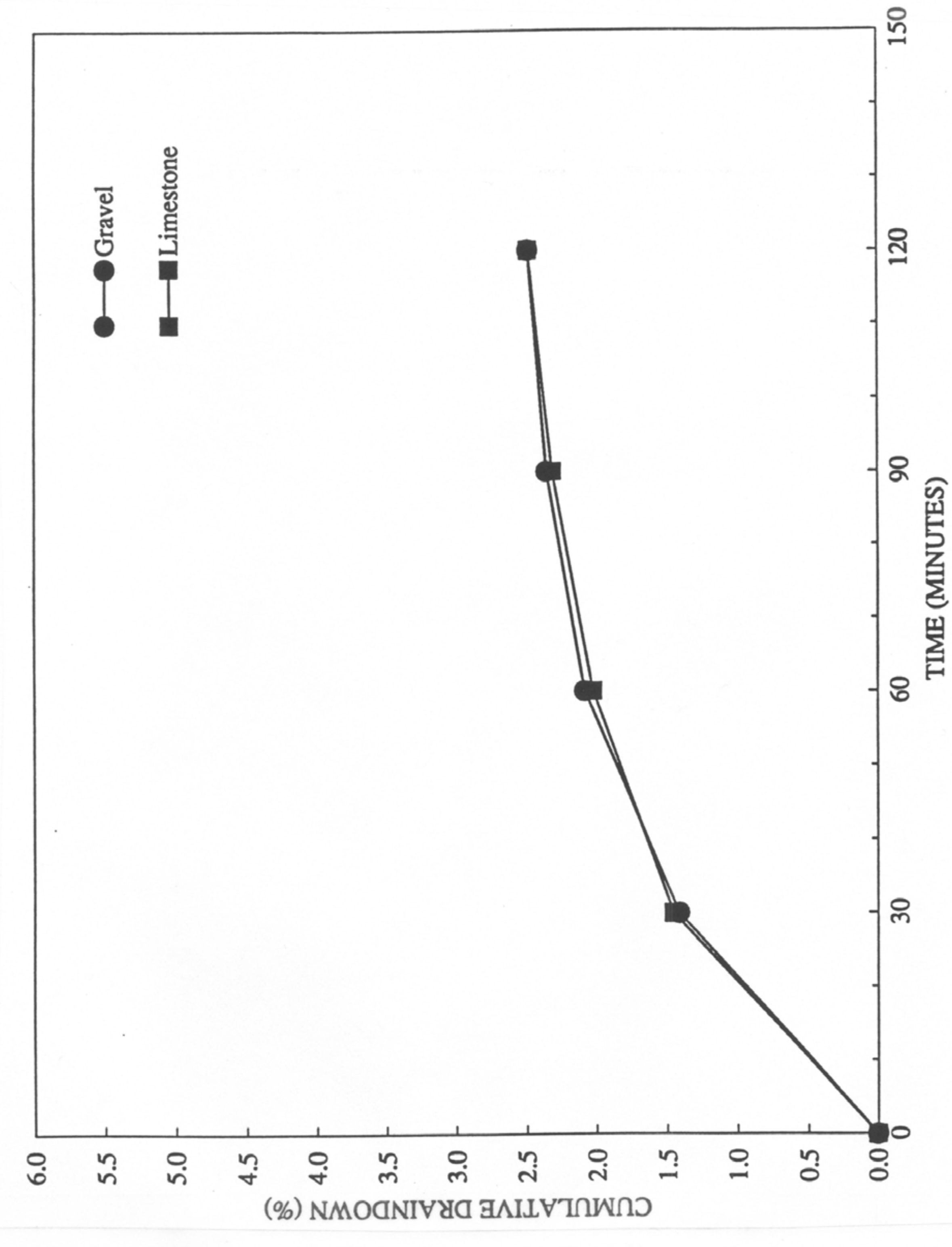

Figure 21. Draindown versus Time for Mixes with Different Types of Aggregates

Table 13. Summary of Analysis of Variance Results of Draindown Tests of Gravel Mixes (Results at 120 Minutes Used)

Source	DF	Type 1 SS	Mean Square	F Value	Pr > F
Filler	1	461.70	461.70	128.37	0.0001
Percent Passing 4.75 mm (No. 4) Sieve	2	774.32	387.16	107.65	0.0001
Fiber	6	421.91	70.32	19.55	0.0001
% AC	1	204.84	204.84	56.95	0.0001

Note: SS - Sum of Squares
DF - Degrees of Freedom
Pr - Probability

Table 14. Summary of Analysis of Variance Results of Draindown Tests of Limestone Mixes (Results at 120 Minutes Used)

Source	DF	Type 1 SS	Mean Square	F Value	Pr > F
Filler	1	639.31	639.31	153.94	0.0001
Percent Passing 4.75 mm (No. 4) Sieve	2	887.25	443.63	106.82	0.0001
Fiber	6	199.02	33.17	7.99	0.0001
% AC	1	295.36	295.36	71.12	/0.0001

Note: SS - Sum of Squares
DF - Degrees of Freedom
Pr - Probability

Table 15. Grouping of Variables on the Basis of Draindown Values of Gravel Mixes (Results at 120 Minutes Used)

Variable	Type of Value of Variable	Mean Value of Draindown (%)	Group
AC Content	7%	3.37	A
	6%	1.57	B
Filler	Marble	3.82	A
	Baghouse Fines	1.12	B
Percent Passing 4.75 mm (No. 4) Sieve	20	4.72	A
	30	2.27	B
	50	0.44	C
Additive	Control (Plain)	3.88	A
	Vestoplast, 3%	3.70	A
	Vestoplast, 8%	3.43	A
	Mineral Fiber, 0.1%	3.13	A
	European Fiber, 0.1%	1.68	B
	Mineral Fiber, 0.3%	1.13	C B
	European Fiber, 0.3%	0.36	C

Note: Means with the same letter are not significantly different
Levels of significance, alpha = 0.05

Table 16. Grouping of Variables on the Basis of Draindown Values of Limestone Mixes (Results at 120 Minutes Used)

Variable	Type of Value of Variable	Mean Value of Draindown (%)	Group
AC Content	7%	3.56	A
	6%	1.39	B
Filler	Marble	4.07	A
	Baghouse Fines	0.89	B
Percent Passing 4.75 mm (No. 4) Sieve	20	4.86	A
	30	2.31	B
	50	0.27	C
Additive	Vestoplast, 3%	3.53	A
	Control (Plain)	3.16	A
	European Fiber, 0.1%	2.84	A
	Mineral Fiber, 0.1%	2.78	A
	Vestoplast, 8%	2.78	A
	European Fiber, 0.3%	1.22	B
	Mineral Fiber, 0.3%	1.13	B

Note: Means with the same letter are not significantly different
Levels of significance, alpha = 0.05

Correlation of Properties of Marshall and COE GTM Specimens

Plots of air voids against total number of revolutions in the COE GTM are shown in Figures 22 and 23 for granite and limestone respectively. The plots were developed with an SMA mixture having three percent air voids when compacted with 50 blows of the Marshall mechanical hammer. The raw data is presented in Appendix C. It is observed from the best fit line that for gravel mixes 73 revolutions in the COE GTM correlates with 50 blows with a mechanical Marshall hammer in terms of air voids. For limestone approximately 103 revolutions in the COE GTM, set at one degree angle and 120 psi, produced similar air voids as produced by 50 blows with a mechanical Marshall hammer. Work in the past at NCAT has involved use of the COE GTM. Any fuure work should require 90 revolutions with the COE GTM to get a density similar to that with the Marshall hammer. The 90 revolutions required for SMA is much less than the 300 revolutions that have been used to compact dense graded mixtures to a density equivalent to 75 blow Marshall compaction. Figures 22 and 23 show that 90 revolutions with the GTM produced average air voids of 2.8 and 3.5 respectively. This verifies that 90 revolutions in the GTM is a reasonable estimate of 50 blow mechanical Marshall for SMA mixes.

Evaluation of Stone-on-Stone Contact in SMA Mixes

The variations of voids in mineral aggregate (VMA) and voids in coarse aggregate (VCA) with percent of fines are shown in Figures 24 and 25 for gravel and limestone respectively. The VCA for the dry rodded weight is also shown as an indication of the point where stone-to-stone contact begins to occur. The raw data is presented in Appendix D. From the plots it appears that at around 30 percent passing the No. 4 Sieve stone-to-stone contact begins to occur in both gravel and limestone mixes, since the slope of VCA changes significantly around that point and the VMA begins to increase as the percent passing the No. 4 is decreased below 30 percent. Also, VCA with no fine aggregate as determined from the dry rodded test lies very near to the 30 percent passing the No. 4 Sieve point in both the mixes. This indicates that the dry rodded test can likely be used to determine the density of the coarse aggregate required for stone-on-stone contact. It is believed that stone-on-stone contact occurs when the density of the coarse aggregate in the SMA mixture is equal to or higher than that measured in the dry rodded test.

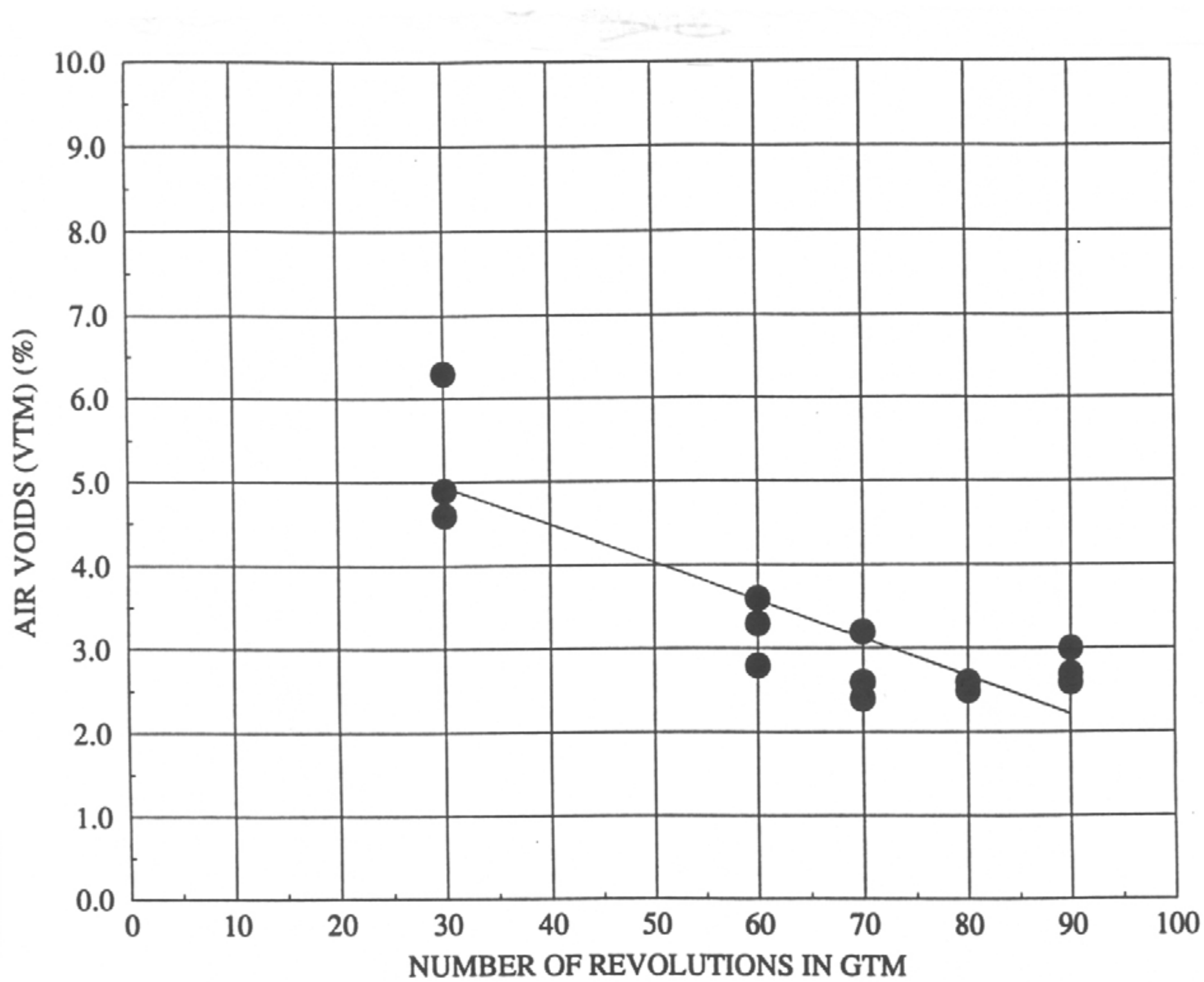

Figure 22. Correlation of Air Voids with Number of Revolutions in COE GTM for Gravel Mix

