STATE OF FLORIDA

ANALYSIS OF BACK CALCULATION METHOD FOR DETERMINATION OF BULK SPECIFIC GRAVITY AT N_{DESIGN} AND $N_{INITIAL}$ LEVELS OF GYRATION

Research Report
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Gregory A. Sholar
Bryan R. Cawley
James A. Musselman
Gale C. Page

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STATE MATERIALS OFFICE

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The current Superpave mix design procedure requires that specimens be compacted to the maximum number of gyrations, N_{max} , for the specified traffic level. Volumetric data for the design number of gyrations, N_{des}, and the initial number of gyrations, N_{ini}, are then back calculated based on the bulk specific gravity, G_{mb}, of the N_{max} specimens and the height data generated during the compaction process of those same specimens.

When computing volumes using the height data and cross sectional area of the mold, the calculated volume is always higher than the actual volume of the sample because the sample contains surface voids. The volume of the surface voids are mostly excluded in the determination of the volume of the specimen by the saturated surface dry method (such as AASHTO T 166 specification). This happens because the water in the pores either runs out of the pores upon removal of the specimen from the water bath or the water is removed from the pores as the specimen is rolled on the towel prior to determining the saturated surface dry weight.. Therefore, a correction factor is determined for the N_{max} specimens. The correction factor is computed as:

$$C.F. = \frac{G_{mb,measured}}{G_{mb,estimated}}$$

where: C.F. = correction factor
$G_{mb,measured}$ = measured bulk specific gravity at N_{max}
$G_{mb,estimated}$ = estimated bulk specific gravity at N_{max}

The correction factor is then applied to the estimated G_{mb} values for the specimens compacted to

N_{des} and N_{ini} compaction levels using the following formula:

$$G_{mb,corrected} = C.F.\ X\ G_{mb,estimated}$$

where: $G_{mb,corrected}$ = corrected bulk specific gravity at N_{des} or N_{ini}

The issue in question is whether the correction factor calculated at N_{max} is applicable or accurate for the N_{des} and N_{ini} levels of gyration. One might reason that the correction factor might increase as the number of gyrations decreased due to the increasing size and number of voids present on the surfaces of a specimen. If the correction factor were not constant throughout the gyration process, then the back calculated values for G_{mb} and other volumetric properties such as air voids would be incorrect. One possible solution would be to actually gyrate samples to the N_{des} and N_{ini} levels during the mix design process, eliminating the need for a correction factor.

PURPOSE AND SCOPE OF EXPERIMENT

The purpose of this research study was to determine the error, if any, that occurs by back calculating volumetric properties based on a correction factor determined at N_{max}.

Six different coarse graded Superpave mix designs were tested. The mixes consisted of three Florida limestone mixes and three Georgia granite mixes. None of the mixes contained reclaimed asphalt pavement. Within each aggregate type, there was a 9.5, 12.5 and 19.0 mm mix type. See **Table 1** for a summary of the six mixes used.

For each mix type, four samples were gyrated to the N_{max}, N_{des}, and N_{ini} compaction levels. This amounted to 12 samples per mix type for a total of 72 samples for the study. All mixes were designed for traffic level five (10 - 30 million ESAL's) and were compacted to the following number of gyrations: N_{max} - 152; N_{des} - 96; N_{ini} - 8.

The G_{mb}'s of all specimens were determined in accordance with Florida Method FM 1-T 166 Method B (non-destructive). This Florida Method is the same as AASHTO Method T 166 Method A for determination of bulk specific gravity. In addition the G_{mb}'s of the N_{ini} specimens were also determined using a granular medium method for comparison. The granular medium used was glass beads conforming to AASHTO M 247-81 Type I. Basically, the glass beads replace the water in the above referenced methods. The procedure for determining the G_{mb} using glass beads was obtained from an article in March 1998 Asphalt Contractor Periodical *(1)*.

RESULTS

The raw data for G_{mb}, G_{mm}, % air voids, outlier determination, etc. is included in the **Appendix**. The variability in the G_{mb} values, as determined by FM 1-T 166, within a few of the mixes was high (see **Table 2)**. The variability in this study is being defined as the range between the highest and lowest G_{mb} values for a set of four specimens. AASHTO T 166 states a maximum allowable range of 0.02 between two specimens *(2)*. Since this study is using four specimens, the allowable range would be higher. ASTM D 2726-93a states a maximum allowable range of 0.045 for four specimens for single-operator precision *(3)*. The multi-laboratory precision for four specimens is 0.097. As will be discussed later, the specimens made in this study were all prepared with the same equipment but with different operators. Therefore, a precision value somewhere in between single-operator and multi-laboratory would be appropriate. A precision statement for the glass bead method of G_{mb} determination was not available.

The source(s) of the variability is difficult to determine, but is most likely due to operator error with some variability due to natural variation in materials and variability in the gyratory compaction process. The following conditions occurred during the study:

1. The aggregate gradations were fabricated by several lab technicians.
2. The same technician performed all mixing duties.
3. All mixes were aged for two hours prior to compaction, therefore compaction temperatures were most likely consistent.
4. Three technicians performed gyration duties.
5. Bulk specific gravity measurements were performed by several technicians.

The G_{mb} data was then analyzed for outliers using the FDOT method for outlier determination *(4)*. Excluding the outliers, the variability within each mix improved, as expected (see **Table 3)**.

With respect to air voids, the data was analyzed with and without the outliers. Both methods of analysis resulted in the same trends with slightly different magnitudes. For the four N_{des} specimens of each mix type, the average air voids were determined and subtracted from the average air voids back calculated from the N_{max} specimens. Therefore, a positive difference would indicate that the back calculation method was overestimating air voids at N_{des}, whereas a negative difference would indicate that the back calculation method was underestimating air voids at N_{des}. The same procedure was used at N_{ini} except that two methods for determining the G_{mb} of the N_{ini} specimens were used, FM 1-T 166 Method B (water bath method) and glass beads. The results including the outliers are displayed in **Table 4** and **Figures 1 and 2** and the results excluding the outliers are displayed in **Table 5** and **Figure 3 and 4**.

For the N_{des} specimens, the results show three mixes with positive differences and three mixes with negative differences, whether including the outliers or not. The magnitude of the differences is larger with the limestone mixes compared to the granite mixes.

For the N_{ini} specimens, the results show all of the mixes having a positive difference, indicating that the back calculation method is overestimating air voids at the N_{ini} level. The magnitude of the difference also increases as the nominal maximum aggregate size increases. This is logical due to the larger void spaces present on the surfaces of specimens containing larger size aggregates. The differences calculated do not vary greatly between the water bath method and glass bead method for the 9.5 and 12.5 mm mixes. However, for the 19 mm mixes, the differences are more pronounced. The differences are higher for the water bath method. This is because, at high air void levels, water will flow out of the specimen as it is lifted out of the water bath, affecting the accuracy of the results. This results in a lower saturated surface dry weight and therefore a calculated higher bulk density and lower air void content. Therefore, for the N_{ini} specimens, it is more appropriate to use the values calculated by the glass bead method for the 19.0 mm mixes.

