STATE OF FLORIDA

EXAMINATION OF AGGREGATE DEGRADATION AND EFFECT ON VOLUMETRIC PROPERTIES

Research Report
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STATE MATERIALS OFFICE

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ABSTRACT

The reduction in volumetric properties of an asphalt mixture, air voids and voids in the mineral aggregate (VMA), that occurs during the production process has, in some instances, been attributed to a rounding/breakdown of the aggregate particles in the mixture. This study was initiated to relatively quantify this phenomenon between aggregate types. For this study, three different asphalt mixtures were sampled and tested at various points during the production/laydown operation to ascertain the magnitude of aggregate breakdown and the corresponding effect on asphalt mixture properties. Each mixture was characterized principally by the major source of aggregate present in the mixture. The types of aggregate examined were Georgia granite, West-Central Florida limestone, and South Florida limestone. Aggregate gradations were obtained from the following points in the production/laydown operation: 1) belt-cut samples, 2) asphalt mixture from the truck bed, 3) asphalt mixture behind the asphalt paver at the roadway but prior to compaction, 4) asphalt mixture after roller compaction at the roadway, and 5) from gyratory compacted specimens at the asphalt plant. Between 0.6% and 1.5% dust was generated during the mixing process in the drum. The gyratory compactor generated 0.8% dust for the granite mixture and approximately 1.5% dust for the limestone mixtures. Roadway compaction resulted in similar breakdown to the gyratory compactor. The Los Angeles abrasion test results for each predominant aggregate type correlated well with the amount of aggregate breakdown observed. The three mixtures were then reproduced in the lab with varying percentages of dust to examine the effects on volumetric properties. In general, results indicate that removing 1% dust will increase air voids by approximately 0.8%, increase VMA by 0.5% and decrease voids filled with asphalt (VFA) by 5% at the design level of gyrations.

INTRODUCTION

The implementation of the Superpave system for asphalt mixture design by the Florida Department of Transportation (FDOT) in 1996 led to the routine testing of plant-produced asphalt mixtures for volumetric properties by Quality Control (QC) personnel. It was discovered that frequently the air voids and VMA would drop below minimal acceptable levels, especially for mixtures containing Florida limestone aggregates. It was hypothesized that the most significant contributor to the reduction in air voids and VMA was the increase in dust content (aggregate material passing the No. 200 [75 μm] sieve) caused by aggregate breakdown in the production process and in the gyratory compactor. Though this breakdown had been occurring with the Marshall mix design procedure used prior to the implementation of Superpave, the effect was less pronounced because QC personnel had not been monitoring volumetric properties routinely.

Another area of concern relates to the use of heavier rollers with Superpave mixtures, mostly in the vibratory mode, to compact the mixtures to higher density levels at the roadway. The higher density levels were implemented to reduce water permeability (primarily in coarse graded mixtures). There is concern that the heavier rollers in vibratory mode may be degrading the aggregate and adversely affecting the field performance of the pavement.

This study was undertaken to examine aggregate gradations and mixture properties at various points in the production/laydown operation. Additionally, the mixtures were reproduced in the laboratory to examine the effects of varying amounts of dust on the volumetric properties.
The experimental plan was designed to obtain some general conclusions about aggregate

breakdown for a hard stone (granite) versus a softer stone (limestone) and the subsequent effects on volumetric properties.

It should be noted that the mixtures studied were dissimilar in many ways: different nominal maximum aggregate sizes, the use of fine and coarse gradations, different design levels for gyration, and different sources of RAP, sands, etc. These dissimilarities minimize the exact variables that can be examined and the conclusions that can be drawn. The reason the study was conducted in this manner was because it was desirable to obtain mixtures that went through plant production and were compacted on the roadway, therefore the researchers were limited to actual mix designs and materials that contractors were using at the time of the study.

EXPERIMENTAL PLAN

Three mixtures were examined that each contained a majority of one of three types of aggregates that are most commonly used in asphalt mixtures in Florida. The three predominate aggregate types examined were Georgia granite, West-Central Florida (WCF) limestone, and South Florida (SF) limestone. The WCF limestone comes from the Suwannee formation and the SF limestone comes from the Miami Oolite formation. Of the two Florida limestones, the SF limestone has a higher aggregate specific gravity, lower absorption and less LA abrasion loss than the WCF limestone. The two limestone formations occurred at different periods in time and contain different fossil types. The SF formation also contains more silicates and less calcium carbonates that the WCF formation. All of the mixtures were dense graded structural mixtures. **Table 1** lists the three mixtures tested, the Superpave mixture type, the design number of gyrations (N_{des}), the maximum number of gyrations (N_{max}), the aggregate types present in each mixture, and the percentages of each aggregate type. For each of the three mixtures, the following activities were performed and are broken down into the following categories: plant, roadway and laboratory. It should be noted that standard FDOT test methods were used unless otherwise specified.