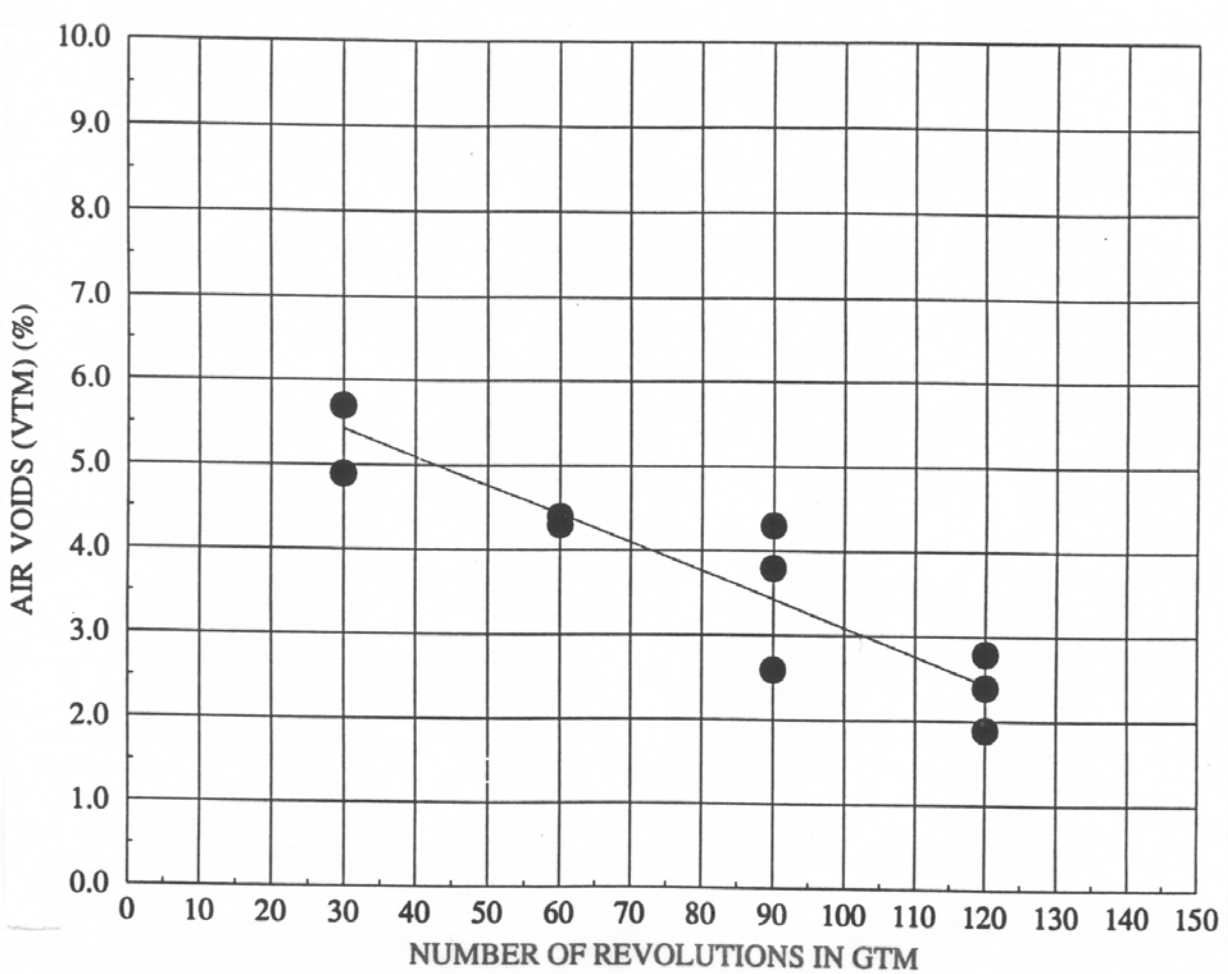

Figure 23. Correlation of Air Voids with Number of Revolutions in COE GTM for Limestone Mix

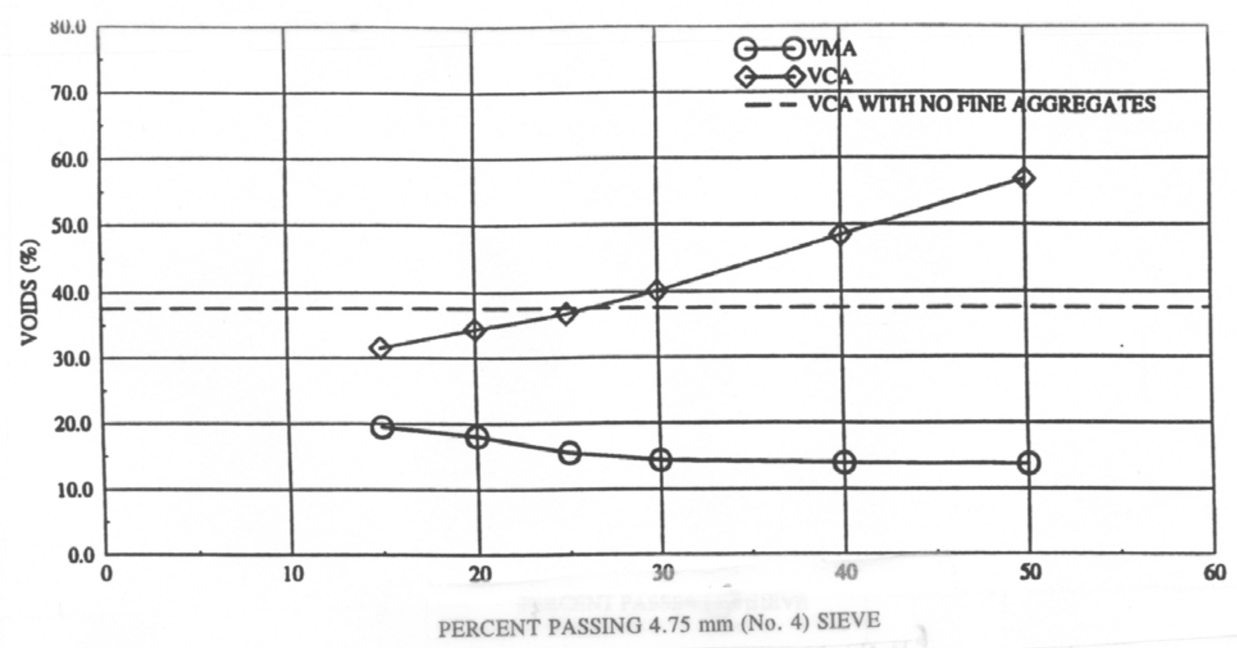

Figure 24. Variation of Voids with Percent Passing No. 4 Sieve for Gravel Mix

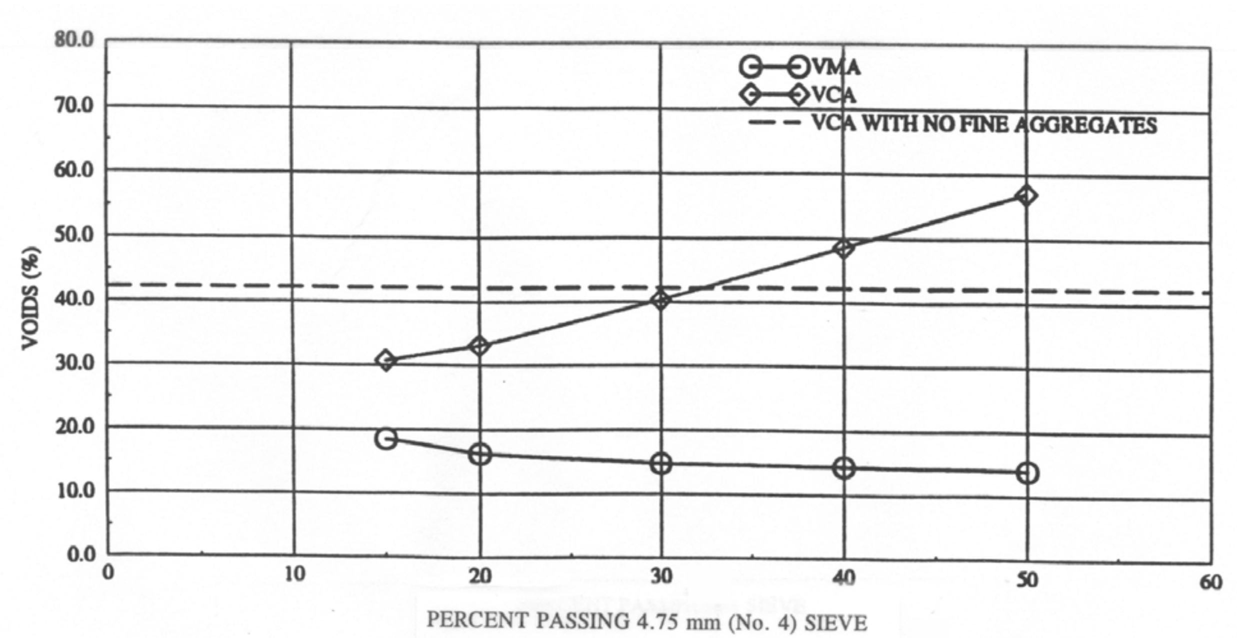

Figure 25. Variation of Voids with Percent Passing 4.75 (No. 4) Sieve for Limestone Mix

This study has identified three possible ways to ensure stone-on-stone contact in the coarse aggregate portion of SMA mixtures. The first way is to develop a plot of voids in coarse aggregate versus percent passing the No. 4 Sieve. In this series of tests the percent passing the No. 4 Sieve is decreased to a point at which the straight line relationship begins to curve. This curve is caused by the development of stone-on-stone contact which prevents a closer packing of the coarse aggregate as the amount of fine aggregate is reduced. This occurs at approximately 30 percent passing the No. 4 Sieve for the two mixtures evaluated (Figures 24 and 25).

A second method that appears to have some possibility of identifying when stone-on-stone contact in the coarse aggregate fraction occurs is the voids in mineral aggregate plot. This data is generated at the same time as the VCA data so no extra testing is required. As the percent passing the No. 4 Sieve is decreased the VMA plot is essentially flat until stone-on-stone contact begins to develop then the VMA begins to increase. This increase in VMA results because the coarse aggregate can not be moved closer together with a reduction in the percentage of fine aggregate when stone-on-stone contact exists. This method can be used to estimate the point at which stone-on-stone contact occurs in a similar way as the VCA method. However, both of these methods require a significant amount of testing.

A third method that was tried in the project to measure stone-on-stone contact involved using the dry rodded test for coarse aggregate. This test can be used to determine the voids in a dry rodded (compacted) coarse aggregate. Only coarse aggregate is used in this test and the dry rodded condition is a measure of stone-on-stone contact. As long as the density of the coarse aggregate is equal to or exceeds the dry rodded density, then stone-on-stone contact should exist. This condition can also be quantified by VCA rather than density. This is a very simple test and involves very little time. It appears from Figures 24 and 25 that this method gives about the same results as the VCA and VMA methods described earlier. These new methods seem promising but more data needs to be generated and other possible methods of measuring stone-on-stone contact should be evaluated.

Evaluation of Creep Properties of SMA mix with Different Percents Passing the No. 4 Sieve

The dynamic creep test has been used for some time at NCAT and in other laboratories to evaluate rutting potential of HMA. Results to date seem to indicate that this test is a good indicator of rutting potential.

Plots of creep strain and modulus against percent of fines are shown in Figures 26 through 29. The raw data is presented in Appendix E.

From Figures 26 and 27 it is observed that gravel creep strain increases with an increase in percent passing the No. 4 Sieve, with an initial drop in strain at 25 percent passing the No. 4 Sieve. The creep modulus decreases with an increase in percent passing the No. 4 Sieve after exceeding the peak value at 25 percent passing. From Figures 28 and 29 it is observed for limestone that strain decreases with an increase in percent passing the No. 4 Sieve and modulus increases with an increase in percent passing the No. 4 Sieve. However, both strain and modulus reach optimum values at approximately 25 percent passing the No. 4 Sieve. In both gravel and limestone it is observed that strain values are higher and creep modulus values are lower for the SMA mix than the corresponding dense mixes.

The data appears to indicate that there is an optimum amount of material passing the No. 4 Sieve. Above or below this optimum amount will provide a mix less susceptible to rutting. The optimum gradation for the two aggregates evaluated appears to be approximately 25 percent passing the No. 4 Sieve. Obviously this should be evaluated further before definite criteria is

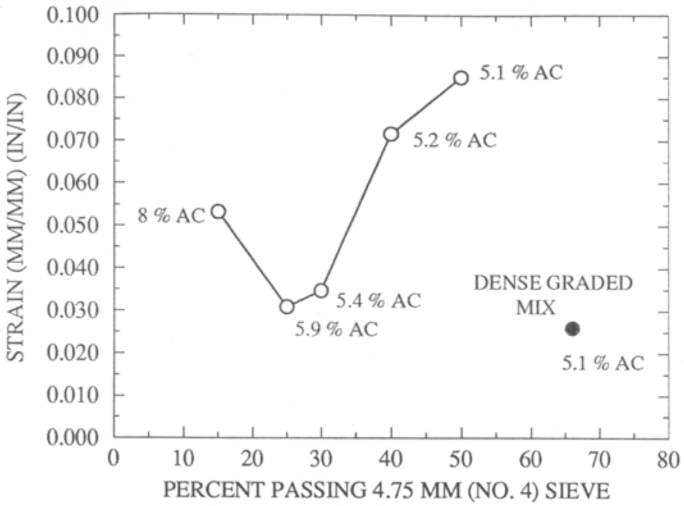

Figure 26. Variation of Creep Strain with Percent Passing the 4.75 mm (No. 4) sieve for SMA Gravel Mix

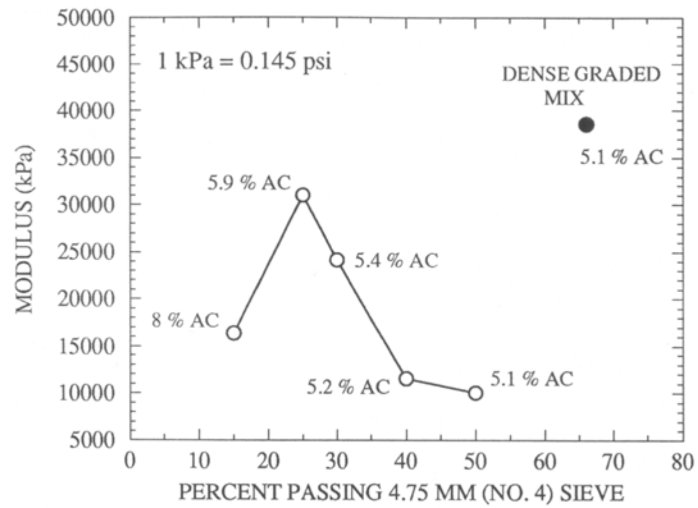

Figure 27. Variation of Creep Modulus with Percent Passing the 4.75 mm (No. 4) sieve for SMA Gravel Mix