CONCLUSIONS / RECOMMENDATIONS

The N_{des} data can be interpreted in at least two ways. First, it can be argued that because there were three mixes with positive differences and three mixes with negative differences, that no firm conclusions can be drawn from the data and therefore, the current method of back calculation should continue to be used. One could also interpret the data by recognizing that because there is variability between mix types, that this is justification that one should gyrate to N_{des} instead of N_{max}. After a design aggregate blend and binder content is determined, then specimens could be compacted to N_{max} to verify the criteria that the percent of the maximum density is $\leq$ 98%. This would be an after the design check just as moisture sensitivity is currently done. However, the ramifications of failing the N_{max} criteria would likely result in a time consuming redesign of the mix.

The N_{ini} data is more conclusive. The back calculation method overestimates the air voids at this level. This effect is most pronounced for 19.0 mm mixes. This could result in a mix passing the N_{ini} requirements when in reality it should not. One solution is to compact specimens to N_{ini} as a check similar to the N_{max} specimens mentioned above. Another solution is to require N_{ini} specimens to be made for only those mix designs where the back calculated $\%G_{mm}$ at N_{ini} is $\geq$ 86%. This would provide a 3% G_{mm} margin of error. If the back calculated $\%G_{mm}$ was less than 86%, then even with a 3% error in the back calculation method, the % G_{mm} would be $\leq$ 89%.

The findings in this report agree with the findings from Report 98-5 from the National Center for Asphalt Technology (NCAT) *(5)*. That study also recommended that specimens be compacted to N_{des} at mix design. The study examined dense graded and stone matrix asphalt (SMA) mixes. The data showed both positive and negative air void differences at higher gyration levels and larger positive values at lower gyration values (both results similar to the findings in this report).

It should be noted that the current Superpave specifications for $\%G_{mm}$, VMA, VFA, etc. may have been based on the current back calculation method. These specification values may need to be reexamined and possibly adjusted if a if specimens at design are to be gyrated to N_{des} and possibly N_{ini} levels .

REFERENCES

1. Crockford, Bill. *More Tailgate Tips - Estimating Bulk Specific Gravity without Water*. The Asphalt Contractor, Independence, MO, June, 1998.

2. *Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens, AASHTO Standard Method of Test T 166-93*. 1993.

3. *Standard Test Method for Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens, ASTM D 2726-93a*. 1993.

4. *Asphalt Paving Technician Manual, English Version*. Pages 9-9 thru 9-12. Florida Department of Transportation, Gainesville, FL, 1996.

5. Mallick, Rajib B., S. Buchanan, E. R. Brown, M. Huner. *An Evaluation of Superpave Gyratory Compaction of Hot Mix Asphalt*. Report 98-5, National Center for Asphalt Technology, Auburn, AL, January,1998.

Table 1 - Composite Gradation Summary of Mixes Used in Study

Mix #	SP98-0176A	SP98-0177A	SP98-0178A	SP98-0108A	SP97-0071A	SP96-0017B
Nom. Max. Agg. Size, mm	9.5	12.5	19.0	9.5	12.5	19.0
Agg. Type	Fl. Limestone	Fl. Limestone	Fl. Limestone	Ga. Granite	Ga. Granite	Ga. Granite
Gradation % Passing						
19.0 mm	100	100	99	100	100	99
12.5 mm	100	96	91*	100	100	63
9.5 mm	99	90	84	100	78	45
4.75 mm	72	61	53	75	43	35
2.36 mm	46	39	33	47	29	25
1.18 mm	28	22	18	32	18	20
600µm	15	11	9.5	23	12	14
300µm	8.1	6.0	5.5	16	8.6	11
150µm	4.9	4.1	4.2	11	5.9	7.2
75µm	3.9	3.6	3.7	6.4	3.7	4.5

* By definition, this composition gradation does not meet the Superpave requirements for a 19.0 mm mix because the % passing the 12.5 mm sieve is 91 %. This is 1% greater than that of the FDOT approved mix design.

Table 2 - Maximum Range in G_{mb} Values of Four Specimens for Each Mix Type and Gyration Level (Including Outliers)

Mix ID	Nmax	Ndes	Nini (SSD)	Nini (Beads)
176A-9.5 LS	0.053	0.026	0.038	0.056
177A-12.5 LS	0.013	0.089	0.018	0.045
	3 samples			
178A-19.0 LS	0.045	0.040	0.027	0.063
108A-9.5 GR	0.029	0.005	0.046	0.039
71A-12.5 GR	0.051	0.074	0.025	0.018
17B-19.0 GR	0.016	0.030	0.007	0.049

Table 3 - Maximum Range in G_{mb} Values of Three or Four Specimens for Each Mix Type and Gyration Level (Excluding Outliers)

Mix ID	Nmax	Ndes	Nini (SSD)	Nini (Beads)
176A-9.5 LS	0.009	0.026	0.038	0.056
	3 samples	4 samples	4 samples	4 samples
177A-12.5 LS	0.013	0.023	0.018	0.045
	4 samples	3 samples	4 samples	4 samples
178A-19.0 LS	0.022	0.015	0.027	0.030
	3 samples	3 samples	4 samples	3 samples
108A-9.5 GR	0.007	0.005	0.046	0.011
	3 samples	4 samples	4 samples	3 samples
71A-12.5 GR	0.012	0.042	0.006	0.018
	3 samples	3 samples	3 samples	4 samples
17B-19.0 GR	0.004	0.030	0.007	0.049
	3 samples	4 samples	4 samples	4 samples

Table 4 - Air Void Data Including Outliers

Summary, 176A - 9.5 Limerock	N_{des}	N_{ini}	
Average air voids, back calculated	5.23	16.28	16.28
Average air voids actual, SSD	5.43	15.73	NA
Average air voids actual, beads	NA	NA	15.16
Difference (Back calculated - actual)	-0.20	0.54	1.12

Summary, 177A - 12.5 Limerock	N_{des}	N_{ini}	
Average air voids, back calculated	4.37	15.65	15.65
Average air voids actual, SSD	5.65	14.36	NA
Average air voids actual, beads	NA	NA	14.51
Difference (Back calculated - actual)	-1.28	1.29	1.14