Plant Activities

1. Each of the stockpiled aggregate components and asphalt binder were sampled for use at the State Materials Office (SMO) Research Lab.

2. The plant was stopped during production and belt-cut samples were taken from the virgin aggregate and RAP belt feeds.

3. Mix was sampled from the truck bed. The sampling was timed such that the truck mix that was sampled was approximately the same material that was sampled from the aggregate belt feeds.

4. Specimens were gyrated to the N_{max} number of gyrations at the asphalt plant using the asphalt mixture sampled from the truck bed. This study was conducted before the specification change was adopted to gyrate to the N_{des} number of gyrations. Samples were also split out for maximum specific gravity (G_{mm}) and extraction/gradation testing.

Roadway Activities

1. The same truck that was sampled at the plant was followed to the roadway. The mix from that truck was then sampled from the roadway behind the paver but prior to roller compaction. The mix was sampled at three transverse locations across the twelve-foot wide mat.

2. After roller compaction and prior to cooling, mix was then sampled by shoveling from three locations within a few feet from the previous locations.

Laboratory Activities

1. Aggregates were oven dried and fractionated. Composition gradations and Los Angeles (LA) abrasion tests were performed for each component. However, LA abrasion tests were not performed on the RAP or sand materials.

2. The bulk specific gravities (G_{mb}) of the plant gyratory specimens were determined and G_{mm} values for the truck mix were determined.

3. Trichloroethylene solvent reflux extraction and gradation tests were performed on the following materials: belt-cut RAP, truck mix, plant-gyrated specimens, roadway samples before roller compaction, and roadway samples after roller compaction. A standard wash gradation was determined for the virgin belt-cut material.

4. Aggregate bulk specific gravities and fine aggregate angularities were determined for the following materials: belt-cut samples, plant gyratory specimens, and roadway samples after roller compaction. The belt-cut virgin and RAP materials were combined in the same proportion that they were being fed into the drum at the plant.

5. Laboratory fabricated specimens (for extraction/gradation, G_{mm}, and gyratory compaction) were made with a gradation that closely matched the design job mix formula and specimens were also fabricated for two other similar gradations where only the percentage of dust was varied. Gyratory specimens were gyrated to the N_{des} number of gyrations. The gyratory specimens with the design dust content were extracted using the trichloroethylene solvent reflux extraction test to determine if the extra dust generated during gyratory compaction matched the amount of dust generated with the plant-gyrated specimens.

DATA ANALYSIS

Summaries of the plant and roadway data for each of the three mixtures are presented in **Tables 2-4**. Shown are the properties of the material as obtained from: the belt-cut samples, mixture from the truck prior to leaving the plant, gyratory specimens from the plant, roadway mix from behind the paver but prior to compaction, roadway mix after compaction and the job-mix formula (JMF) properties of the mix design. Additional information shown is the fine aggregate angularity values, aggregate specific gravities, volumetric properties and LA abrasion values. Summaries of the laboratory data are presented in **Tables 5-7**. Shown are the gradations for the fabricated blends without mixing or compaction, the gradations of gyrated specimens and the JMF gradations. Also shown are the volumetric properties of compacted specimens fabricated with varying amounts of dust. Values reported in **Tables 1-7** are the average of two test results unless noted otherwise in the text. Test values reported for LA abrasion are single test values. The following data is presented by mixture property and compared between the three mixtures for each property.

<u>Gradation Between Belt-Cut and Truck Uncompacted Samples</u>

For all three mixtures the gradation became finer as it went through the drum. The granite mixture and the WCF limestone mixture became finer on every sieve. The SF limestone mixture became finer for every sieve below the 3/8" sieve. In some instances, the increase in % passing was more than 2%. With respect to the amount of dust (-200 material), the granite mix was 0.6% finer, the WCF limestone mix was 0.7% finer and the SF limestone mix was 1.5% finer. The respective plant operators indicated that no dust was being wasted for the granite and SF limestone mixtures and all of the dust was being wasted for the WCF limestone mixture. A previous study conducted by the FDOT (1) using a North Florida limestone found that dust increased by 0.4% in the mixture even after all dust was being wasted. The majority of the breakdown in that study was attributed to the screenings used.