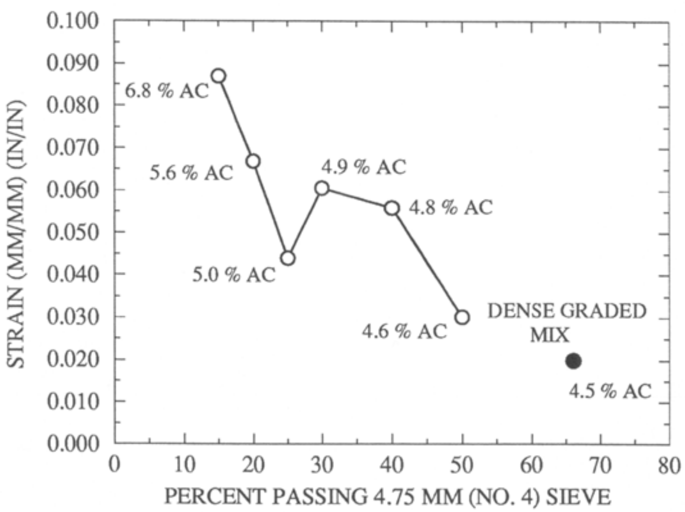

Figure 28. Variation of Creep Strain with Percent Passing the 4.75 mm (No. 4) sieve for SMA Limestone Mix

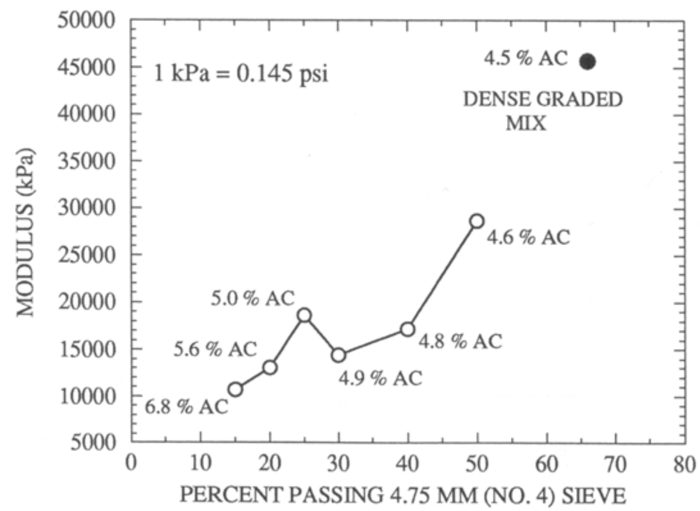

Figure 29. Variation of Creep Modulus with Percent Passing the 4.75 mm (No. 4) sieve for SMA Limestone Mix

established but the data developed in this report supports the 25 percent passing. The data for creep tests seem to show that the dense graded mix would be more resistant to rutting than SMA mixtures. These numbers are not significantly different for the gravel mix but are significant for the limestone mix. However, data from actual performance shows that SMA mixes do a better job of resisting rutting. One possible explanation for this is that these mixtures were evaluated at optimum asphalt content only. Past work at NCAT has shown that dense graded mixtures are more sensitive to changes in asphalt content than SMA mixtures. If these mixtures were evaluated over a range of asphalt contents that would include normal variations in the design and production of HMA, the SMA mixture would likely do better. Work needs to be performed to compare SMA and dense mixes over a range of asphalt contents to help show the advantages of SMA over dense graded mixes.

CONCLUSIONS

On the basis of the studies carried out to evaluate different properties of SMA mixes the following conclusions can be made.

1. Variability in optimum asphalt content of SMA mixes is significantly greater than that for dense graded mixes. The variability of theoretical maximum specific gravity values is approximately the same for both SMA and dense graded mixes. The variability in VMA for SMA mixes is approximately the same as that for dense graded mixes.
2. Draindown of asphalt cement in SMA mixes is significantly affected by type of filler, percent passing the 4.75 mm (No. 4) sieve (higher percent passing-lower draindown), asphalt content (higher asphalt content-higher draindown), type of stabilizer, and amount of stabilizer (higher amount of stabilizer-lower draindown). Mix temperature is a major factor but it was not evaluated in this study. The mixes with 0.3 percent cellulose or 0.3 percent mineral fiber exhibited lower draindown than the mixes with lower stabilizer rates or the polymer. The draindown test developed at NCAT is a fast, simple and inexpensive test that appears to quantitatively evaluate the draindown potential of an SMA mixture.
3. For gravel mixes, 73 revolutions in the Corps of Engineers Gyratory Testing Machine gave similar air voids as produced by 50 blows of a fixed base mechanical Marshall hammer. For limestone mixes the number of revolutions was found to be around 103. Hence it is recommended that 90 revolutions be used for SMA mixtures if a correlation can not be developed. At this time, the GTM should be used for research only. Mix designs should be performed with the Marshall mechanical hammer until additional research is performed to fully evaluate other compaction methods.
4. Plots of VMA and VCA can be used to identif if stone-to-stone contact exists. For the mixture evaluated in this study, stone-on-stone contact in the coarse aggregate portion began to occur at around 30 percent passing the No. 4 Sieve. The dry rodded test appears to be an easy way to determine the VCA necessary for stone-on-stone contact. These three methods appear to give similar results.
5. For both gravel and limestone mixes strain values are found to be higher and creep modulus values are found to be lower than those of the corresponding dense graded mixes. These findings are contrary to observed field performance. The optimum condition for SMA appears to occur at approximately 25 percent passing the No. 4 Sieve.

RECOMMENDATIONS

It is recommended that further research be carried out to observe and evaluate the following:

1. Effect of mixture temperature on draindown.
2. Effect of amount and size of material passing the No. 200 Sieve on draindown.
3. Effect of normal variations in mixture proportions on laboratory properties of SMA and dense graded mixes.

4. Comparison of laboratory draindown results with draindown in the field.
5. A mix design procedure to ensure a mix is selected with stone-on-stone contact that is not susceptible to draindown.

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APPENDIX A

RESULTS OF DRAINDOWN STUDY

Project: SMA- Drainage

Aggregate = Gravel
Filler = Bag House Fines
Gradation = 20 percent passing #4
10 percent passing #200 Mix A

	Time	6 Percent AC				7 Percent AC			
		Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
No additives plain AC-20	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.81	0.38	0.67	0.62	5.26	4.86	4.90	5.01
	60 min	1.22	0.56	1.01	0.93	6.55	6.14	6.22	6.30
	90 min	1.62	0.67	1.18	1.15	6.98	6.59	6.64	6.74
	120 min	1.78	0.75	1.30	1.28	7.09	6.84	6.87	6.93
European fiber 0.1% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.52	0.23	0.33	0.36	2.70	2.53	2.47	2.57
	60 min	1.06	0.40	0.59	0.68	4.30	3.55	3.73	3.86
	90 min	1.21	0.44	0.71	0.79	4.99	4.15	4.42	4.52
	120 min	1.39	0.47	0.82	0.89	5.33	4.47	4.76	4.85
European fiber 0.3% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.09	0.05	0.08	0.07	1.35	1.26	1.25	1.29
	60 min	0.19	0.17	0.17	0.18	2.28	2.12	2.17	2.19
	90 min	0.24	0.26	0.26	0.25	3.00	2.88	2.84	2.91
	120 min	0.29	0.30	0.30	0.30	3.42	3.24	3.19	3.28
Mineral fiber 0.1% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.13	0.11	0.10	0.11	2.20	3.89	2.79	2.96
	60 min	0.22	0.18	0.18	0.19	3.61	5.62	4.48	4.57
	90 min	0.26	0.19	0.21	0.22	4.30	6.11	5.14	5.18
	120 min	0.29	0.23	0.24	0.25	4.57	6.33	5.39	5.43
Mineral fiber 0.3% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.03	0.02	0.03	0.02	0.32	0.31	0.17	0.27
	60 min	0.04	0.03	0.05	0.04	0.48	0.33	0.27	0.36
	90 min	0.04	0.04	0.07	0.05	0.60	0.46	0.35	0.47
	120 min	0.05	0.04	0.08	0.06	0.65	0.52	0.40	0.53
Vestoplast 3% of binder	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.49	0.48	0.50	0.49	2.14	2.85	2.71	2.57
	60 min	0.74	0.74	0.75	0.74	3.73	5.02	4.31	4.35
	90 min	0.90	0.90	0.90	0.90	4.32	5.53	4.88	4.91
	120 min	1.00	0.98	0.99	0.99	4.51	5.76	5.10	5.12
Vestoplast 3% of binder	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.06	0.10	0.12	0.09	1.39	1.26	1.25	1.30
	60 min	0.09	0.18	0.22	0.16	2.60	2.37	2.43	2.47
	90 min	0.20	0.26	0.31	0.25	3.52	3.38	3.44	3.45
	120 min	0.31	0.32	0.39	0.34	4.18	4.05	4.09	4.11

Project: SMA- Drainage

Aggregate = Gravel
Filler = Bag House Fines
Gradation = 30 percent passing #4
10 percent passing #200 Mix B

	Time	6 Percent AC				7 Percent AC			
		Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
No additives plain AC-20	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.08	0.12	0.11	0.10	1.08	0.92	0.95	0.98
	60 min	0.15	0.21	0.19	0.19	1.65	1.39	1.46	1.50
	90 min	0.23	0.28	0.26	0.26	1.94	1.67	1.76	1.79
	120 min	0.23	0.29	0.26	0.26	2.07	1.81	1.91	1.93
European fiber 0.1% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.02	0.01	0.01	0.01	0.32	0.27	0.33	0.31
	60 min	0.06	0.03	0.03	0.04	0.58	0.45	0.57	0.53
	90 min	0.09	0.04	0.03	0.05	0.68	0.51	0.65	0.61
	120 min	0.09	0.04	0.03	0.06	0.68	0.58	0.72	0.66
European fiber 0.3% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	60 min	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.01
	90 min	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.01
	120 min	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.01
Mineral fiber 0.1% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.03	0.07	0.05	0.05	0.40	0.84	0.66	0.63
	60 min	0.10	0.18	0.13	0.14	0.64	1.06	0.95	0.89
	90 min	0.12	0.20	0.17	0.17	0.82	1.11	1.02	0.98
	120 min	0.12	0.23	0.19	0.18	0.94	1.22	1.11	1.09
Mineral fiber 0.3% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.00	0.00	0.00	0.00	0.09	0.19	0.15	0.15
	60 min	0.00	0.00	0.00	0.00	0.20	0.40	0.33	0.31
	90 min	0.00	0.00	0.00	0.00	0.30	0.64	0.48	0.47
	120 min	0.00	0.00	0.00	0.00	0.35	0.82	0.56	0.57
Vestoplast 3% of binder	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.14	0.09	0.11	0.11	1.38	1.26	1.27	1.30
	60 min	0.26	0.22	0.21	0.23	2.32	2.18	2.18	2.22
	90 min	0.36	0.31	0.29	0.32	2.74	2.64	2.73	2.71
	120 min	0.40	0.36	0.33	0.36	3.04	2.92	3.00	2.98
Vestoplast 3% of binder	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.13	0.07	0.10	0.10	0.34	0.58	0.46	0.46
	60 min	0.29	0.14	0.17	0.20	0.84	1.03	0.89	0.92
	90 min	0.35	0.23	0.25	0.27	1.06	1.26	1.15	1.16
	120 min	0.37	0.25	0.29	0.30	1.24	1.45	1.37	1.35

Project: SMA- Drainage

Aggregate = Gravel
Filler = Bag House Fines
Gradation = 50 percent passing #4
10 percent passing #200 Mix C