Summary, 178A - 19.0 Limerock	N_{des}	N_{ini}	
Average air voids, back calculated	6.89	17.75	17.75
Average air voids actual, SSD	6.45	15.06	NA
Average air voids actual, beads	NA	NA	15.74
Difference (Back calculated - actual)	0.43	2.69	2.01

Summary, 108A - 9.5 Granite	N_{des}	N_{ini}	
Average air voids, back calculated	4.11	13.26	13.26
Average air voids actual, SSD	3.54	11.66	NA
Average air voids actual, beads	NA	NA	11.21
Difference (Back calculated - actual)	0.56	1.60	2.04

Summary, 71A - 12.5 Granite	N_{des}	N_{ini}	
Average air voids, back calculated	5.58	15.37	15.37
Average air voids actual, SSD	5.76	12.81	NA
Average air voids actual, beads	NA	NA	13.17
Difference (Back calculated - actual)	-0.18	2.56	2.19

Summary, 17B - 19.0 Granite	N_{des}	N_{ini}	
Average air voids, back calculated	4.26	13.68	13.68
Average air voids actual, SSD	4.11	9.43	NA
Average air voids actual, beads	NA	NA	10.36
Difference (Back calculated - actual)	0.16	4.26	3.32

Table 5 - Air Void Data Excluding Outliers

Summary, 176A - 9.5 Limerock	N_{des}	N_{ini}	
Average air voids, back calculated	4.68	15.66	15.66
Average air voids actual, SSD	5.43	15.73	NA
Average air voids actual, beads	NA	NA	15.16
Difference (Back calculated - actual)	-0.75	-0.07	0.50

Summary, 177A - 12.5 Limerock	N_{des}	N_{ini}	
Average air voids, back calculated	4.37	15.65	15.65
Average air voids actual, SSD	6.46	14.36	NA
Average air voids actual, beads	NA	NA	14.51
Difference (Back calculated - actual)	-2.09	1.29	1.14

Summary, 178A - 19.0 Limerock	N_{des}	N_{ini}	
Average air voids, back calculated	7.22	18.14	18.14
Average air voids actual, SSD	6.09	15.06	NA
Average air voids actual, beads	NA	NA	16.24
Difference (Back calculated - actual)	1.13	3.09	1.90

Summary, 108A - 9.5 Granite	N_{des}	N_{ini}	
Average air voids, back calculated	3.84	13.02	13.02
Average air voids actual, SSD	3.54	11.66	NA
Average air voids actual, beads	NA	NA	11.55
Difference (Back calculated - actual)	0.30	1.37	1.48

Summary, 71A - 12.5 Granite	N_{des}	N_{ini}	
Average air voids, back calculated	5.16	15.05	15.05
Average air voids actual, SSD	5.20	12.59	NA
Average air voids actual, beads	NA	NA	13.17
Difference (Back calculated - actual)	-0.04	2.46	1.87

Summary, 17B - 19.0 Granite	N_{des}	N_{ini}	
Average air voids, back calculated	4.40	13.90	13.90
Average air voids actual, SSD	4.11	9.43	NA
Average air voids actual, beads	NA	NA	10.36
Difference (Back calculated - actual)	0.29	4.47	3.54