Gradation Between Truck Uncompacted Samples and Plant Gyratory Specimens

For all three mixtures, the gradations of the gyratory specimens were finer than the gradations of the truck mix samples for the #30 sieve and below. The SF limestone mix was finer on every sieve for the gyratory specimens compared to the truck mix samples. The granite mix had an increase of 0.8% dust for the gyratory specimens as compared to the truck mix samples, whereas the WCF and SF limestone mixtures had an increase in dust of 1.3% and 1.4% respectively. Collins et al. (2) had similar increases in dust in their study on gyratory compacted mixtures with granite aggregates. Murphy (3) reported an average increase in dust of 1.41% on plant-gyrated specimens compared to uncompacted specimens. The mix Murphy tested was nearly identical to the SF limestone mixture tested in this study.

Gradation Between Roadway Uncompacted Samples and Roadway Roller-Compacted Samples

For all three mixtures, the gradations were finer for the roller-compacted samples for the #16 sieve and below. The SF limestone mixture was finer for the 3/8” sieve and below. The granite mix had an increase of 0.7% dust for the roller-compacted gradations as compared to the uncompacted roadway samples, whereas the WCF and SF limestone mixtures had an increase in dust of 0.6% and 1.7% respectively. For the granite and SF limestone mixtures the % dust created in the gyratory compactor was nearly the same as the % dust created by the vibratory rollers used at the roadway.

Gradation Between Laboratory Uncompacted Samples and Laboratory Gyratory Specimens

The laboratory specimens were gyrated to the N_{des} level of gyrations and then extracted using the trichloroethylene solvent reflux extraction method. The gradations of the recovered aggregates were then compared to the gradations of laboratory uncompacted samples. The laboratory uncompacted samples were batched (virgin and RAP aggregates) but were not mixed with asphalt cement. These samples were also extracted with trichloroethylene solvent due to the asphalt cement contained in the RAP. The granite mixture had an increase in dust after gyratory compaction of 0.9%, the WCF limestone mixture had an increase in dust of 1.5%, and the SF limestone mixture had an increase of 3.0%. Some of the increase in dust could be attributed to the laboratory mixing process, however previous research conducted by the FDOT (4) indicates this amount to be very small for the aggregate types examined in this study. The increases in dust percentage for laboratory samples were very comparable to the results obtained when comparing the increases in dust percentage between the plant-gyrated specimen gradations and the uncompacted truck mix gradations. The increase in dust due to gyratory compaction for the granite and WCF limestone laboratory specimens were nearly identical to the plant-gyrated specimens even though the laboratory specimens were compacted to N_{des} and the plant specimens were compacted to N_{max} gyrations. However, the SF mixture had a substantially larger increase in dust for the laboratory gyrated specimens as compared to the plant-gyrated specimens (3.0% vs. 1.4%) even though it was compacted to less gyrations (96 vs. 152). Additional laboratory specimens were tested and confirmed the previous results, however no additional truck mix was available to confirm the field results.

Fine Aggregate Angularity (FAA)

Fine aggregate angularity values were calculated for the following materials: belt-cut samples, extracted gyratory samples, and extracted roadway roller-compacted samples. For all three mixtures, the gyratory and roadway FAA values were slightly lower than the belt-cut FAA value, indicating some rounding of the aggregate may have occurred. Interestingly, the roadway roller-compacted FAA values were always less than the gyratory FAA values. It should be noted that even though the FAA values decreased after gyratory or roadway compaction compared to belt-cut samples, it is unclear if the amount of change is significant. Not enough information about the sensitivity of this aggregate property as related to performance is known.

<u>Los Angeles Abrasion Test Results</u>

The LA abrasion test was performed on the coarse aggregate virgin components and the modified LA abrasion test was performed on the fine aggregate virgin components for the three mixtures. FDOT specifications permit a maximum loss of 45% for coarse aggregates and a maximum loss of 23% for fine aggregates unless the fine aggregate comes from an approved coarse aggregate source, in which case there is no specified value for the fine aggregate portion. For this study, the specification for the fine aggregate does not apply because for the three mixtures tested, all of the fine aggregates came from approved coarse aggregate sources. However, the modified LA abrasion test was performed on the fine aggregates for informational purposes. With respect to the coarse aggregate, the granite components had LA abrasion values of slightly less than 20, the WCF components were in the mid 30's, and the SF components were in the low 30's. With respect to the fine aggregate, the granite component value was 11 and the limestone components were slightly less than 20.