	Time	6 Percent AC				7 Percent AC			
		Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
No additives plain AC-20	0 min 30 min 60 min 90 min 120 min	0.00 0.03 0.04 0.04 0.04	0.00 0.03 0.04 0.04 0.04	0.00 0.05 0.07 0.08 0.08	0.00 0.04 0.05 0.05 0.05	0.00 0.24 0.34 0.38 0.41	0.00 0.18 0.25 0.34 0.41	0.00 0.22 0.29 0.35 0.39	0.00 0.21 0.29 0.36 0.40
European fiber 0.1% of mix	0 min 30 min 60 min 90 min 120 min	0.00 0.08 0.10 0.11 0.11	0.00 0.10 0.13 0.14 0.16	0.00 0.09 0.14 0.15 0.16	0.00 0.09 0.12 0.13 0.15	0.00 0.07 0.08 0.14 0.19	0.00 0.09 0.18 0.24 0.28	0.00 0.08 0.14 0.20 0.23	0.00 0.08 0.14 0.19 0.23
European fiber 0.3% of mix	0 min 30 min 60 min 90 min 120 min	0.00 0.09 0.09 0.10 0.10	0.00 0.06 0.06 0.07 0.07	0.00 0.07 0.08 0.09 0.09	0.00 0.07 0.08 0.09 0.09	0.00 0.11 0.14 0.19 0.20	0.00 0.08 0.09 0.10 0.12	0.00 0.10 0.11 0.11 0.11	0.00 0.10 0.12 0.13 0.14
Mineral fiber 0.1% of mix	0 min 30 min 60 min 90 min 120 min	0.00 0.09 0.09 0.09 0.09	0.00 0.08 0.08 0.08 0.08	0.00 0.08 0.08 0.08 0.08	0.00 0.08 0.08 0.08 0.08	0.00 0.15 0.26 0.34 0.35	0.00 0.16 0.25 0.34 0.35	0.00 0.18 0.30 0.36 0.39	0.00 0.16 0.27 0.35 0.36
Mineral fiber 0.3% of mix	0 min 30 min 60 min 90 min 120 min	0.00 0.04 0.05 0.05 0.05	0.00 0.03 0.03 0.03 0.03	0.00 0.05 0.06 0.06 0.06	0.00 0.04 0.05 0.05 0.05	0.00 0.10 0.13 0.14 0.14	0.00 0.13 0.19 0.22 0.22	0.00 0.12 0.16 0.17 0.17	0.00 0.12 0.16 0.18 0.18
Vestoplast 3% of binder	0 min 30 min 60 min 90 min 120 min	0.00 0.17 0.23 0.23 0.23	0.00 0.15 0.22 0.25 0.25	0.00 0.11 0.18 0.22 0.23	0.00 0.14 0.21 0.23 0.24	0.00 0.40 0.54 0.63 0.67	0.00 0.24 0.43 0.58 0.66	0.00 0.24 0.40 0.51 0.57	0.00 0.29 0.46 0.57 0.63
Vestoplast 3% of binder	0 min 30 min 60 min 90 min 120 min	0.00 0.14 0.16 0.16 0.16	0.00 0.15 0.19 0.20 0.20	0.00 0.18 0.24 0.26 0.26	0.00 0.16 0.20 0.20 0.20	0.00 0.08 0.12 0.13 0.13	0.00 0.10 0.14 0.17 0.18	0.00 0.13 0.18 0.20 0.22	0.00 0.10 0.15 0.17 0.17

Project: SMA- Drainage

Aggregate = Gravel
Filler = Marble
Gradation = 20 percent passing #4
10 percent passing #200 Mix A

	Time	6 Percent AC				7 Percent AC			
		Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
No additives plain AC-20	0 min 30 min 60 min 90 min 120 min	0.00 3.89 7.93 8.89 9.43	0.00 4.10 7.87 8.81 9.33	0.00 4.46 7.21 8.21 8.73	0.00 4.15 7.67 8.64 9.16	0.00 8.46 10.32 11.08 11.19	0.00 7.47 10.44 11.09 11.30	0.00 7.71 10.33 11.01 11.19	0.00 7.88 10.37 11.06 11.22
European fiber 0.1% of mix	0 min 30 min 60 min 90 min 120 min	0.00 0.81 1.86 2.46 2.68	0.00 0.86 1.88 2.56 2.67	0.00 0.94 1.96 2.64 2.84	0.00 0.87 1.90 2.55 2.73	0.00 6.00 8.05 8.47 8.59	0.00 5.79 7.91 8.34 8.45	0.00 6.16 8.04 8.45 8.56	0.00 5.98 8.00 8.42 8.53
European fiber 0.3% of mix	0 min 30 min 60 min 90 min 120 min	0.00 0.04 0.05 0.06 0.09	0.00 0.03 0.03 0.04 0.06	0.00 0.03 0.04 0.05 0.06	0.00 0.03 0.04 0.05 0.07	0.00 0.13 0.18 0.19 0.23	0.00 0.15 0.18 0.19 0.21	0.00 0.13 0.16 0.18 0.19	0.00 0.14 0.17 0.19 0.21
Mineral fiber 0.1% of mix	0 min 30 min 60 min 90 min 120 min	0.00 4.28 7.02 7.47 7.79	0.00 4.09 6.67 7.22 7.51	0.00 4.19 6.69 7.30 7.61	0.00 4.19 6.79 7.33 7.63	0.00 8.80 10.29 10.67 10.73	0.00 8.45 10.03 10.54 10.59	0.00 8.39 9.77 10.21 10.25	0.00 8.55 10.03 10.47 10.53
Mineral fiber 0.3% of mix	0 min 30 min 60 min 90 min 120 min	0.00 1.70 2.84 3.41 3.63	0.00 1.61 2.71 3.39 3.59	0.00 1.64 2.73 3.34 3.52	0.00 1.65 2.76 3.38 3.58	0.00 3.63 5.63 6.06 6.18	0.00 3.31 5.34 5.78 5.93	0.00 3.14 5.07 5.48 5.63	0.00 3.36 5.35 5.77 5.91
Vestoplast 3% of binder	0 min 30 min 60 min 90 min 120 min	0.00 3.13 6.97 7.99 8.49	0.00 3.51 7.43 8.56 9.10	0.00 3.24 6.99 8.05 8.57	0.00 3.30 7.13 8.20 8.72	0.00 8.46 9.97 10.51 10.71	0.00 8.35 10.14 10.78 10.11	0.00 8.11 10.34 11.04 11.41	0.00 8.31 10.15 10.78 11.07
Vestoplast 3% of binder	0 min 30 min 60 min 90 min 120 min	0.00 1.82 4.08 5.72 6.57	0.00 2.38 4.69 6.07 6.83	0.00 2.64 5.32 6.61 7.38	0.00 2.28 4.70 6.13 6.93	0.00 8.08 10.60 11.64 11.92	0.00 6.26 9.89 10.85 11.26	0.00 6.83 9.82 10.83 11.20	0.00 7.06 10.10 11.10 11.46

Project: SMA- Drainage

Aggregate = Gravel
Filler = Marble
Gradation = 30 percent passing #4
10 percent passing #200 Mix B

	Time	6 Percent AC				7 Percent AC			
		Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
No additives plain AC-20	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	2.62	2.39	2.28	2.43	6.17	5.53	5.72	5.81
	60 min	4.08	3.87	3.84	3.93	7.67	7.30	7.50	7.49
	90 min	4.70	4.79	4.66	4.71	8.77	8.07	7.75	8.20
	120 min	5.13	5.99	5.96	5.03	9.26	8.29	7.89	8.48
European fiber 0.1% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.19	0.09	0.15	0.14	0.89	0.46	0.66	0.67
	60 min	0.28	0.19	0.24	0.24	0.99	0.69	0.88	0.85
	90 min	0.33	0.20	0.28	0.27	1.04	0.70	0.95	0.90
	120 min	0.34	0.20	0.31	0.28	1.05	0.72	0.95	0.91
European fiber 0.3% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.05	0.03	0.02	0.03	0.03	0.00	0.02	0.01
	60 min	0.05	0.04	0.03	0.04	0.03	0.00	0.03	0.02
	90 min	0.05	0.05	0.03	0.04	0.03	0.00	0.04	0.03
	120 min	0.05	0.05	0.03	0.04	0.03	0.00	0.04	0.03
Mineral fiber 0.1% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	1.61	1.54	1.62	1.59	6.27	4.68	4.02	4.99
	60 min	2.59	2.33	2.36	2.42	7.73	6.60	5.72	6.68
	90 min	3.08	2.57	2.63	2.76	7.99	6.93	5.95	6.96
	120 min	3.36	2.57	2.85	3.00	8.13	7.13	6.09	7.12
Mineral fiber 0.3% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.31	0.31	0.43	0.35	1.36	0.56	0.69	0.87
	60 min	0.55	0.55	0.60	0.57	2.06	0.60	0.96	1.21
	90 min	0.63	0.63	0.66	0.64	2.28	0.74	1.11	1.38
	120 min	0.68	0.67	0.73	0.70	2.45	0.95	1.21	1.54
Vestoplast 3% of binder	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	3.67	4.27	3.75	3.90	5.27	4.89	4.72	4.96
	60 min	5.14	5.65	4.95	5.25	6.81	6.27	6.17	6.41
	90 min	5.63	5.97	5.46	5.69	7.37	6.77	6.58	6.90
	120 min	5.84	6.14	5.62	5.87	7.65	7.00	6.77	7.14
Vestoplast 3% of binder	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	1.91	1.53	1.69	1.71	5.51	5.22	4.80	5.18
	60 min	4.13	2.91	3.44	3.50	8.05	7.59	7.03	7.56
	90 min	4.89	3.85	4.75	4.50	8.74	8.43	8.12	8.43
	120 min	5.37	4.26	5.00	4.88	9.11	8.69	8.37	8.72

Project: SMA- Drainage

Aggregate = Gravel
Filler = Marble
Gradation = 50 percent passing #4
10 percent passing #200 Mix C

	Time	6 Percent AC				7 Percent AC			
		Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
No additives plain AC-20	0 min 30 min 60 min 90 min 120 min	0.00 0.08 0.14 0.15 0.17	0.00 0.19 0.26 0.28 0.33	0.00 0.09 0.16 0.17 0.17	0.00 0.12 0.19 0.20 0.23	0.00 0.42 0.89 1.13 1.35	0.00 0.76 1.26 1.65 1.94	0.00 0.61 1.10 1.36 1.61	0.00 0.60 1.08 1.38 1.63
European fiber 0.1% of mix	0 min 30 min 60 min 90 min 120 min	0.00 0.03 0.04 0.04 0.04	0.00 0.02 0.04 0.05 0.05	0.00 0.03 0.05 0.06 0.06	0.00 0.03 0.05 0.05 0.05	0.00 0.58 0.81 0.90 0.93	0.00 0.49 0.83 0.93 0.94	0.00 0.35 0.61 0.70 0.72	0.00 0.48 0.75 0.84 0.86
European fiber 0.3% of mix	0 min 30 min 60 min 90 min 120 min	0.00 0.08 0.08 0.08 0.08	0.00 0.03 0.03 0.03 0.03	0.00 0.02 0.03 0.03 0.03	0.00 0.04 0.05 0.05 0.05	0.00 0.08 0.13 0.16 0.16	0.00 0.05 0.09 0.11 0.11	0.00 0.03 0.08 0.10 0.11	0.00 0.05 0.10 0.12 0.13
Mineral fiber 0.1% of mix	0 min 30 min 60 min 90 min 120 min	0.00 0.05 0.11 0.15 0.20	0.00 0.04 0.12 0.20 0.23	0.00 0.07 0.13 0.17 0.20	0.00 0.05 0.12 0.17 0.21	0.00 0.55 1.18 1.57 1.71	0.00 0.59 1.18 1.70 1.87	0.00 0.50 1.01 1.42 1.60	0.00 0.55 1.12 1.56 1.73
Mineral fiber 0.3% of mix	0 min 30 min 60 min 90 min 120 min	0.00 0.09 0.09 0.10 0.10	0.00 0.07 0.09 0.11 0.11	0.00 0.08 0.09 0.11 0.11	0.00 0.08 0.09 0.11 0.11	0.00 0.13 0.24 0.33 0.41	0.00 0.14 0.25 0.34 0.41	0.40 0.17 0.27 0.35 0.40	0.00 0.15 0.26 0.34 0.41
Vestoplast 3% of binder	0 min 30 min 60 min 90 min 120 min	0.00 0.18 0.22 0.27 1.32	0.00 0.14 0.16 0.20 0.27	0.00 0.15 0.21 0.24 0.26	0.00 0.15 0.20 0.24 0.28	0.00 0.46 0.72 0.96 1.09	0.00 0.40 0.65 0.84 0.94	0.00 0.41 0.72 0.89 1.00	0.00 0.43 0.69 0.89 1.01
Vestoplast 3% of binder	0 min 30 min 60 min 90 min 120 min	0.00 0.07 0.26 0.39 0.48	0.00 0.13 0.25 0.35 0.43	0.00 0.14 0.26 0.35 0.43	0.00 0.11 0.26 0.36 0.44	0.00 1.33 1.86 2.21 2.36	0.00 1.18 1.61 1.95 2.08	0.00 1.11 1.66 2.11 2.19	0.00 1.21 1.71 2.09 2.21

Project: SMA- Drainage

Aggregate = Limestone
Filler = Bag House Fines
Gradation = 20 percent passing #4
10 percent passing #200 Mix A

	Time	6 Percent AC				7 Percent AC			
		Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
No additives	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
plain AC-20	30 min	0.19	0.07	0.11	0.12	1.71	1.23	1.32	1.42
	60 min	0.33	0.15	0.21	0.23	3.09	2.33	2.60	2.67
	90 min	0.41	0.19	0.23	0.28	3.88	2.99	3.30	3.39
	120 min	0.46	0.26	0.29	0.34	4.07	3.15	3.47	3.56
European	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fiber 0.1%	30 min	0.00	0.00	0.00	0.00	0.59	0.58	0.49	0.55
of mix	60 min	0.01	0.03	0.03	0.02	1.35	1.52	1.32	1.40
	90 min	0.03	0.05	0.07	0.05	2.54	2.68	2.36	2.53
	120 min	0.05	0.09	0.12	0.09	3.89	3.94	3.51	3.78
European	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fiber 0.3%	30 min	0.03	0.03	0.03	0.03	0.10	0.15	0.13	0.13
of mix	60 min	0.03	0.03	0.04	0.03	0.19	0.30	0.26	0.25
	90 min	0.03	0.03	0.04	0.03	0.25	0.40	0.33	0.33
	120 min	0.03	0.03	0.04	0.04	0.35	0.51	0.44	0.44
Mineral	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fiber 0.1%	30 min	0.04	0.13	0.10	0.09	1.49	0.79	1.27	1.18
of mix	60 min	0.10	0.31	0.28	0.23	3.67	2.64	3.55	3.29
	90 min	0.19	0.53	0.50	0.40	6.27	5.13	6.30	5.90
	120 min	0.29	0.84	0.73	0.62	9.16	8.04	9.41	8.87
Mineral	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fiber 0.3%	30 min	0.18	0.02	0.07	0.09	0.08	0.22	0.13	0.14
of mix	60 min	0.25	0.03	0.12	0.13	0.18	0.35	0.25	0.26
	90 min	0.27	0.04	0.14	0.15	0.28	0.40	0.35	0.34
	120 min	0.29	0.04	0.17	0.17	0.36	0.46	0.40	0.41
Vestoplast	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3% of	30 min	0.22	0.47	0.36	0.35	2.24	1.86	1.76	1.96
binder	60 min	0.75	0.80	0.68	0.74	4.61	4.37	4.29	4.42
	90 min	1.14	1.04	0.95	1.04	6.96	5.45	5.56	5.99
	120 min	1.45	1.23	1.20	1.29	7.48	6.40	6.22	6.70
Vestoplast	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3% of	30 min	0.07	0.03	0.05	0.05	0.67	1.03	0.72	0.81
binder	60 min	0.14	0.09	0.12	0.12	1.47	2.13	1.65	1.75
	90 min	0.17	0.21	0.20	0.20	2.06	2.79	2.29	2.38
	120 min	0.20	0.24	0.25	0.23	2.51	3.49	2.77	2.92