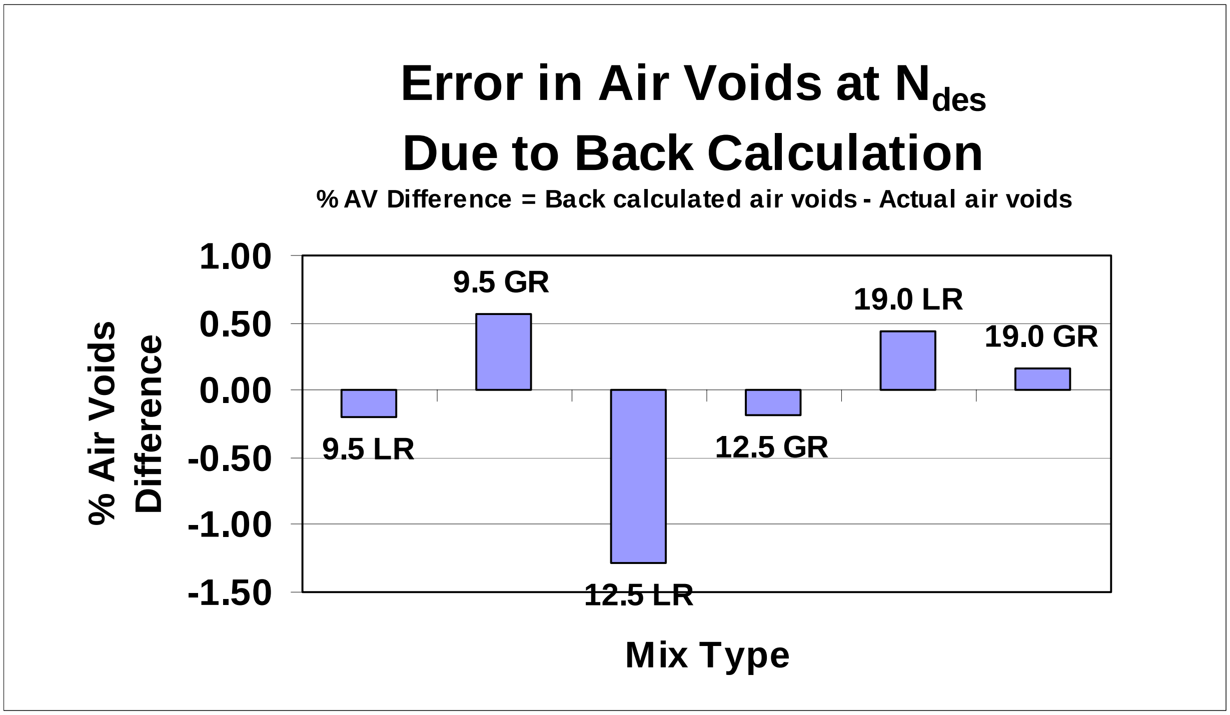

Figure 1 - N_{des} Air Void Data Including Outliers

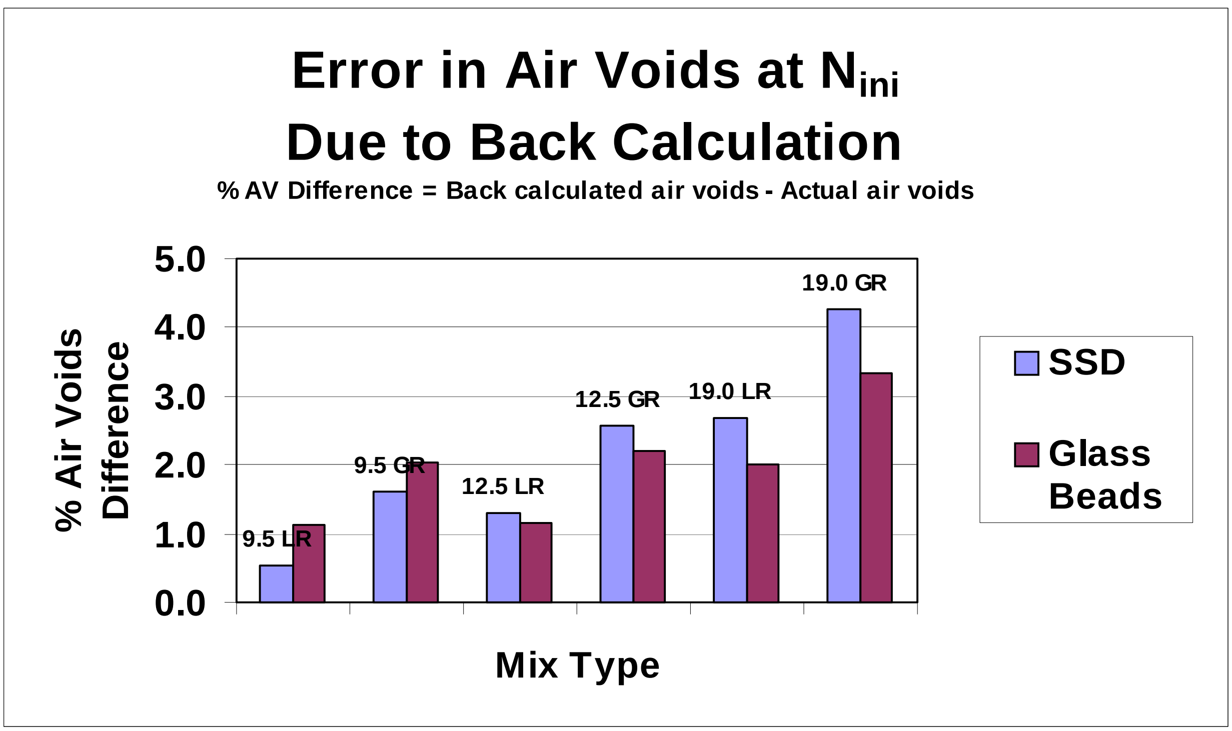

Figure 2 - N_{ini} Air Void Data Including Outliers

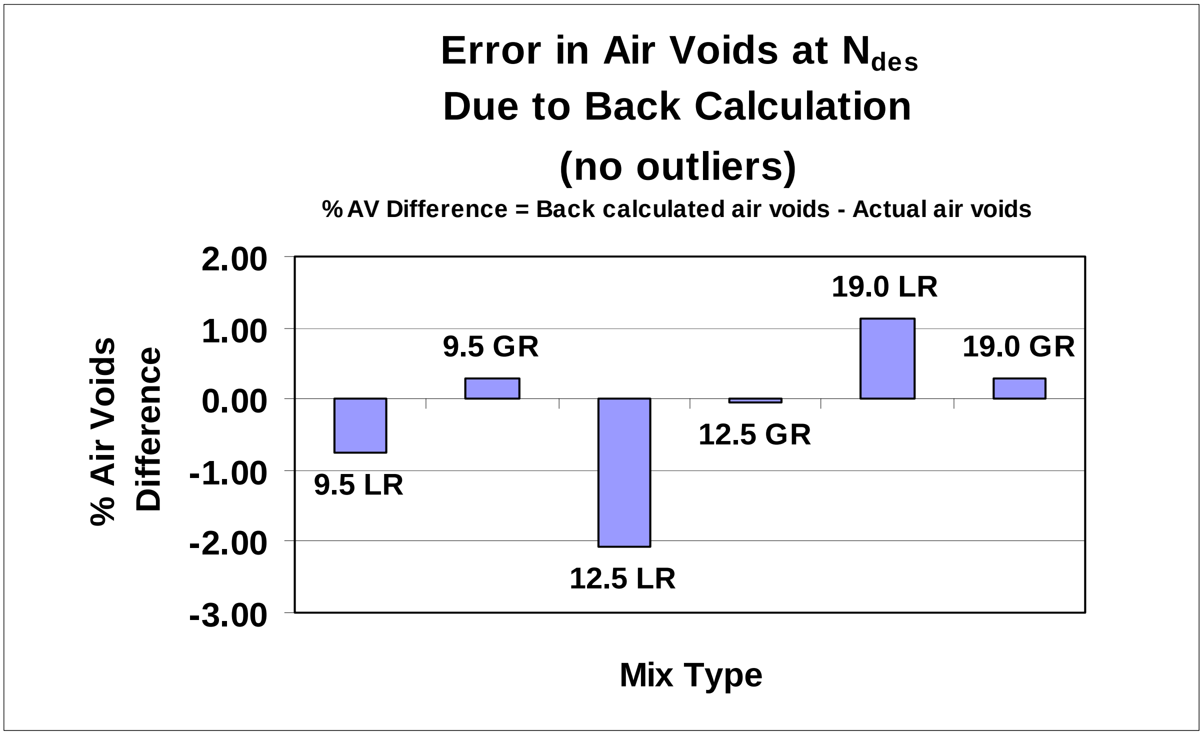

Figure 3 - N_{des} Air Void Data Excluding Outliers

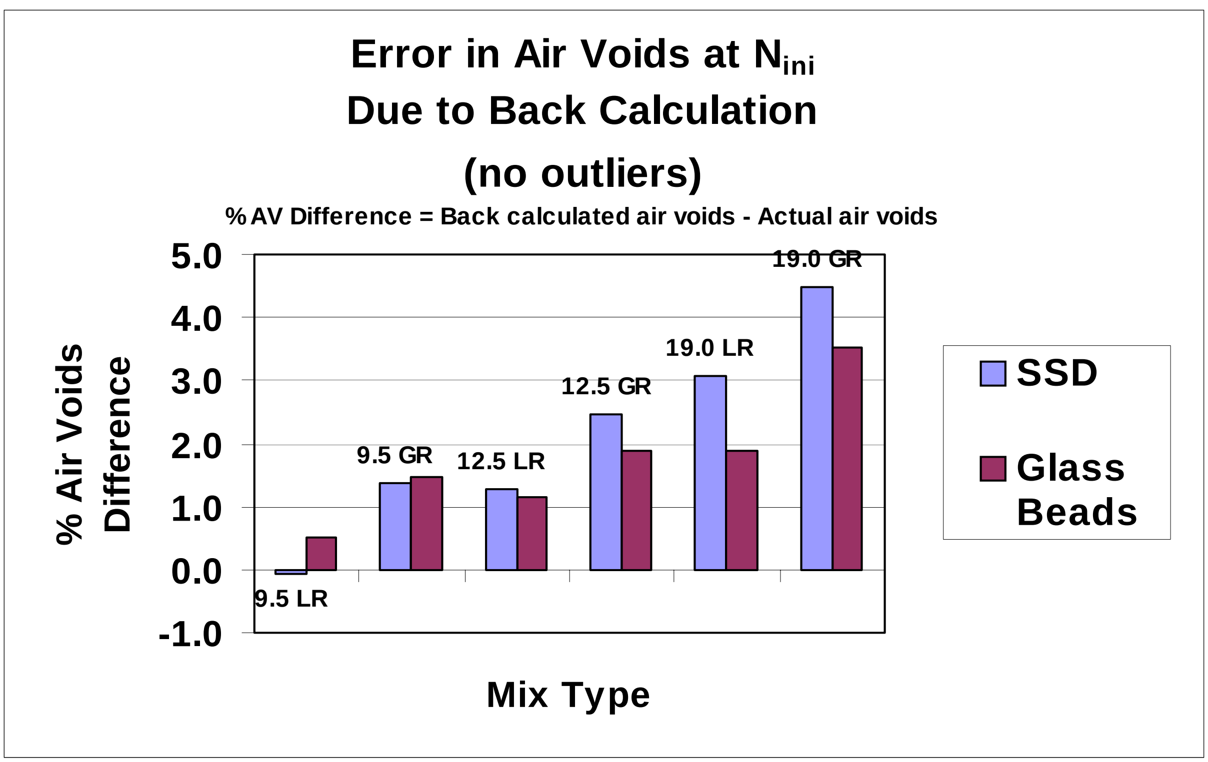

Figure 4 - N_{ini} Air Void Data Excluding Outliers

APPENDIX

Calculations for Mix 176A-9.5 LR (Including Outliers)

N_{max} SSD method

Sample ID	A	B	C	D	Range	
Dry Wt.	4509.1	4499.7	4506.8	4506.5	9.4	
Wt. In H_20	2499.8	2501.6	2502.7	2459.6		
SSD Wt.	4513.2	4502.6	4508.8	4511.6		
Volume	2013.4	2001.0	2006.1	2052.0		St. Dev.
G_{mb}	2.240	2.249	2.247	2.196	0.053	0.025
G_{mm}	2.311	2.311	2.311	2.311		
Air Voids	3.09	2.69	2.79	4.97	2.3	
		Avg air voids		3.39		

N_{des} SSD method

Sample ID	E	F	G	H	Range	
Dry Wt.	4503.7	4506.5	4501.7	4500.2	6.3	
Wt. In H_20	2440.4	2446.4	2460.9	2454.2		
SSD Wt.	4514.3	4512.3	4508.9	4508.5		
Volume	2073.9	2065.9	2048.0	2054.3		St. Dev.
G_{mb}	2.172	2.181	2.198	2.191	0.026	0.011
G_{mm}	2.311	2.311	2.311	2.311		
Air Voids	6.03	5.61	4.89	5.21	1.1	
		Avg air voids		5.43		

N_{ini} SSD method

Sample ID	I	J	K	L	Range	
Dry Wt.	4510.2	4502.1	4508.0	4516.4	14.3	
Wt. In H_20	2380.2	2396.5	2389.7	2392.1		
SSD Wt.	4679.2	4727.4	4681.1	4733.4		
Volume	2299.0	2330.9	2291.4	2341.3		St. Dev.
G_{mb}	1.962	1.931	1.967	1.929	0.038	0.020
G_{mm}	2.311	2.311	2.311	2.311		
Air Voids	15.11	16.42	14.87	16.53	1.7	
		Avg air voids		15.73		

N_{ini} - Glass Beads tested by Brian Cawley

Sample ID	I	J	K	L	
Dry Wt.	4510.2	4502.1	4508.0	4516.4	