<u>Change in Volumetric Properties with Change in Dust Percentage for Laboratory Specimens</u>

Three specimens for the granite mixture were prepared at the design dust content, -1% dust, and -1.5% (nine specimens total). Three specimens for each of the two limestone mixtures were prepared at the design dust content, -1% dust, and -2% dust. The volumetric properties (% air voids, VMA, and VFA) at N_{des} gyrations are graphically displayed in **Figures 1-3**. The linear regression lines for each volumetric property are approximately parallel for each aggregate source. This indicates that for these three mixes the variation in dust has a similar effect and magnitude on the volumetric property in question. With respect to % air voids, removing 1% dust will increase air voids approximately 0.8%. With respect to VMA, removing 1% dust will increase VMA approximately 0.5%. With respect to VFA, removing 1% dust will decrease VFA approximately 5%. Moseley's research (5) with Georgia granite mixtures and varying dust percentages reached similar conclusions with respect to % air voids and VMA. VFA results were not reported.

CONCLUSIONS

Based on the test results discussed above, the following general conclusions can be drawn:

1. Depending on the aggregate type, the % dust generated due to breakdown during the mixing process in the drum may account for 0.5% to 1.2% reduction in air voids and 0.3% to 0.8% reduction in VMA. These results will vary depending on the amount of dust being wasted from the drum.

2. The gyratory compaction process results in additional degradation of the aggregate in the plant-produced mix, however, this breakdown should also occur during the mix design process. Therefore, a reduction of air voids or VMA during production should not be attributed to breakdown in the gyratory compactor.

3. Compaction at the roadway results in comparable aggregate breakdown to that which occurs in the gyratory compactor. Therefore, the final asphalt mixture in place at the roadway may have a finer gradation than the uncompacted mix samples at the plant or the gradation used at mix design.

4. Fine aggregate angularity values decreased slightly for gyratory and roadway compacted samples when compared to uncompacted plant-produced mixture.

5. For these three mixtures, LA abrasion test results correlated well with the amount of aggregate breakdown measured. Collins et al. (2) also had similar conclusions in their study of granite aggregates with low and high LA abrasion test results. Kandhal and Parker (6) found that the LA abrasion test correlated fairly well with breakdown in the gyratory compactor, however, their study indicates that the Micro-Deval test was a better test than the LA abrasion test with respect to actual field performance.

6. A 1% reduction in dust will result in an increase of approximately 0.8% air voids, 0.5% VMA, and a reduction of 5% VFA regardless of the aggregate type used in this study.

7. Georgia Granite degraded to a much lesser extent than the two Florida limestones tested. This is best observed when comparing the controlled laboratory gradations before and after gyratory compaction.

8. It is speculated but not proven in this report that the effect of degradation may be less serious for fine graded mixes because the reduction in % air voids and VMA due to the dust generated by aggregate breakdown may be partially or totally offset by the increase in % air voids and VMA created by the further separation of the gradation curve from the maximum density line due to the mix becoming finer. However, for coarse graded mixtures, the degradation may be more serious because the majority of the aggregate that is breaking down would occur on those sieve sizes where the gradation went below the maximum density line and restricted zone. The gradation would become finer on these sieves resulting in even lower air voids and VMA.

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Table 1 – Mixture Information

Mix ID	Mix Type	Aggregate Type	Percentage
1	12.5 Fine	Georgia granite (GA-185)	70
	N_{des} = 86	RAP (FL limestone, AL limestone)	20
	N_{max} = 134	Local washed sand	10
2	19.0 Fine	West-Central Florida limestone (08-012)	70
	N_{des} = 86	RAP (FL limestone)	20
	N_{max} = 134	Local sand	10
3	12.5 Coarse	South Florida limestone (87-145)	67
	N_{des} = 96	North Florida limestone screenings (29-361)	18
	N_{max} = 152	RAP (FL limestone)	15