Project: SMA- Drainage

Aggregate = Limestone
Filler = Bag House Fines
Gradation = 30 percent passing #4
10 percent passing #200 Mix B

	Time	6 Percent AC				7 Percent AC			
		Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
No additives plain AC-20	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.11	0.10	0.12	0.11	0.53	0.70	0.61	0.61
	60 min	0.27	0.29	0.27	0.28	0.76	0.94	0.83	0.84
	90 min	0.45	0.44	0.41	0.44	0.92	1.10	1.01	1.01
	120 min	0.60	0.56	0.54	0.57	1.05	1.25	1.14	1.15
European fiber 0.1% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.01	0.03	0.02	0.02	0.07	0.06	0.10	0.08
	60 min	0.04	0.03	0.04	0.04	0.12	0.13	0.16	0.14
	90 min	0.04	0.03	0.05	0.04	0.14	0.14	0.20	0.16
	120 min	0.04	0.03	0.05	0.04	0.15	0.14	0.22	0.17
European fiber 0.3% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.02	0.01	0.03	0.02	0.03	0.02	0.04	0.03
	60 min	0.03	0.03	0.04	0.03	0.05	0.05	0.07	0.06
	90 min	0.04	0.03	0.07	0.05	0.07	0.06	0.08	0.07
	120 min	0.04	0.03	0.08	0.05	0.12	0.07	0.09	0.09
Mineral fiber 0.1% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.05	0.03	0.06	0.05	0.34	0.46	0.41	0.41
	60 min	0.07	0.04	0.09	0.07	0.54	0.80	0.71	0.68
	90 min	0.09	0.06	0.10	0.08	0.63	1.17	0.95	0.92
	120 min	0.11	0.08	0.12	0.10	0.80	1.49	0.12	1.14
Mineral fiber 0.3% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.02	0.03	0.03	0.03	0.07	0.07	0.08	0.07
	60 min	0.03	0.04	0.03	0.05	0.12	0.09	0.13	0.12
	90 min	0.04	0.04	0.07	0.05	0.14	0.10	0.19	0.14
	120 min	0.04	0.04	0.08	0.05	0.15	0.10	0.20	0.15
Vestoplast 3% of binder	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.10	0.13	0.16	0.13	0.31	0.33	0.35	0.33
	60 min	0.13	0.16	0.24	0.18	0.51	0.51	0.54	0.52
	90 min	0.15	0.22	0.29	0.22	0.59	0.62	0.67	0.63
	120 min	0.15	0.24	0.32	0.24	0.64	0.68	0.72	0.68
Vestoplast 3% of binder	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.06	0.04	0.06	0.05	0.14	0.29	0.24	0.22
	60 min	0.08	0.06	0.09	0.08	0.33	0.41	0.40	0.38
	90 min	0.09	0.07	0.10	0.09	0.37	0.51	0.47	0.45
	120 min	0.09	0.07	0.11	0.09	0.41	0.56	0.53	0.50

Project: SMA- Drainage

Aggregate = Limestone
Filler = Bag House Fines
Gradation = 50 percent passing #4
10 percent passing #200 Mix C

	Time	6 Percent AC				7 Percent AC			
		Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
No additives plain AC-20	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.06	0.05	0.07	0.06	0.03	0.02	0.06	0.03
	60 min	0.06	0.06	0.08	0.07	0.03	0.03	0.08	0.05
	90 min	0.06	0.06	0.09	0.07	0.05	0.03	0.09	0.06
	120 min	0.06	0.06	0.09	0.07	0.05	0.03	0.10	0.06
European fiber 0.1% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.09	0.04	0.06	0.06	0.03	0.03	0.06	0.04
	60 min	0.09	0.04	0.09	0.07	0.05	0.04	0.08	0.06
	90 min	0.09	0.04	0.09	0.07	0.07	0.05	0.08	0.06
	120 min	0.09	0.04	0.09	0.07	0.07	0.06	0.08	0.07
European fiber 0.3% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.04	0.03	0.05	0.04	0.18	0.10	0.13	0.14
	60 min	0.05	0.03	0.06	0.05	0.34	0.16	0.21	0.24
	90 min	0.05	0.03	0.06	0.05	0.55	0.23	0.32	0.37
	120 min	0.05	0.03	0.06	0.05	0.62	0.25	0.39	0.42
Mineral fiber 0.1% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.03	0.02	0.04	0.03	0.08	0.17	0.13	0.12
	60 min	0.03	0.03	0.06	0.04	0.14	0.19	0.19	0.17
	90 min	0.03	0.03	0.07	0.05	0.15	0.21	0.21	0.19
	120 min	0.03	0.04	0.07	0.05	0.16	0.21	0.22	0.20
Mineral fiber 0.3% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.04	0.02	0.05	0.04	0.07	0.04	0.06	0.06
	60 min	0.05	0.03	0.07	0.05	0.09	0.07	0.10	0.09
	90 min	0.05	0.03	0.08	0.05	0.13	0.09	0.12	0.12
	120 min	0.05	0.03	0.08	0.05	0.19	0.11	0.13	0.14
Vestoplast 3% of binder	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.11	0.05	0.07	0.08	0.34	0.21	0.26	0.27
	60 min	0.15	0.09	0.12	0.12	0.82	0.46	0.50	0.59
	90 min	0.22	0.11	0.17	0.17	1.22	0.58	0.65	0.82
	120 min	0.26	0.11	0.20	0.19	1.36	0.68	0.74	0.93
Vestoplast 3% of binder	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.14	0.10	0.13	0.12	0.24	0.34	0.26	0.28
	60 min	0.16	0.11	0.17	0.15	0.27	0.41	0.31	0.33
	90 min	0.17	0.15	0.19	0.17	0.32	0.44	0.38	0.38
	120 min	0.18	0.17	0.20	0.18	0.40	0.46	0.42	0.43

Project: SMA- Drainage

Aggregate = Limestone
Filler = Marble
Gradation = 20 percent passing #4
10 percent passing #200 Mix A

	Time	6 Percent AC				7 Percent AC			
		Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
No additives plain AC-20	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	4.44	7.37	6.41	6.07	10.57	9.38	9.63	9.86
	60 min	6.69	9.47	6.73	7.63	11.68	10.86	10.28	10.94
	90 min	7.29	10.02	7.18	8.16	12.11	11.55	10.45	11.37
	120 min	7.51	10.17	7.41	8.36	12.28	11.76	10.65	11.56
European fiber 0.1% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	4.73	4.81	3.32	4.29	9.16	8.19	8.64	8.66
	60 min	6.63	6.77	5.18	6.19	10.41	9.80	10.02	10.08
	90 min	7.18	7.35	6.23	6.92	10.82	10.27	10.45	10.51
	120 min	7.52	7.80	6.51	7.28	11.18	10.52	10.77	10.82
European fiber 0.3% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.66	0.67	0.68	0.67	2.36	2.32	2.76	2.48
	60 min	0.95	1.17	0.98	1.03	3.50	3.09	5.42	4.00
	90 min	1.24	1.60	1.25	1.36	3.66	3.55	6.34	4.52
	120 min	1.50	2.06	1.55	1.70	3.78	3.68	6.86	4.77
Mineral fiber 0.1% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	2.83	2.83	2.53	2.73	7.17	7.84	6.87	7.29
	60 min	3.87	3.43	3.55	3.62	8.18	8.92	7.96	8.36
	90 min	4.18	3.91	3.92	4.00	8.34	9.27	8.25	8.62
	120 min	4.35	4.16	4.09	4.20	8.41	9.41	8.32	8.71
Mineral fiber 0.3% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.18	0.15	0.14	0.16	6.77	7.38	6.76	6.97
	60 min	0.22	0.20	0.19	0.20	8.50	8.61	8.12	8.41
	90 min	0.26	0.22	0.22	0.23	9.00	9.18	8.62	8.94
	120 min	0.26	0.23	0.23	0.24	9.32	9.32	8.79	9.10
Vestoplast 3% of binder	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	3.93	5.46	5.03	4.81	9.81	10.22	9.53	9.85
	60 min	6.32	7.92	7.44	7.23	11.21	11.82	11.13	11.39
	90 min	7.37	8.36	7.96	7.77	11.60	12.22	11.53	11.79
	120 min	7.36	8.67	8.21	8.08	11.74	12.39	11.69	11.94
Vestoplast 3% of binder	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	3.49	3.78	2.90	3.39	8.07	8.00	8.38	8.15
	60 min	6.21	6.76	5.85	6.27	10.26	10.35	11.07	10.56
	90 min	7.57	8.27	7.11	7.65	10.93	11.07	12.05	11.35
	120 min	8.05	8.79	7.88	8.24	11.21	11.32	12.42	11.65

Project: SMA- Drainage

Aggregate = Limestone
Filler = Marble
Gradation = 30 percent passing #4
10 percent passing #200 Mix B

	Time	6 Percent AC				7 Percent AC			
		Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
No additives plain AC-20	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	1.42	2.01	1.67	1.70	5.88	5.66	5.06	5.53
	60 min	2.05	2.95	2.50	2.50	7.97	7.59	7.29	7.62
	90 min	2.33	3.39	3.03	2.92	8.75	8.45	8.07	8.42
	120 min	2.57	3.66	3.34	3.19	8.94	8.71	8.28	8.64
European fiber 0.1% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	2.22	1.48	2.01	1.90	5.50	4.65	4.97	5.04
	60 min	3.10	2.41	3.00	2.83	7.21	6.38	6.74	6.78
	90 min	3.59	2.97	3.50	3.35	7.33	7.08	7.31	7.31
	120 min	3.88	3.38	3.81	3.69	7.70	7.24	7.57	7.50
European fiber 0.3% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.78	1.06	0.92	0.92	3.01	3.14	2.82	2.99
	60 min	1.14	1.47	1.31	1.31	4.40	4.20	3.99	4.20
	90 min	1.34	1.68	1.49	1.50	5.20	4.85	4.71	4.92
	120 min	1.53	1.81	1.64	1.66	5.64	5.23	5.04	5.30
Mineral fiber 0.1% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.70	0.96	0.85	0.83	3.89	5.87	4.42	4.72
	60 min	1.16	1.44	1.37	1.32	5.54	7.95	6.20	6.56
	90 min	1.41	1.78	1.39	1.63	6.26	8.51	6.87	7.21
	120 min	1.54	1.97	1.84	1.78	6.46	8.77	7.03	7.42
Mineral fiber 0.3% of mix	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.28	0.22	0.25	0.25	1.34	1.04	0.99	1.12
	60 min	0.43	0.39	0.39	0.41	1.62	1.28	1.28	1.39
	90 min	0.54	0.47	0.49	0.50	1.68	1.36	1.44	1.49
	120 min	0.57	0.49	0.51	0.53	1.74	1.41	1.51	1.55
Vestoplast 3% of binder	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	1.57	1.21	1.33	1.37	3.43	4.56	4.39	4.13
	60 min	2.58	2.22	2.35	2.38	5.38	6.40	6.24	6.01
	90 min	3.24	2.86	2.98	3.03	6.99	7.04	7.04	7.02
	120 min	3.30	3.31	3.08	3.23	7.42	7.32	7.29	7.34
Vestoplast 3% of binder	0 min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 min	0.35	0.33	0.36	0.35	4.20	1.85	2.19	2.75
	60 min	0.81	0.73	0.68	0.74	6.19	4.28	4.54	5.00
	90 min	1.20	1.00	0.99	1.06	7.20	5.37	5.76	6.11
	120 min	1.29	1.15	1.12	1.12	7.78	5.90	6.36	6.68

Project: SMA- Drainage

Aggregate = Limestone
Filler = Marble
Gradation = 50 percent passing #4
10 percent passing #200 Mix C