Wt. partial wet	4557.5	4556.5	4565.2	4575.4	
Wt.w/ beads & bkt.(1) kg	32.80	32.70	32.84	32.76	
Wt.w/ beads & bkt.(2) kg	32.80	32.72	32.80	32.74	
Wt.w/ beads & bkt.(3) kg	32.80	32.70	32.82	32.68	
Wt.w/ beads & bkt.(avg)	32.80	32.71	32.82	32.73	
Bucket wt.	8.7041	8.7041	8.7041	8.7041	
Wt. of beads, g	19538.4	19446.1	19550.7	19447.2	
Volume of beads, cm^3	11805.2	11749.4	11812.6	11750.1	
Pill vol = bkt vol - bead vol	2274.3	2330.1	2266.9	2329.4	Range
G_{mb} pill	1.983	1.932	1.989	1.939	0.056
G_{mm}	2.311	2.311	2.311	2.311	
Air Voids	14.19	16.39	13.95	16.10	2.4
		Avg air voids		15.16	

N_{max} dimensional method

Ht @ N_{max}, mm	115.4	114.4	114.8	117.6
Area, cm^2	176.7	176.7	176.7	176.7
Volume, cm^3	2039.3	2021.6	2028.7	2078.2
Dry wt.	4509.1	4499.7	4506.8	4506.5
G_{mb}	2.211	2.226	2.222	2.169
G_{mb} corr. fact.	1.013	1.010	1.011	1.013

Gmb, Nmax	Dens(pcf)	Ht, Nmax	Mass	Dens(pcf)
2.240	139.7	115.4	4509.1	139.7
2.249	140.3	114.4	4499.7	140.3
2.247	140.2	114.8	4506.8	140.2
2.196	137.0	117.6	4506.5	137.0

Bucket Wt. (Empty)		8.7041	kg		
Bucket Volume		14079.5	cm^3		
Beads and Bucket		1	2	3	
		32.02	32.02	31.98	kg
Avg. (beads and bucket)		32.01	kg		
Avg. minus bucket wt.		23.30	kg		
G_{mb} of beads		1.655			

N_{des} dimensional method

Ht @ N_{des}, mm	117.6	116.6	117.0	120.0	
Area, cm^2	176.7	176.7	176.7	176.7	
Volume, cm^3	2078.2	2060.5	2067.6	2120.6	
Dry wt.	4509.1	4499.7	4506.8	4506.5	
G_{mb}	2.170	2.184	2.180	2.125	Range
G_{mb} * CF	2.198	2.206	2.204	2.152	0.054
G_{mm}	2.311	2.311	2.311	2.311	
Air Voids (corr)	4.90	4.53	4.62	6.87	2.3
		Avg air voids, corr.		5.23	