Table 2 – Plant and Roadway Data for Granite Mixture

	% Passing					
Sieve Size	Belt Cut	Truck	Gyratory	Rd. No Comp.	Rd. Comp.	JMF
3/4"	100.0	100.0	100.0	100.0	100.0	100
1/2"	98.1	98.8	98.5	98.6	97.9	99
3/8"	92.2	94.0	93.8	94.0	93.0	90
4	65.8	68.2	68.1	69.0	67.0	66
8	43.3	46.2	46.6	46.4	46.3	48
16	31.4	34.0	34.7	34.2	34.5	36
30	22.7	25.1	26.0	25.0	25.6	25
50	14.0	15.9	17.0	15.6	16.4	17
100	7.3	8.5	9.6	8.2	9.0	7
200	4.0	4.6	5.4	4.3	5.0	4.5
% AC	NA	4.8	4.9	5.4	4.9	5.2
FAA %	44.7	NA	44.1	NA	43.7	45.4
FAA Gsb	2.643	NA	2.647	NA	2.627	
CASG	2.674		2.718		2.686	
Grav. -100	2.710		2.710		2.710	
Mix Gsb	2.665		2.691		2.666	2.645
Gmm		2.511				2.495
Gmb (Nmax)			2.432			2.415
Gmb (Ndes)			2.407			2.394
Gmb (Nini)			2.227			2.221
%AV (Nmax)			3.1			3.2
%AV (Ndes)			4.1			4.0
%AV (Nini)			11.3			11.0
VMA (Nmax)			14.1			13.4
VMA (Ndes)			14.9			14.2
VMA (Nini)			21.3			20.4
VFA (Nmax)			77.7			76.2
VFA (Ndes)			72.4			71.5
VFA (Nini)			46.9			46.1
Gse		2.707				
Pbe			4.7			4.4
Dust/Pbe			1.1			1.0
		#7 Stone	#89 Stone	W-10 Scrns.		
LA Abrasion Values		19.5	18.9	10.8		
(% Loss)		Pass	Pass	NA		

Table 3 - Plant and Roadway Data for West-Central Florida Limestone Mixture

Sieve Size	% Passing					
	Belt Cut	Truck	Gyratory	Rd. No Comp.	Rd. Comp.	JMF
1"	100.0	100.0	100.0	100.0	100.0	100
3/4"	95.5	97.3	95.3	98.5	98.1	97
1/2"	86.4	87.3	84.3	90.6	89.6	85
3/8"	80.0	81.3	77.2	84.9	84.1	79
4	61.1	62.5	59.0	67.0	66.7	63
8	44.3	45.7	43.4	49.3	49.9	46
16	32.7	34.2	33.7	36.8	38.1	36
30	24.4	26.8	27.1	29.0	30.0	28
50	15.6	17.6	18.7	19.3	20.1	18
100	6.7	7.5	9.0	8.4	9.1	8
200	4.3	5.0	6.3	5.6	6.2	4.5
% AC	NA	5.4	5.3	6.0	5.8	5.7
FAA %	41.7		40.6		39.0	49.2
FAA Gsb	2.508		2.484		2.515	
CASG	2.360		2.387		2.357	
Grav. -100	2.669		2.669		2.669	
Mix Gsb	2.433		2.443		2.446	2.443
Gmm		2.357				2.350
Gmb (Nmax)			2.320			2.272
Gmb (Ndes)			2.296			2.255
Gmb (Nini)			2.134			2.087
%AV (Nmax)			1.6			3.3
%AV (Ndes)			2.6			4.0
%AV (Nini)			9.5			11.2
VMA (Nmax)			10.1			12.3
VMA (Ndes)			11.1			13.0
VMA (Nini)			17.3			19.4
VFA (Nmax)			84.4			73.1
VFA (Ndes)			76.4			68.8
VFA (Nini)			45.4			42.4
Gse		2.545				
Pbe			3.7			4.1
Dust/Pbe			1.7			1.1
		#57 Stone	3/8 Stone	130C Scrns.		
LA Abrasion Values		36.0	36.7	19.0		
(% Loss)		Pass	Pass	NA		

Table 4 - Plant and Roadway Data for South Florida Limestone Mixture

	% Passing					
Sieve Size	Belt Cut	Truck	Gyratory	Rd. No Comp.	Rd. Comp.	JMF
3/4"	100.0	100.0	100.0	100.0	100.0	100
1/2"	98.1	97.9	98.4	98.7	98.2	98
3/8"	94.1	93.0	94.4	94.4	94.9	90
4	56.8	58.5	63.1	59.3	64.3	54
8	25.6	27.4	33.2	27.8	33.5	28
16	18.8	20.3	24.7	20.8	25.0	22
30	14.9	16.5	19.9	17.1	20.5	17
50	11.5	13.6	16.2	14.1	17.1	12
100	7.0	9.0	11.0	9.4	12.1	6
200	3.9	5.4	6.8	6.4	8.1	4.5
% AC	NA	7.1	7.1	7.2	7.2	7.5
FAA %	45.8	NA	45.3	NA	44.1	46.0
FAA Gsb	2.395	NA	2.474	NA	2.426	
CASG	2.374		2.364		2.361	
Grav. -100	2.719		2.719		2.719	
Mix Gsb	2.399		2.423		2.413	2.352
Gmm		2.301				2.269
Gmb (Nmax)			2.234			2.224
Gmb (Ndes)			2.183			2.178
Gmb (Nini)			1.904			1.917
%AV (Nmax)			2.9			2.0
%AV (Ndes)			5.1			4.0
%AV (Nini)			17.2			15.5
VMA (Nmax)			14.3			12.5
VMA (Ndes)			16.3			14.3
VMA (Nini)			27.0			24.6
VFA (Nmax)			79.8			84.2
VFA (Ndes)			68.5			72.0
VFA (Nini)			36.1			37.0
Gse		2.541				
Pbe			5.3			4.9
Dust/Pbe			1.3			0.9
		S1A	S1B	5/16" Stone	Scrns.	
LA Abrasion Values		33.0	32.1	27.7	17.2	
(% Loss)		Pass	Pass	Pass	NA	