	Time	6 Percent AC				7 Percent AC			
		Rep 1	Rep 2	Rep 3	Mean	Rep 1	Rep 2	Rep 3	Mean
No additives plain AC-20	0 min 30 min 60 min 90 min 120 min	0.00 0.04 0.05 0.05 0.05	0.00 0.03 0.04 0.04 0.04	0.00 0.05 0.07 0.07 0.07	0.00 0.04 0.05 0.05 0.05	0.00 0.23 0.30 0.36 0.47	0.00 0.15 0.19 0.19 0.25	0.00 0.21 0.29 0.33 0.38	0.00 0.20 0.26 0.30 0.37
European fiber 0.1% of mix	0 min 30 min 60 min 90 min 120 min	0.00 0.12 0.14 0.15 0.15	0.00 0.15 0.20 0.22 0.22	0.00 0.14 0.17 0.19 0.20	0.00 0.14 0.17 0.19 0.19	0.00 0.19 0.28 0.34 0.35	0.00 0.22 0.33 0.40 0.42	0.00 0.16 0.27 0.35 0.37	0.00 0.19 0.29 0.36 0.38
European fiber 0.3% of mix	0 min 30 min 60 min 90 min 120 min	0.00 0.08 0.09 0.09 0.10	0.00 0.09 0.10 0.11 0.11	0.00 0.11 0.14 0.14 0.14	0.00 0.09 0.11 0.12 0.12	0.00 0.10 0.12 0.12 0.12	0.00 0.06 0.07 0.07 0.07	0.00 0.07 0.08 0.08 0.08	0.00 0.08 0.09 0.09 0.09
Mineral fiber 0.1% of mix	0 min 30 min 60 min 90 min 120 min	0.00 0.04 0.06 0.06 0.06	0.00 0.05 0.08 0.08 0.08	0.00 0.06 0.08 0.09 0.09	0.00 0.05 0.07 0.07 0.07	0.00 0.11 0.23 0.25 0.34	0.00 0.14 0.23 0.27 0.33	0.00 0.12 0.19 0.22 0.24	0.00 0.12 0.22 0.25 0.30
Mineral fiber 0.3% of mix	0 min 30 min 60 min 90 min 120 min	0.00 0.03 0.03 0.03 0.03	0.00 0.02 0.03 0.03 0.03	0.00 0.03 0.04 0.04 0.05	0.00 0.02 0.03 0.03 0.04	0.00 0.03 0.03 0.03 0.03	0.00 0.03 0.04 0.07 0.08	0.00 0.03 0.05 0.07 0.08	0.00 0.03 0.04 0.06 0.06
Vestoplast 3% of binder	0 min 30 min 60 min 90 min 120 min	0.00 0.10 0.14 0.16 0.17	0.00 0.08 0.13 0.15 0.16	0.00 0.09 0.15 0.17 0.18	0.00 0.09 0.14 0.16 0.17	0.00 0.94 1.24 1.36 1.38	0.00 1.05 1.50 1.66 1.71	0.00 0.89 1.43 1.60 1.67	0.00 0.96 1.39 1.54 1.59
Vestoplast 3% of binder	0 min 30 min 60 min 90 min 120 min	0.00 0.11 0.14 0.20 0.21	0.00 0.15 0.20 0.26 0.26	0.00 0.09 0.13 0.15 0.17	0.00 0.12 0.16 0.20 0.22	0.00 0.43 0.70 0.96 1.14	0.00 0.41 0.73 0.98 1.16	0.00 0.45 0.69 0.95 1.11	0.00 0.43 0.71 0.96 1.14

APPENDIX B

RESULTS OF STATISTICAL ANALYSIS OF DRAINDOWN DATA

The SAS System **2**
21:58 Monday, November 8, 1993

Analysis Variable: DRAIN120

N	Mean	Std Dev	Minimum	Maximum
252	2.4754762	3.2977002	0	11.9200000

The SAS System 3
21:58 Monday, November 8, 1993

General Linear Models Procedure
Class Level Information

Class	Levels	Values
Filler	2	BAGFINE MARBLE
No. 4 Pass	3	20 30 50
Fiber	7	EURO.1 EURO.3 MINO.1 Plain VES3.0 VES8.0
AC Pcnt	2	6 7

Number of observations in data set = 252

The SAS System **4**
21:58 Monday, November 8, 1993

General Linear Models Procedure

Dependent Variable: DRAIN120

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	1862.78605	186.27861	51.79	0.0001
Error	241	866.79539	3.59666		
Corrected Total	251	2729.58144			
	R-Square	C.V.	Root MSE	Drain120	Mean
	0.682444	76.61098	1.89649		2.47548

General Linear Models Procedure

Dependent Variable: DRAIN120

Source	DF	Type I SS	Mean Square	F Value	Pr > F
FILLER	1	461.703214	461.703214	128.37	0.0001
N04 PASS	2	774.328036	387.164018	107.65	0.0001
FIBER	6	421.914165	70.319028	19.55	0.0001
AC-PCNT	1	204.840635	204.840635	56.95	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
FILLER	1	461.703214	461.703214	128.37	0.0001
N04 PASS	2	774.328036	387.164018	107.65	0.0001
FIBER	6	421.914165	70.319028	19.55	0.0001
AC-PCNT	1	204.840635	204.840635	56.95	0.0001

General Linear Models Procedure

Duncan's Multiple Range Test for variable: DRAIN120

NOTE: This test controls the type I comparison-wise error rate, not the experiment-wise error rate

Alpha= 0.05 df= 241 MSE= 3.596661

Number of Means	2
Critical Range	.4747

Means with the same letter are not significantly different

Duncan Grouping	Mean	N	FILLER
A	3.8290	126	MARBLE
B	1.1219	126	BAGFINE

The SAS System **7**
21:58 Monday, November 8, 1993

General Linear Models Procedure

Duncan's Multiple Range Test for variable: DRAIN120

NOTE: This test controls the type I comparison-wise error rate, not the experiment-wise error rate

Alpha= 0.05 df= 241 MSE= 3.596661

Number of Means	2	3
Critical Range	.5813	.6113

Means with the same letter are not significantly different

Duncan Grouping	Mean	N	N04_PASS
A	4.7189	84	20
B	2.2671	84	30

The SAS System **8**
21:58 Monday, November 8, 1993

General Linear Models Procedure

Duncan Grouping	Mean	N	N04_PASS
C	0.4404	84	50

The SAS System **9**
21:58 Monday, November 8, 1993

General Linear Models Procedure

Duncan’s Multiple Range Test for variable: DRAIN120

NOTE: This test controls the type I Comparison-wise error rate, not the experiment-wise error rate

Alpha= 0.05 df= 241 MSE= 3.596661

Number of Means	2	3	4	5	6	7
Critical Range	0.888	0.934	0.963	0.985	1.004	1.019

Means with the same letter are not significantly different

Duncan Grouping	Mean	N	FIBER
A	3.8842	36	PLAIN
A	3.7025	36	VES3.O

General Linear Models Procedure

Duncan Grouping		Mean	N	FIBER
	A			
	A	3.4272	36	VES8.O
	A			
	A	3.1339	36	MINO.1
	B	1.6836	36	EURO.1
	B			
C	B	1.1347	36	MINO.3
C				
C		0.3622	36	EURO.3

General Linear Models Procedure

Duncan's Multiple Range Test for variable: DRAIN120

NOTE: This test controls the type I Comparison-wise error rate, not the experiment-wise error rate

Alpha= 0.05 df= 241 MSE= 3.596661

Number of Means	2
Critical Range	.4747

Means with the same letter are not significantly different

Duncan Grouping	Mean	N	AC_PCNT
A	3.3771	126	7
B	1.5739	126	6

The SAS System **1**
23:40 Monday, November 8, 1993

Analysis Variable : DRAIN120

N	Mean	Std Dev	Minimum	Maximum
252	2.4825397	3.4697387	0.0300000	12.4200000

The SAS System **2**
23:40 Monday, November 8, 1993

General Linear Models Procedure
Class Level Information

Class	Levels	Values
Filler	2	BAGFINE MARBLE
No. 4 Pass	3	20 30 50
Fiber	7	EURO.1 EURO.3 MINO.1 Plain VES3.0 VES8.0
AC Pcnt	2	6 7

Number of observations in data set = 252

The SAS System **3**
23:40 Monday, November 8, 1993

General Linear Models Procedure

Dependent Variable: DRAIN120

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	2020.94813	202.09481	48.66	0.0001
Error	241	1000.86264	4.15296		
Corrected Total	251	3021.81077			
	R-Square	C.V.	Root MSE	Drain120	Mean
	0.668787	82.08854	2.03788		2.48254

The SAS System **4**
23:40 Monday, November 8, 1993

General Linear Models Procedure

Dependent Variable: DRAIN120

Source	DF	Type I SS	Mean Square	F Value	Pr > F
FILLER	1	639.309144	639.309144	153.94	0.0001
N04 PASS	2	887.254363	443.627181	106.82	0.0001
FIBER	6	199.024497	33.170749	7.99	0.0001
AC-PCNT	1	295.360129	295.360129	71.12	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
FILLER	1	639.309144	639.309144	153.94	0.0001
N04 PASS	2	887.254363	443.627181	106.82	0.0001
FIBER	6	199.024497	33.170749	7.99	0.0001
AC-PCNT	1	295.360129	295.360129	71.12	0.0001

The SAS System **5**
23:40 Monday, November 8, 1993

General Linear Models Procedure

Duncan's Multiple Range Test for variable: DRAIN120

NOTE: This test controls the type I comparison-wise error rate, not the experiment-wise error rate

Alpha= 0.05 df= 241 MSE= 4.152957

Number of Means	2
Critical Range	.5100

Means with the same letter are not significantly different

Duncan Grouping	Mean	N	FILLER
A	4.0753	126	MARBLE
B	0.8898	126	BAGFINE

The SAS System **6**
23:40 Monday, November 8, 1993

General Linear Models Procedure

Duncan's Multiple Range Test for variable: DRAIN120

NOTE: This test controls the type I comparison-wise error rate, not the experiment-wise error rate

Alpha= 0.05 df= 241 MSE= 4.152957

Number of Means	2	3
Critical Range	.6247	.6569

Means with the same letter are not significantly different

Duncan Grouping	Mean	N	N04_PASS
A	4.8613	84	20
B	2.3117	84	30

The SAS System **7**
23:40 Monday, November 8, 1993

General Linear Models Procedure

Duncan Grouping	Mean	N	N04_PASS
C	0.2746	84	50

The SAS System **8**
23:40 Monday, November 8, 1993

General Linear Models Procedure

Duncan's Multiple Range Test for variable: DRAIN120

NOTE: This test controls the type I comparison-wise error rate, not the experiment-wise error rate

Alpha= 0.05 df= 241 MSE= 4.152957

Number of Means	2	3	4	5	6	7
Critical Range	0.954	1.003	1.035	1.059	1.079	1.095

Means with the same letter are not significantly different

Duncan Grouping	Mean	N	FIBER
A	3.5314	36	VES3.0
A			
B	3.1603	36	PLAIN

The SAS System **9**
23:40 Monday, November 8, 1993

General Linear Models Procedure

Duncan Grouping	Mean	N	FIBER
A			
A	2.8403	36	EURO.1
A			
A	2.7892	36	MINO.1
A			
A	2.7883	36	VES8.0
B	1.2272	36	EURO.3
B			
B	1.0411	36	MINO.3

The SAS System **10**
23:40 Monday, November 8, 1993

General Linear Models Procedure

Duncan's Multiple Range Test for variable: DRAIN120

NOTE: This test controls the type I comparison-wise error rate, not the experiment-wise error rate

Alpha= 0.05 df= 241 MSE= 4.152957

Number of Means	2
Critical Range	.5100

Means with the same letter are not significantly different

Duncan Grouping	Mean	N	AC_PCNT
A	3.5652	126	7
B	1.3999	126	6

APPENDIX C

RAW DATA OF CORRELATION OF MARSHALL AND COE GTM SPECIMENS

OBJECTIVE: To find a correlation between air voids (VTM) and number of revolutions in the Corps of Engineers GTM at an asphalt content which gives 3.0 % air voids (VTM) when compacted by 50 blows of Marshall hammer.

RESULTS:

Granite SMA mix

50 blow Marshall results

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	Stab (lb)	Flow (0. 1 in)
50-1	5.5	147.0	2.474	4.8	16.0	70.3	2075	11
50-2	5.5	146.9	2.474	4.8	16.1	69.9	1850	10
50-3	5.5	146.8	2.474	4.9	16.2	69.5	1875	12
avg	5.5	146.9	2.474	4.8	16.1	69.9	1933	11
50-1	6.0	147.7	2.456	3.6	16,1	77.5	2050	13
50-2	6.0	147.2	2.456	4.0	16.4	75.9	2100	13
50-3	6.0	148.2	2.456	3.3	15.8	79.3	2075	14
avg	6.0	147.7	2.456	3.6	16.1	77.6	2075	13
50-1	6.5	147.4	2.438	3.1	16.7	81.4	1750	10
50-2	6.5	147.4	2.438	3. 1	16.7	81.5	1925	11
50-3	6.5	148.0	2.438	2.7	16.4	83.6	1950	13
avg	6.5	147.6	2.438	3.0	16.6	82.2	1875	11

Granite SMA mix

COE GTM results (First part of Spec. # indicates number of revolutions)

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	Stab (lb)	Flow (0. 1 in)
30-1	6.5	144.7	2.438	4.9	18.2	73.3	1200	18
30-2	6.5	145.2	2.438	4.6	18.0	74.5	1152	18
30-3	6.5	142.6	2.438	6.3	19.4	67.8	1032	18
avg	6.5	144.2	2.438	5.2	18.5	71.9	1128	18
60-1	6.5	147.9	2.438	2.8	16.4	83.2	1525	18
60-2	6.5	147.1	2.438	3.3	16.9	80.3	1550	18
60-3	6.5	146.7	2.438	3.6	17.1	79.1	1575	18
avg	6.5	147.2	2.438	3.2	16.8	80.9	1550	18

COE GTM results (First part of Spec. # indicates number of revolutions)