Summary, 176A - 9.5 Limerock	N_{des}	N_{ini}	
Average air voids, back calculated	5.23	16.28	16.28
Average air voids actual, SSD	5.43	15.73	NA
Average air voids actual, beads	NA	NA	15.16
Difference (back calculated-actual)	-0.20	0.54	1.12

N_{ini} dimensional method

Ht @ N_{ini}, mm	133.1	131.4	132.4	136.5	
Area, cm^2	176.7	176.7	176.7	176.7	
Volume, cm^3	2352.1	2322.0	2339.7	2412.2	
Dry wt.	4509.1	4499.7	4506.8	4506.5	
G_{mb}	1.917	1.938	1.926	1.868	Range
G_{mb} * CF	1.942	1.958	1.948	1.892	0.066
G_{mm}	2.311	2.311	2.311	2.311	
Air Voids (corr)	15.98	15.28	15.71	18.13	2.8
		Avg air voids corr.		16.28	

Calculations for Mix 177A-12.5 LR (Including Outliers)

N_{max} SSD method

Sample ID	A	B	C	D	Range	
Dry Wt.	4538.5	v	4549.7	4546.1	11.2	
Wt. In $H_2$0	2544.9	o	2547.6	2537.4		
SSD Wt.	4543.5	l	4553.7	4551.1		
Volume	1998.6	d	2006.1	2013.7		St. Dev.
G_{mb}	2.271		2.268	2.258	0.013	0.007
G_{mm}	2.322		2.322	2.322		
Air Voids	2.20		2.33	2.77	0.6	
		Avg air voids		2.44		

N_{max} dimensional method

Ht @ N_{max}, mm	114.8	v	115.2	115.9
Area, cm^2	176.7	o	176.7	176.7
Volume, cm^3	2028.7	l	2035.8	2048.1
Dry wt.	4538.5	d	4549.7	4546.1
G_{mb}	2.237		2.235	2.220
G_{mb} corr. fact.	1.015		1.015	1.017

N_{des} dimensional method

Ht @ N_{des}, mm	117.2	v	117.5	118.2	
Area, cm^2	176.7	o	176.7	176.7	
Volume, cm^3	2071.1	l	2076.4	2088.8	
Dry wt.	4538.5	d	4549.7	4546.1	
G_{mb}	2.191		2.191	2.176	Range
G_{mb} * CF	2.224		2.224	2.214	0.011
G_{mm}	2.322		2.322	2.322	
Air Voids (corr)	4.21		4.24	4.67	0.5
		Avg air voids, corr.		4.37	

N_{ini} dimensional method

Ht @ N_{ini}, mm	132.8	v	133.6	133.7	
Area, cm^2	176.7	o	176.7	176.7	
Volume, cm^3	2346.8	l	2360.9	2362.7	
Dry wt.	4538.5	d	4549.7	4546.1	
G_{mb}	1.934		1.927	1.924	Range
G_{mb} * CF	1.963		1.956	1.957	0.007
G_{mm}	2.322		2.322	2.322	
Air Voids (corr)	15.46		15.78	15.72	0.3
		Avg air voids corr.		15.65	

N_{des} SSD method

Sample ID	E	F	G	H	Range	
Dry Wt.	4554.7	4554.0	4546.5	4540.5	14.2	
Wt. In $H_2$0	2480.0	2531.8	2458.3	2470.9		
SSD Wt.	4570.7	4558.8	4565.7	4553.4		
Volume	2090.7	2027.0	2107.4	2082.5		St. Dev.
G_{mb}	2.179	2.247	2.157	2.180	0.089	0.039
G_{mm}	2.322	2.322	2.322	2.322		
Air Voids	6.18	3.24	7.09	6.10	3.8	
		Avg air voids		5.65		

Gmb, Nmax	Dens(pcf)	Ht, Nmax	Mass	Dens(pcf)
2.271	141.7	114.8	4538.5	141.7
2.268	141.5	115.2	4549.7	141.5
2.258	140.9	115.9	4546.1	140.9

Summary, 177A - 12.5 Limerock	N_{des}	N_{ini}	
Average air voids, back calculated	4.37	15.65	15.65
Average air voids actual, SSD	5.65	14.36	NA
Average air voids actual, beads	NA	NA	14.51
Difference (back calculated-actual)	-1.28	1.29	1.14

N_{ini} SSD method

Sample ID	I	J	K	L	Range	
Dry Wt.	4550.0	4545.8	4555.2	4547.7	9.4	
Wt. In $H_2$0	2459.4	2456.9	2452.1	2452.3		
SSD Wt.	4736.3	4752.4	4735.4	4748.8		
Volume	2276.9	2295.5	2283.3	2296.5		St. Dev.
G_{mb}	1.998	1.980	1.995	1.980	0.018	0.010
G_{mm}	2.322	2.322	2.322	2.322		
Air Voids	13.94	14.72	14.08	14.72	0.8	
		Avg air voids		14.36		

N_{ini} - Glass Beads tested by Bryan Cawley

Sample ID	I	J	K	L	
Dry Wt.	4550.0	4545.8	4555.2	4547.7	
Wt. partial wet	4594.8	4593.1	4601.1	4587.5	
Wt.w/ beads & bkt.(1) kg	32.77	32.66	32.72	32.74	
Wt.w/ beads & bkt.(2) kg	32.74	32.69	32.74	32.70	
Wt.w/ beads & bkt.(3) kg	32.77	32.68	32.73	32.71	
Wt.w/ beads & bkt.(avg)	32.76	32.68	32.73	32.72	
Bucket wt.	8.7041	8.7041	8.7041	8.7041	
Wt. of beads, g	19461.1	19379.5	19424.8	19425.1	
Volume of beads, cm^3	11810.8	11761.3	11788.8	11789.0	
Pill vol = bkt vol - bead vol	2268.7	2318.2	2290.7	2290.5	Range
G_{mb} pill	2.006	1.961	1.989	1.985	0.045
G_{mm}	2.322	2.322	2.322	2.322	
Air Voids	13.63	15.55	14.36	14.49	1.9
		Avg air voids		14.51	

Bucket Wt. (Empty)	8.7041	kg			
Bucket Volume	14079.5	cm^3			
Beads and Bucket	1	2	3		
	31.89	31.93	31.89	kg	
Avg. (beads and bucket)	31.90	kg			
Avg. minus bucket wt.	23.20	kg			
G_{mb} of beads	1.648				

Calculations for Mix 178A-19.0 LR (Including Outliers)