Table 5 - Laboratory Data for Granite Mixture

Sieve Size	% Passing Fabricated	% Passing Gyratory	% Passing JMF
1"	100.0	100.0	100
3/4"	100.0	100.0	100
1/2"	98.7	98.4	99
3/8"	94.1	93.5	90
4	69.3	70.0	66
8	48.5	49.1	48
16	36.5	37.0	36
30	27.1	27.9	25
50	17.1	18.2	17
100	9.2	10.3	7
200	5.1	6.0	4.5
% AC	5.2	5.16	5.2

	Percent Dust Removed 0.0%	1.0%	1.5%
Gmm	2.507	2.507	2.506
Mix Gsb	2.665	2.665	2.664
Gmb (Ndes)	2.431	2.414	2.407
Gmb (Nini)	2.247	2.227	2.231
%AV (Ndes)	3.0	3.7	3.9
%AV (Nini)	10.4	11.2	11.0
VMA (Ndes)	13.5	14.1	14.3
VMA (Nini)	20.1	20.8	20.6
VFA (Ndes)	77.6	73.7	72.5
VFA (Nini)	48.4	46.2	46.7
Gse	2.721	2.721	2.720
Pbe	4.4	4.4	4.5
Des. Dust/Pbe	1.1	0.9	0.8
Gyr. Dust/Pbe	1.4	1.1	1.0

Table 6 - Laboratory Data for West-Central Florida Limestone Mixture

Sieve Size	% Passing Fabricated	% Passing Gyratory	% Passing JMF
1"	100.0	100.0	100
3/4"	96.5	96.9	97
1/2"	86.2	86.4	85
3/8"	79.0	80.4	79
4	64.5	65.5	63
8	48.1	49.5	46
16	36.7	38.2	36
30	28.4	30.0	28
50	19.6	21.4	18
100	8.1	9.9	8
200	5.1	6.6	4.5
% AC	5.7	5.44	5.7

	Percent Dust Removed 0.0%	1.0%	2.0%
Gmm	2.340	2.350	2.354
Mix Gsb	2.440	2.438	2.436
Gmb (Ndes)	2.301	2.292	2.275
Gmb (Nini)	2.142	2.139	2.120
%AV (Ndes)	1.7	2.5	3.4
%AV (Nini)	8.5	9.0	10.0
VMA (Ndes)	11.1	11.4	11.9
VMA (Nini)	17.2	17.3	17.9
VFA (Ndes)	84.9	78.3	71.9
VFA (Nini)	50.8	48.0	44.5
Gse	2.535	2.547	2.552
Pbe	4.2	4.0	3.9
Des. Dust/Pbe	1.2	1.0	0.8
Gyr. Dust/Pbe	1.6	1.4	1.2

Table 7 - Laboratory Data for South Florida Limestone Mixture

Sieve Size	% Passing Fabricated	% Passing Gyratory	% Passing JMF
1"	100.0	100.0	100
3/4"	100.0	100.0	100
1/2"	98.4	98.4	98
3/8"	90.4	90.8	90
4	56.1	60.9	54
8	30.5	35.4	28
16	21.4	26.6	22
30	17.0	21.6	17
50	12.2	16.2	12
100	7.0	10.6	6
200	4.3	7.3	4.5
% AC	7.1	7.07	7.5

	Percent Dust Removed		
	0.0%	1.0%	2.0%
Gmm	2.293	2.290	2.292
Mix Gsb	2.400	2.397	2.394
Gmb (Ndes)	2.226	2.206	2.173
Gmb (Nini)	1.946	1.936	1.910
%AV (Ndes)	2.9	3.7	5.2
%AV (Nini)	15.1	15.5	16.7
VMA (Ndes)	13.9	14.5	15.7
VMA (Nini)	24.7	25.0	25.9
VFA (Ndes)	78.8	74.8	66.8
VFA (Nini)	38.7	38.1	35.6
Gse	2.530	2.526	2.529
Pbe	5.1	5.1	5.0
Des. Dust/Pbe	0.9	0.8	0.9
Gyr. Dust/Pbe	1.4	1.4	1.5