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	Stab (lb)	Flow (0. 1 in)
70-1	6.5	148.1	2.438	2.6	16.3	83.8	1550	16
70-2	6.5	147.3	2.438	3.2	16.8	81.0	1500	17
70-3	6.5	148.5	2.438	2.4	16.1	85.0	1450	14
avg	6.5	147.9	2.438	2.8	16.4	83.3	1500	16
80-1	6.5	148.3	2.438	2.5	16.2	84.4	1875	16
80-2	6.5	148.3	2.438	2.5	16.2	84.4	1550	17
80-3	6.5	148.2	2.438	2.6	16.3	84. 1	1525	15
avg	6.5	148.3	2.438	2.6	16.2	84.3	1650	16
90-1	6.5	148.0	2.438	2.7	16.4	83.4	1650	16
90-2	6.5	148.1	2.438	2.6	16.3	83.9	1750	15
90-3	6.5	147.6	2.438	3.0	16.6	82.0	1725	17
avg	6.5	147.9	2.438	2.8	16.4	83.1	1708	16

Limestone SMA mix

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	Stab (lb)	Flow (0. 1 in)
50-1	4.5	157.4	2.613	3.5	14.3	75.6	2337	9
50-2	4.5	156.2	2.613	4.2	15.0	71.8	2423	9
50-3	4.5	156.2	2.613	4.2	15.0	71.8	2109	11
avg	4.5	156.6	2.613	4.0	14.8	73.1	2290	10
50-1	4.6	158.0	2.609	2.9	14.1	79.1	2138	10
50-2	4.6	157.5	2.609	3.2	14.3	77.3	2280	10
50-3	4.6	156.9	2.609	3.6	14.7	75.2	2052	10
avg	4.6	157.5	2.609	3.3	14.4	77.2	2157	10
50-1	4.7	158.4	2.605	2.5	13.9	81.9	2223	9
50-2	4.7	158.2	2.605	2.7	14.1	80.8	2166	11
50-3	4.7	157.7	2.605	3.0	14.3	79.2	1966	12
avg	4.7	158.1	2.605	2.7	14.1	80.6	2119	11
50-1	4.8	159.0	2.600	2.0	13.7	85.3	2499	9
50-2	4.8	158.4	2.600	2.3	14.0	83.2	2138	9
50-3	4.8	158.2	2.600	2.5	14.1	82.5	2023	11
avg	4.8	158.5	2.600	2.3	14.0	83.7	2220	10

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	Stab (lb)	Flow (0. 1 in)
50-1	5.0	157.6	2.592	2.6	14.6	82.5	2280	13
50-2	5.0	158.0	2.592	2.3	14.4	84.1	2223	12
50-3	5.0	157.5	2.592	2.6	14.7	82.1	2052	10
avg	5.0	157.7	2.592	2.5	14.6	82.9	2185	12
50-1	5.5	156.2	2.571	2.6	15.9	83.3	2052	12
50-2	5.5	157.1	2.571	2.1	15.4	86.4	1881	12
50-3	5.5	157.0	2.571	2.1	15.4	86.2	1995	12
avg	5.5	156.8	2.571	2.3	15.5	85.3	1976	12
50-1	6.0	157.0	2.551	1.4	15.8	91.5	1852	13
50-2	6.0	156.0	2.551	2.0	16.4	87.7	1771	14
50-3	6.0	156.5	2.551	1.7	16.2	89.4	1744	15
avg	6.0	156.5	2.551	1.7	16.1	89.5	1789	14
50-1	6.5	155.8	2.530	1.3	16.9	92.4		
50-2	6.5	155.6	2.530	1.4	17.0	91.7	1635	16
50-3	6.5	156.1	2.530	1.1	16.8	93.4	1717	16
avg	6.5	155.9	2.530	1.3	16.9	92.5	1117	16

COE GTM results (first part of spec. # indicates number of revolutions)

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	Stab (lb)	Flow (0. 1 in)
30-1	4.6	153.5	2.609	5.7	16.5	65.3		
30-2	4.6	153.5	2.609	5.7	16.5	65.4		
30-3	4.6	154.8	2.609	4.9	15.8	68.8		
avg	4.6	153.9	2.609	5.5	16.3	66.5		
60-1	4.6	155.6	2.609	4.4	15.4	71.2		
60-2	4.6	155.8	2.609	4.3	15.3	71.7		
60-3	4.6	155.7	2.609	4.4	15.3	71.6		
avg	4.6	155.7	2.609	4.4	15.3	71.5		
90-1	4.6	155.8	2.609	4.3	15.3	71.8		
90-2	4.6	156.6	2.609	3.8	14.8	74.3		
90-3	4.6	158.6	2.609	2.6	13.7	81.2		
avg	4.6	157.0	2.609	3.6	14.6	75.8		
120-1	4.6	159.8	2.609	1.9	13.1	85.7		
120-2	4.6	158.9	2.609	2.4	13.6	82.4		
120-3	4.6	158.2	2.609	2.8	14.0	79.8		
	4.6	159.0	2.609	2.4	13.5	82.6		

APPENDIX D

RAW DATA OF EVALUATION OF STONE-TO-STONE CONTACT IN SMA MIX

OBJECTIVE: To observe the variation of VCA and VMA with changes in percent of materials passing # 4 sieve and infer at what point does stone-to-stone contact begin.

RESULTS:

Gravel SMA mix (compacted by 50 blow Marshall hammer)

MIX A (containing 50% of material passing # 4 sieve)

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	VCA
50-1	5.0	146.8	2.435	3.4	14.0	75.9	57.0
50-2	5.0	147.0	2.435	3.3	13.9	76.4	57.0
50-3	5.0	146.7	2.435	3.4	14.0	75.6	57.0
avg	5.0	146.8	2.435	3.4	14.0	76.0	57.0
50-1	5.5	146.9	2.418	2.6	14.4	81.7	57.2
50-2	5.5	147.7	2.418	2.1	13.9	84.8	57.0
50-3	5.5	148.2	2.418	1.8	13.7	86.9	56.8
avg	5.5	147.6	2.418	2.2	14.0	84.5	57.0
50-1	6.0	147.6	2.400	1.5	14.5	89.9	57.2
50-2	6.0	147.0	2.400	1.9	14.8	87.5	57.4
50-3	6.0	147.3	2.400	1.6	14.6	88.7	57.3
avg	6.0	147.3	2.400	1.7	14.6	88.7	57.3
50-1	6.5	146.7	2.384	1.4	15.4	91.2	57.7
50-2	6.5	146.8	2.384	1.3	15.3	91.5	57.7
50-3	6.5	146.7	2.384	1.4	15.4	90.9	57.7
avg	6.5	146.7	2.384	1.4	15.4	91.2	57.7
50-1	5.1	146.7	2.431	3.3	14.1	76.8	57.1
50-2	5.1	147.9	2.431	2.5	13.5	81.3	56.7
avg	5.1	147.3	2.431	2.9	13.8	79.1	56.9

MIX B (containing 40% of materials passing # 4 sieve)

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	VCA
50-1	5.0	146.8	2.435	3.4	14.0	75.9	48.4
50-2	5.0	146.0	2.435	3.9	14.5	73.0	48.7
50-3	5.0	146.5	2.435	3.6	14.2	74.9	48.5
avg	5.0	146.5	2.435	3.6	14.2	74.6	48.5

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	VCA
50-1	5.5	148.1	2.418	1.8	13.7	86.7	48.2
50-2	5.5	147.3	2.418	2.4	14.2	83.2	48.5
50-3	5.5	147.2	2.418	2.5	14.3	82.7	48.6
avg	5.5	147.5	2.418	2.2	14.0	84.2	48.4
50-1	6.0	147.5	2.401	1.5	14.5	89.4	48.7
50-2	6.0	147.4	2.401	1.6	14.6	89.0	48.7
50-3	6.0	147.0	2.401	1.9	14.8	87.2	48.9
avg	6.0	147.3	2.401	1.7	14.6	88.5	48.8
50-1	6.5	147.6	2.384	0.8	14.9	94.9	48.9
50-2	6.5	146.8	2.384	1.3	15.4	91.4	49.2
50-3	6.5	146.5	2.384	1.5	15.5	90.3	49.3
avg	6.5	147.0	2.384	1.2	15.3	92.2	49.2
50-1	5.2	147.0	2.429	3.0	14.1	78.5	48.5
50-2	5.2	147.0	2.429	3.0	14.1	78.7	48.4
50-3	5.2	147.3	2.429	2.8	13.9	79.8	48.3
avg	5.2	147.1	2.429	2.9	14.0	79.0	48.4

MIX C (containing 30% of materials passing # 4 sieve)

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	VCA
50-1	4.5	146.5	2.449	4.2	13.8	69.8	39.6
50-2	4.5	144.1	2.449	5.7	15.1	62.4	40.6
50-3	4.5	144.4	2.449	5.5	15.0	63.2	40.5
avg	4.5	145.0	2.449	5.1	14.6	65.1	40.2
50-1	5.0	144.8	2.431	4.5	15.2	70.2	40.6
50-2	5.0	145.2	2.431	4.3	15.0	71.2	40.5
50-3	5.0	144.1	2.431	5.0	15.6	67.8	40.9
avg	5.0	144.7	2.431	4.6	15.2	69.8	40.7
50-1	5.5	146.3	2.414	2.9	14.7	80.6	40.3
50-2	5.5	146.4	2.414	2.8	14.7	80.8	40.3
50-3	5.5	144.1	2.414	4.4	16.0	72.9	41.2
avg	5.5	145.6	2.414	3.3	15.2	78.1	40.6
50-1	6.0	146.4	2.397	2.1	15.1	86.1	40.6
50-2	6.0	146.6	2.397	2.0	15.0	86.9	40.5
50-3	6.0	146.9	2.397	1.8	14.9	87.9	40.4
avg	6.0	146.7	2.397	2.0	15.0	87.0	40.5

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	VCA
50-1	5.4	146.6	2.418	2.8	14.5	80.6	40.1
50-2	5.4	146.7	2.418	2.8	14.4	80.8	40.1
avg	5.4	146.7	2.418	2.8	14.4	80.7	40.1

MIX D (containing 20% of materials passing # 4 sieve)

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	VCA
50-1	4.5	141.2	2.446	7.5	16.9	55.6	33.5
50-2	4.5	141.1	2.446	7.6	16.9	55.3	33.5
50-3	4.5	141.2	2.446	7.5	16.8	55.6	33.5
avg	4.5	141.2	2.446	7.5	16.9	55.5	33.5
50-1	5.0	140.9	2.428	7.0	17.5	59.8	34.0
50-2	5.0	141.8	2.428	6.4	16.9	62.2	33.5
50-3	5.0	141.5	2.428	6.6	17.1	61.3	33.7
avg	5.0	141.4	2.428	6.7	17.2	61.1	33.7
50-1	5.5	141.9	2.411	5.7	17.3	67.1	33.9
50-2	5.5	142.9	2.411	5.0	16.8	69.9	33.4
50-3	5.5	142.0	2.411	5.6	17.3	67.4	33.8
avg	5.5	142.2	2.411	5.5	17.1	68.1	33.7
50-1	6.0	142.2	2.394	4.8	17.6	72.7	34.1
50-2	6.0	144.1	2.394	3.6	16.5	78.4	33.2
50-3	6.0	142.3	2.394	4.8	17.5	72.9	34.0
avg	6.0	142.8	2.394	4.4	17.2	74.6	33.8
50-1	6.6	142.2	2.374	4.0	18.1	77.1	34.5
50-2	6.6	142.4	2.374	3.9	18.0	78.5	34.4
50-3	6.6	142.3	2.374	3.9	18.0	78.3	34.4
avg	6.6	142.3	2.374	3.9	18.1	78.2	34.4

MIX E (containing 15% of materials passing # 4 sieve)

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	VCA
50-1	6.0	140.7	2.409	6.4	18.5	65.3	30.7
50-2	6.0	139.6	2.409	7.1	19.1	62.7	31.2
50-3	6.0	140.4	2.409	6.6	18.6	64.5	30.8
avg	6.0	140.2	2.409	6.7	18.7	64.2	30.9

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	VCA
50-1	6.5	140.4	2.392	5.9	19.0	69.0	31.2
50-2	6.5	140.6	2.392	5.8	19.0	69.3	31.1
50-3	6.5	140.8	2.392	5.7	18.8	69.8	31.0
avg	6.5	140.6	2.392	5.8	18.9	69.4	31.1
50-1	7.0	140.3	2.375	5.3	19.5	72.9	31.6
50-2	7.0	140.8	2.375	5.0	19.2	74.2	31.4
50-3	7.0	140.0	2.375	5.5	19.7	71.9	31.8
avg	7.0	140.4	2.375	5.3	19.5	73.0	31.6
50-1	7.5	141.6	2.359	3.8	19.2	80.2	31.4
50-2	7.5	141.3	2.359	4.0	19.4	79.3	31.5
50-3	7.5	141.0	2.359	4.2	19.6	78.5	31.6
avg	7.5	141.3	2.359	4.0	19.4	79.3	31.5
50-1	8.0	141.6	2.343	3.2	19.7	84.0	31.7
50-2	8.0	142.5	2.343	2.6	19.2	86.7	31.3
50-3	8.0	141.9	2.343	2.9	19.5	84.9	31.6
avg	8.0	142.0	2.343	2.9	19.5	85.2	31.5

MIX F (containing 25% of materials passing # 4 sieve)