N_{max} SSD method

Sample ID	A	B	C	D	Range	
Dry Wt.	4579.5	4572.1	4578.7	4581.6	9.5	
Wt. In $H_2$0	2554.2	2531.0	2517.7	2532.8		
SSD Wt.	4590.7	4585.2	4595.0	4597.5		
Volume	2036.5	2054.2	2077.3	2064.7		St. Dev.
G_{mb}	2.249	2.226	2.204	2.219	0.045	0.019
G_{mm}	2.341	2.341	2.341	2.341		
Air Voids	3.94	4.92	5.85	5.21	1.9	
		Avg air voids		4.98		

N_{max} dimensional method

Ht @ N_{max}, mm	117.0	118.1	119.6	119.2
Area, cm^2	176.7	176.7	176.7	176.7
Volume, cm^3	2067.6	2087.0	2113.5	2106.4
Dry wt.	4579.5	4572.1	4578.7	4581.6
G_{mb}	2.215	2.191	2.166	2.175
G_{mb} corr. fact.	1.015	1.016	1.017	1.020

N_{des} dimensional method

Ht @ N_{des}, mm	119.4	120.5	122.1	121.6	
Area, cm^2	176.7	176.7	176.7	176.7	
Volume, cm^3	2110.0	2129.4	2157.7	2148.8	
Dry wt.	4579.5	4572.1	4578.7	4581.6	
G_{mb}	2.170	2.147	2.122	2.132	Range
G_{mb} * CF	2.204	2.181	2.159	2.175	0.044
G_{mm}	2.341	2.341	2.341	2.341	
Air Voids (corr)	5.87	6.82	7.77	7.08	1.9
		Avg air voids, corr.		6.89	

N_{ini} dimensional method

Ht @ N_{ini}, mm	134.7	135.9	138.9	138.0	
Area, cm^2	176.7	176.7	176.7	176.7	
Volume, cm^3	2380.3	2401.6	2454.6	2438.7	
Dry wt.	4579.5	4572.1	4578.7	4581.6	
G_{mb}	1.924	1.904	1.865	1.879	Range
G_{mb} * CF	1.953	1.934	1.898	1.917	0.055
G_{mm}	2.341	2.341	2.341	2.341	
Air Voids (corr)	16.56	17.38	18.93	18.12	2.4
		Avg air voids corr.		17.75	

N_{des} SSD method

Sample ID	E	F	G	H	Range	
Dry Wt.	4580.2	4588.8	4583.1	4586.7	8.6	
Wt. In $H_2$0	2493.6	2524.6	2522.6	2515.9		
SSD Wt.	4609.7	4609.7	4601.3	4610.5		
Volume	2116.1	2085.1	2078.7	2094.6		St. Dev.
G_{mb}	2.164	2.201	2.205	2.190	0.040	0.018
G_{mm}	2.341	2.341	2.341	2.341		
Air Voids	7.54	5.99	5.82	6.46	1.7	
		Avg air voids		6.45		

Gmb, Nmax	Dens(pcf)	Ht, Nmax	Mass	Dens(pcf)
2.249	140.3	117.0	4579.5	140.3
2.226	138.9	118.1	4572.1	138.9
2.204	137.5	119.6	4578.7	137.5
2.219	138.5	119.2	4581.6	138.5

Summary, 178A - 19.0 Limerock	N_{des}	N_{ini}	
Average air voids, back calculated	6.89	17.75	17.75
Average air voids actual, SSD	6.45	15.06	NA
Average air voids actual, beads	NA	NA	15.74
Difference (back calculated-actual)	0.43	2.69	2.01

N_{ini} SSD method

Sample ID	I	J	K	L	Range	
Dry Wt.	4588.3	4588.2	4591.4	4589.9	3.2	
Wt. In $H_2$0	2497.4	2512.2	2504.1	2511.8		
SSD Wt.	4790.5	4837.2	4815.2	4814.8		
Volume	2293.1	2325.0	2311.1	2303.0		St. Dev.
G_{mb}	2.001	1.973	1.987	1.993	0.027	0.012
G_{mm}	2.341	2.341	2.341	2.341		
Air Voids	14.53	15.70	15.14	14.87	1.2	
		Avg air voids		15.06		

N_{ini} - Glass Beads tested by Bryan Cawley

Sample ID	I	J	K	L	
Dry Wt.	4588.3	4588.2	4591.4	4589.9	
Wt. partial wet	4645.3	4660.8	4652.0	4654.0	
Wt.w/ beads & bkt.(1) kg	32.76	32.68	32.72	32.70	
Wt.w/ beads & bkt.(2) kg	32.82	32.68	32.72	32.72	
Wt.w/ beads & bkt.(3) kg	32.78	32.68	32.74	32.70	
Wt.w/ beads & bkt.(avg)	32.79	32.68	32.73	32.71	
Bucket wt.	8.7041	8.7041	8.7041	8.7041	
Wt. of beads, g	19437.3	19315.1	19370.6	19348.6	
Volume of beads, cm^3	11794.7	11720.6	11754.2	11740.9	
Pill vol = bkt vol - bead vol	2284.8	2358.9	2325.3	2338.6	Range
G_{mb} pill	2.008	1.945	1.975	1.963	0.063
G_{mm}	2.341	2.341	2.341	2.341	
Air Voids	14.22	16.91	15.65	16.16	2.7
		Avg air voids		15.74	

Bucket Wt. (Empty)	8.7041	kg		
Bucket Volume	14079.5	cm^3		
Beads and Bucket	1	2	3	
	31.84	31.92	31.96	kg
Avg. (beads and bucket)	31.91	kg		
Avg. minus bucket wt.	23.20	kg		
G_{mb} of beads	1.648			

Calculations for Mix 108A-9.5 GR (Including Outliers)

N_{max} SSD method

Sample ID	A	B	C	D	Range	
Dry Wt.	4993.5	5001.3	4997.4	4981.5	19.8	
Wt. In $H_2$0	2938.4	2960.2	2958.1	2954.6		
SSD Wt.	4996.6	5003.2	4999.8	4983.9		
Volume	2058.2	2043.0	2041.7	2029.3		St. Dev.
G_{mb}	2.426	2.448	2.448	2.455	0.029	0.012
G_{mm}	2.515	2.515	2.515	2.515		
Air Voids	3.53	2.66	2.68	2.39	1.1	
		Avg air voids		2.82		

N_{des} SSD method

Sample ID	E	F	G	H	Range	
Dry Wt.	4978.9	4979.1	4975.1	4976.3	4.0	
Wt. In $H_2$0	2929.2	2927.4	2928.0	2930.5		
SSD Wt.	4982.3	4982.2	4978.2	4979.5		
Volume	2053.1	2054.8	2050.2	2049.0		St. Dev.
G_{mb}	2.425	2.423	2.427	2.429	0.005	0.002
G_{mm}	2.515	2.515	2.515	2.515		
Air Voids	3.58	3.65	3.51	3.43	0.2	
		Avg air voids		3.54		