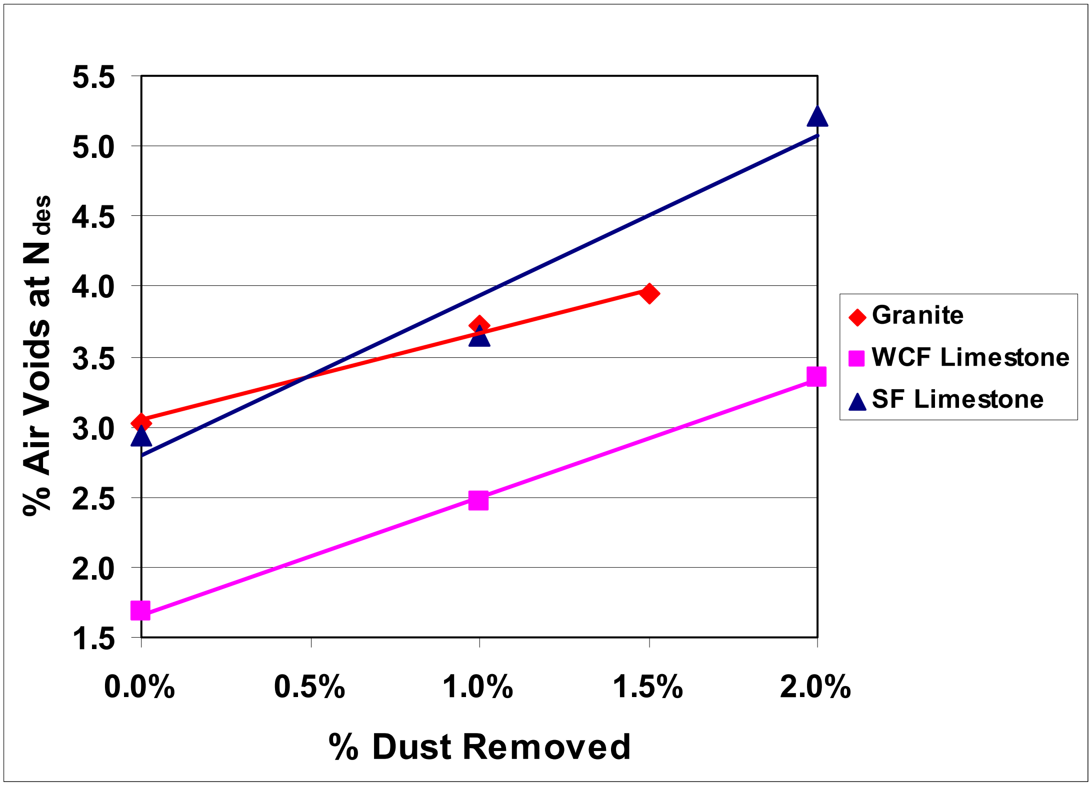

Figure 1 – Effect of Removing Dust (-200 material) on the % Air Voids at N_{des}

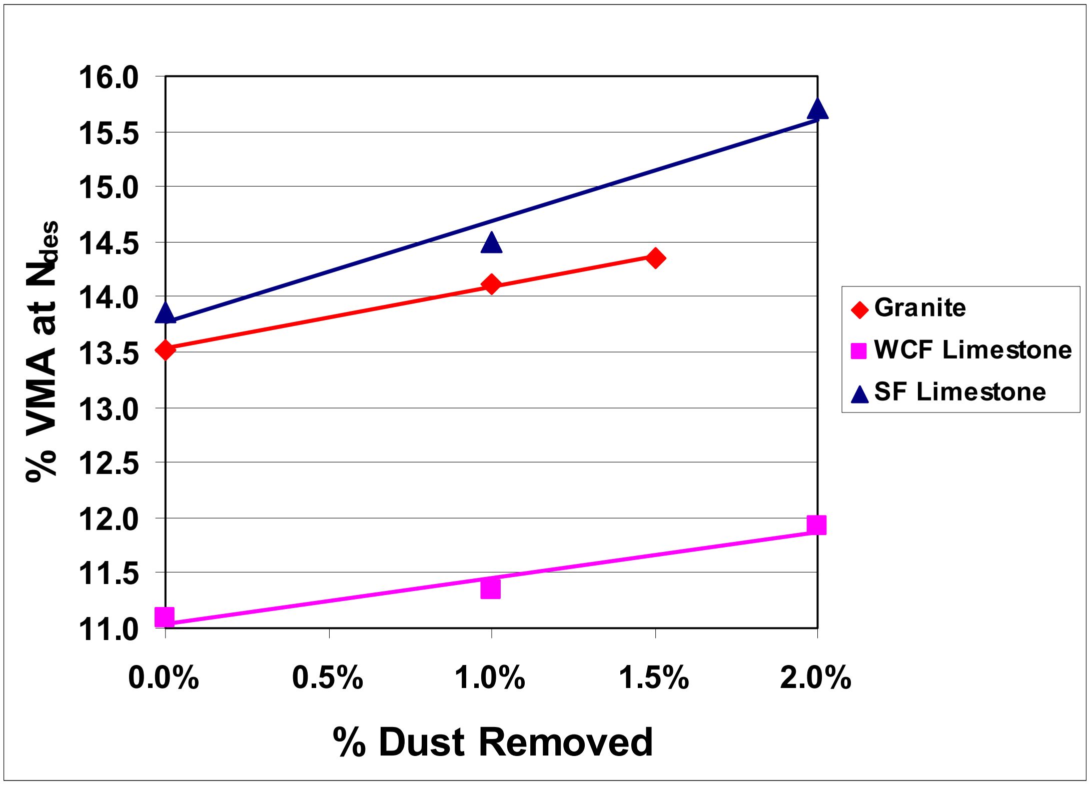