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	VCA
50-1	5.7	144.0	2.414	4.4	16.2	73.1	37.2
50-2	5.7	145.3	2.414	3.5	15.5	77.3	36.6
50-3	5.7	144.6	2.414	4.0	15.9	75.0	36.9
avg	5.7	144.7	2.414	4.0	15.9	75.1	36.9
50-1	6.0	145.9	2.404	2.7	15.4	82.4	36.6
50-2	6.0	145.9	2.404	2.8	15.5	82.1	36.6
50-3	6.0	146.0	2.404	2.7	15.4	82.6	36.5
avg	6.0	145.9	2.404	2.7	15.4	82.4	36.6
50-1	6.5	145.4	2.386	2.3	16.2	85.6	37.1
50-2	6.5	145.8	2.386	2.1	15.9	87.0	37.0
50-3	6.5	145.5	2.386	2.3	16.1	85.8	37.1
avg	6.5	145.6	2.386	2.2	16.1	86.1	37. 1
50-1	7.5	144.3	2.353	1.7	17.7	90.4	38.3
50-2	7.5	144.3	2.353	1.7	17.7	90.4	38.3
50-3	7.5	144.6	2.353	1.5	17.5	91.4	38.1
avg	7.5	144.4	2.353	1.6	17.6	90.7	38.2

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	VCA
50-1	5.9	145.2	2.407	3.3	15.8	78.8	36.8
50-2	5.9	145.9	2.407	2.9	15.3	81.4	36.5
50-3	5.9	145.3	2.407	3.3	15.7	79.2	36.8
avg	5.9	145.5	2.407	3.2	15.6	79.8	36.7

VCA of dry rodded mix = 37.6 %

Limestone SMA mix (compacted by 50 blow Marshall hammer)

MIX A (containing 50% of materials passing # 4 sieve)

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	VCA
50-1	4.0	158.0	2.640	4.1	13.3	69.6	56.7
50-2	4.0	157.6	2.640	4.3	13.6	68.2	56.8
50-3	4.0	157.3	2.640	4.5	13.8	67.1	56.9
avg	4.0	157.6	2.640	4.3	13.6	68.3	56.8
50-1	4.5	157.8	2.619	3.4	13.9	75.3	57.0
50-2	4.5	157.9	2.619	3.4	13.9	75.7	56.9
50-3	4.5	158.3	2.619	3.1	13.7	77.1	56.8
avg	4.5	158.0	2.619	3.3	13.8	76.0	56.9
50-1	5.0	158.3	2.588	2.0	14.1	85.8	57.1
50-2	5.0	158.5	2.588	1.9	14.0	86.6	57.0
50-3	5.0	158.6	2.588	1.8	13.9	87.2	57.0
avg	5.0	158.4	2.588	1.9	14.0	86.6	57.0
50-1	5.5	158.6	2.567	1.0	14.4	93.0	57.2
50-2	5.5	158.3	2.567	1.2	14.6	92.0	57.3
50-3	5.5	158.2	2.567	1.2	14.6	91.5	57.3
avg	5.5	158.4	2.567	1.1	14.5	92.2	57.3
50-1	4.6	157.9	2.605	2.9	14.0	79.4	57.0
50-2	4.6	157.7	2.605	3.0	14.1	78.8	57.0
50-3	4.6	158.1	2.605	2.7	13.9	80.3	56.9
avg	4.6	157.9	2.605	2.9	14.0	79.5	57.0

MIX B (containing 40% of materials passing # 4 sieve)

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	VCA
50-1	4.0	157.6	2.640	4.3	13.6	68.2	48.1
50-2	4.0	156.6	2.640	4.9	14.1	65.1	48.5
50-3	4.0	156.2	2.640	5.2	14.3	64.0	48.6
avg	4.0	156.8	2.640	4.8	14.0	65.8	48.4
50-1	4.5	156.2	2.619	4.4	14.8	70.0	48.9
50-2	4.5	156.7	2.619	4.1	14.5	71.7	48.7
50-3	4.5	157.7	2.619	3.5	14.0	74.8	48.4
avg	4.5	156.8	2.619	4.0	14.5	72.2	48.7

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	VCA
50-1	5.0	158.2	2.588	2.0	14.1	85.7	48.5
50-2	5.0	158.1	2.588	2.1	14.2	85.2	48.5
50-3	5.0	158.0	2.588	2.2	14.3	84.8	48.6
avg	5.0	158.1	2.588	2.1	14.2	85.2	48.5
50-1	4.8	156.9	2.606	3.5	14.7	76.1	48.8
50-2	4.8	157.3	2.606	3.3	14.5	77.5	48.7
50-3	4.8	158.0	2.606	2.8	14.1	79.8	48.5
avg	4.8	157.4	2.606	3.2	14.4	77.8	48.6

MIX C (containing 30% of materials passing # 4 sieve)

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	VCA
50-1	4.0	155.4	2.629	5.3	14.8	64.3	40.4
50-2	4.0	155.4	2.629	5.3	14.8	64.3	40.4
50-3	4.0	155.2	2.629	5.4	14.9	63.8	40.4
avg	4.0	155.3	2.629	5.3	14.8	64.1	40.4
50-1	4.5	155.3	2.608	4.5	15.3	70.2	40.7
50-2	4.5	156.3	2.608	3.9	14.7	73.3	40.3
50-3	4.5	156.4	2.608	3.9	14.7	73.6	40.3
avg	4.5	156.0	2.608	4.1	14.9	72.4	40.4
50-1	5.0	156.8	2.588	2.9	14.9	80.6	40.4
50-2	5.0	157.0	2.588	2.8	14.8	81.3	40.4
50-3	5.0	156.6	2.588	3.0	15.0	79.9	40.5
avg	5.0	156.8	2.588	2.9	14.9	80.6	40.4
50-1	4.9	156.4	2.592	3.3	15.1	77.9	40.6
50-2	4.9	157.2	2.592	2.8	14.6	80.8	40.2
50-3	4.9	157.3	2.592	2.8	14.6	81.0	40.2
avg	4.9	156.9	2.592	3.0	14.8	79.9	40.3

MIX D (containing 20% of materials passing # 4 sieve)

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	VCA
50-1	4.0	154.6	2.635	6.0	15.2	60.8	32.2
50-2	4.0	151.7	2.635	7.7	16.8	54.1	33.4
50-3	4.0	151.8	2.635	7.7	16.8	54.3	33.4
avg	4.0	152.7	2.635	7.1	16.3	56A	33.0

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	VCA
50-1	4.5	152.9	2.613	6.2	16.6	62.4	33.3
50-2	4.5	153.5	2.613	5.8	16.3	64.1	33.0
50-3	4.5	154.2	2.613	5.5	15.9	65.7	32.7
avg	4.5	153.5	2.613	5.8	16.3	64.1	33.0
50-1	5.0	154.1	2.592	4.7	16.4	71.2	33.1
50-2	5.0	154.6	2.592	4.4	16.1	72.7	32.9
50-3	5.0	155.5	2.592	3.9	15.6	75.3	32.5
avg	5.0	154.7	2.592	4.3	16.0	73.1	32.8
50-1	5.5	155.3	2.572	3.2	16.2	80.0	32.9
50-2	5.5	155.0	2.572	3.4	16.4	79.0	33.1
50-3	5.5	155.7	2.572	3.0	16.0	81.4	32.8
avg	5.5	155.3	2.572	3.2	16.2	80.1	32.9
50-1	5.6	154.9	2.568	3.4	16.5	79.6	33.2
50-2	5.6	155.6	2.568	2.9	16.1	81.9	32.9
50-3	5.6	155.2	2.568	3.2	16.3	80.7	33.1
avg	5.6	155.2	2.568	3.1	16.3	80.7	33.1

MIX E (containing 15% of materials passing # 4 sieve)

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	VCA
50-1	5.0	152.0	2.606	6.5	17.5	62.7	29.9
50-2	5.0	152.3	2.606	6.4	17.4	63.4	29.8
50-3	5.0	152.4	2.606	6.3	17.3	63.7	29.7
avg	5.0	152.2	2.606	6.4	17.4	63.3	29.8
50-1	5.5	153.2	2.585	5.0	17.3	70.9	29.7
50-2	5.5	152.9	2.585	5.2	17.5	70.1	29.9
50-3	5.5	153.1	2.585	5.1	17.4	70.7	29.8
avg	5.5	153.0	2.585	5.1	17.4	70.6	29.8
50-1	6.0	153.6	2.565	4.0	17.5	77.1	29.9
50-2	6.0	153.8	2.565	3.9	17.4	77.5	29.8
50-3	6.0	153.8	2.565	3.9	17.4	77.6	29.8
avg	6.0	153.7	2.565	3.9	17.5	77.4	29.8
50-1	6.5	154.6	2.545	2.7	17.5	84.7	29.8
50-2	6.5	153.2	2.545	3.5	18.2	80.6	30.5
50-3	6.5	153.1	2.545	3.6	18.2	80.4	30.5
avg	6.5	153.6	2.545	3.3	18.0	81.9	30.3

Spec. #	AC %	Unit wt.(pcf)	TMD	VTM	VMA	VFA	VCA
50-1	7.0	153.5	2.525	2.6	18.5	85.9	30.7
50-2	7.0	154.2	2.525	2.1	18.1	88.3	30.4
avg	7.0	153.8	2.525	2.4	18.3	87.1	30.5
50-1	6.8	153.4	2.533	3.0	18.4	83.9	30.6
50-2	6.8	153.4	2.533	2.9	18.3	84.0	30.6
50-3	6.8	152.8	2.533	3.3	18.7	82.1	30.9
avg	6.8	153.2	2.533	3.1	18.5	83.3	30.7

VCA of dry rodded mix = 42.2 %

APPENDIX E

RAW DATA OF EVALUATION OF CREEP PROPERTIES OF SMA MIX

Gravel SMA mix

1 hour creep properties

Mix (psi)	% passing #4 sieve	Spec #	AC content	Strain (in/in)	Modulus
A	50	A-1	5.1	0.1008	1190.5
		A-2	5.1	0.0696	1723.2
avg				0.0852	1456.9
B	40	B-1	5.2	0.0705	1702.5
		B-2	5.2	0.0726	1653.3
avg				0.0716	1677.9
C	30	C- 1	5.4	0.0395	3034.2
		C-2	5.4	0.0303	3959.0
avg				0.0349	3496.6
F	25	F- 1	5.9	0.031	3909.9
		F-2	5.9	**0.021**	**5839.4**
		F-3	5.9	0.032	3738.4
avg				0.028	4495.9
D	20	D-1	6.6	FAIL	FAIL
		D-2	6.6	FAIL	FAIL
E	15	E-I	8.0	0.0415	2895.0
		E-2	8.0	0.0649	1849.2
avg				0.0532	2372.1

Limestone SMA mix

1 hour creep properties

Mix (psi)	% passing #4 sieve	Spec #	AC content	Strain (in/in)	Modulus
A	50	A-1	4.6	0.0369	3250.4
		A-2	4.6	0.0237	5057.3
avg				0.0303	4153.9
B	40	B-1	4.8	0.0363	3311.6
		B-2	4.8	0.0757	1585.3
avg				0.0560	2488.5
C	30	C-1	4.9	0.0738	1626.8
		C-2	4.9	0.0472	2544.1
avg				0.0605	2085.5
F	25	F- 1	5.0	**0.027**	**4487.3**
		F-2	5.0	0.045	2690.5
		F-3	5.0	0.044	2700.7
avg				0.039	3292.8
D	20	D-1	5.6	0.0519	2313.2
		D-2	5.6	0.0819	1466.1
avg				0.0669	1889.7
E	15	E-1	6.8	0.0584	2055.9
		E-2	6.8	0.1156	1038.4
avg				0.0870	1547.2

Gravel SMA mix and dense mix

4 hour creep properties

Dense Mix / SMA mix (type F)

Spec #	Strain (in/in)	Modulus (psi)	Time	Spec #	Strain (in/in)	Modulus (psi)
1	0.027	4504.2		1	0.031	3909.9
2	**0.013**	**9098.5**		2	**0.021**	**5839.4**
3	0.038	3155.0		3	0.032	3738.4
avg	0.026	5585.9	1 hour	avg	0.028	4495.9
4	ERROR	ERROR		4	**0.025**	**4810.0**
5	0.035	3435.7		5	0.030	4042.6
6	0.032	3737.9		6	0.031	3864.2
7	0.033	3594.6				
avg	0.033	3589.4	2 hour	avg	0.029	4238.9
				7	0.025	4836.4
8	**0.012**	**10131.1**		8	**0.100**	**1251.2**
9	0.019	6454.7		9	0.036	3355.5
10	0.021	5698.4				
avg	0.017	7428.1	3 hour	avg	0.054	3147.7
				10	0.065	1845.9
11	0.026	4624.5		11	0.108	1109.7
12	0.025	4887.6				
avg	0.026	4756.1	4 hour	avg	0.087	1477.8

Limestone SMA mix and dense mix

4 hour creep properties

Dense Mix		SMA mix (type F)				
Spec #	Strain (in/in)	Modulus (psi)	Time	Spec #	Strain (in/in)	Modulus (psi)
1	**0.030**	**3942.7**		1	**0.027**	**4487.3**
2	0.016	7704.1		2	0.045	2690.5
3	0.015	8236.3		3	0.044	2700.7
avg	0.020	6627.7	1 hour	avg	0.039	3292.8
4	ERROR	ERROR		4	0.037	3216.2
5	0.015	7995.1		5	0.035	3430.3
6	0.010	11473.8		6	0.036	3314.2
avg	0.013	9734.5	2 hour	avg	0.036	3320.2
7	0.014	8462.7		7	0.040	3032.5
8	0.012	10352.5		8	0.053	2271.6
9	0.013	9000.4		9	0.032	3698.6
avg	0.013	9271.9	3 hour	avg	0.042	3000.9
10	0.015	8099.0		10	0.032	3730.1
11	0.012	10378.9		11	0.037	3274.1
12	ERROR	ERROR		12	0.040	2988.5
avg	0.014	9239.0	4 hour	avg	0.036	3330.9