Figure 2 - Effect of Removing Dust (-200 material) on the % VMA at N_{des}

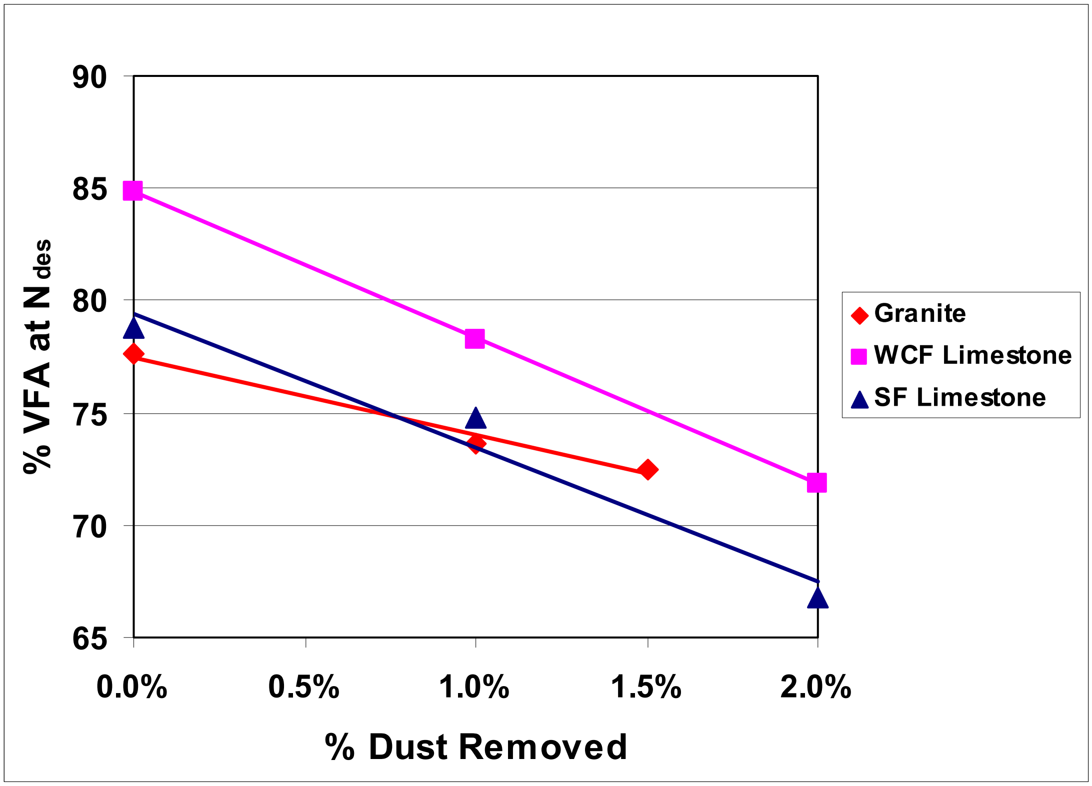

Figure 3 - Effect of Removing Dust (-200 material) on the % VFA at N_{des}