N_{ini} SSD method

Sample ID	I	J	K	L	Range	
Dry Wt.	4978.9	4977.4	4976.7	4976.3	2.6	
Wt. In $H_2$0	2808.5	2806.1	2822.7	2801.7		
SSD Wt.	5062.7	5068.7	5038.9	5030.0		
Volume	2254.2	2262.6	2216.2	2228.3		St. Dev.
G_{mb}	2.209	2.200	2.246	2.233	0.046	0.021
G_{mm}	2.515	2.515	2.515	2.515		
Air Voids	12.18	12.53	10.71	11.20	1.8	
		Avg air voids		11.66		

N_{ini} - Glass Beads tested by Greg Sholar

Sample ID	I	J	K	L	
Dry Wt.	4978.9	4977.4	4976.7	4976.3	
Wt. partial wet	5029.1	5030.7	5026.5	5005.4	
Wt.w/ beads & bkt.(1) kg	33.24	33.24	33.30	33.26	
Wt.w/ beads & bkt.(2) kg	33.26	33.26	33.30	33.26	
Wt.w/ beads & bkt.(3) kg	33.26	33.24	33.32	33.20	
Wt.w/ beads & bkt.(avg)	33.25	33.25	33.31	33.24	
Bucket wt.	8.7041	8.7041	8.7041	8.7041	
Wt. of beads, g	19520.1	19511.9	19576.1	19530.5	
Volume of beads, cm^3	11841.6	11836.6	11875.5	11847.9	
Pill vol = bkt vol - bead vol	2237.9	2242.9	2204.0	2231.6	Range
G_{mb} pill	2.225	2.219	2.258	2.230	0.039
G_{mm}	2.515	2.515	2.515	2.515	
Air Voids	11.54	11.76	10.22	11.34	1.5
		Avg air voids		11.21	

N_{max} dimensional method

Ht @ N_{max}, mm	118.0	117.1	117.1	116.4
Area, cm^2	176.7	176.7	176.7	176.7
Volume, cm^3	2085.2	2069.3	2069.3	2057.0
Dry wt.	4993.5	5001.3	4997.4	4981.5
G_{mb}	2.395	2.417	2.415	2.422
G_{mb} corr. fact.	1.013	1.013	1.014	1.014

Gmb, Nmax	Dens(pcf)	Ht, Nmax	Mass	Dens(pcf)
2.426	151.4	118.0	4993.5	151.4
2.448	152.8	117.1	5001.3	152.8
2.448	152.7	117.1	4997.4	152.7
2.455	153.2	116.4	4981.5	153.2

Bucket Wt. (Empty)	8.7041	kg		
Bucket Volume	14079.5	cm^3		
Beads and Bucket	1	2	3	
	31.86	31.94	31.94	kg
Avg. (beads and bucket)	31.91	kg		
Avg. minus bucket wt.	23.21	kg		
G_{mb} of beads	1.648			

N_{des} dimensional method

Ht @ N_{des}, mm	119.7	118.7	118.6	117.9	
Area, cm^2	176.7	176.7	176.7	176.7	
Volume, cm^3	2115.3	2097.6	2095.8	2083.5	
Dry wt.	4993.5	5001.3	4997.4	4981.5	
G_{mb}	2.361	2.384	2.384	2.391	Range
G_{mb} * CF	2.392	2.415	2.417	2.424	0.032
G_{mm}	2.515	2.515	2.515	2.515	
Air Voids (corr)	4.90	3.98	3.91	3.64	1.3
		Avg air voids, corr		4.11	

Summary, 108A - 9.5 Granite	N_{des}	N_{ini}	
Average air voids, back calculated	4.11	13.26	13.26
Average air voids actual, SSD	3.54	11.66	NA
Average air voids actual, beads	NA	NA	11.21
Difference (back calculated-actual)	0.56	1.60	2.04

N_{ini} dimensional method

Ht @ N_{ini}, mm	132.3	131.3	131.1	130.3	
Area, cm^2	176.7	176.7	176.7	176.7	
Volume, cm^3	2337.9	2320.3	2316.7	2302.6	
Dry wt.	4993.5	5001.3	4997.4	4981.5	
G_{mb}	2.136	2.155	2.157	2.163	Range
G_{mb} * CF	2.164	2.183	2.186	2.193	0.029
G_{mm}	2.515	2.515	2.515	2.515	
Air Voids (corr)	13.96	13.19	13.07	12.81	1.2
		Avg air voids, corr		13.26	

Calculations for Mix 71A-12.5 GR (Including Outliers)

N_{max} SSD method

Sample ID	A	B	C	D	Range	
Dry Wt.	5004.7	4998.0	5002.6	5009.6	11.6	
Wt. In H_2O	2978.2	2934.4	2967.3	2976.8		
SSD Wt.	5011.8	5008.3	5010.1	5017.1		
Volume	2033.6	2073.9	2042.8	2040.3		St. Dev.
G_{mb}	2.461	2.410	2.449	2.455	0.051	0.023
G_{mm}	2.549	2.549	2.549	2.549		
Air Voids	3.45	5.45	3.93	3.67	2.0	
		Avg air voids		4.13		

N_{des} SSD method

Sample ID	E	F	G	H	Range	
Dry Wt.	5005.7	5009.5	5010.0	5003.8	6.2	
Wt. In H_2O	2907.8	2962.8	2958.0	2925.1		
SSD Wt.	5029.8	5022.2	5022.3	5018.6		
Volume	2122.0	2059.4	2064.3	2093.5		St. Dev.
G_{mb}	2.359	2.433	2.427	2.390	0.074	0.034
G_{mm}	2.549	2.549	2.549	2.549		
Air Voids	7.46	4.57	4.79	6.23	2.9	
		Avg air voids		5.76		

N_{ini} SSD method

Sample ID	I	J	K	L	Range	
Dry Wt.	5006.7	5011.4	5010.6	5005.8	5.6	
Wt. In H_2O	2921.6	2916.9	2918.7	2923.6		
SSD Wt.	5172.1	5165.3	5165.1	5192.8		
Volume	2250.5	2248.4	2246.4	2269.2		St. Dev.
G_{mb}	2.225	2.229	2.231	2.206	0.025	0.011
G_{mm}	2.549	2.549	2.549	2.549		
Air Voids	12.72	12.56	12.50	13.46	1.0	
		Avg air voids		12.81		

N_{ini} - Glass Beads tested by Mike Berkowitz

Sample ID	I	J	K	L	
Dry Wt.	5006.7	5011.4	5010.6	5005.8	
Wt. partial wet	5062.8	5069.4	5065.0	5072.4	
Wt.w/ beads & bkt.(1) kg	33.18	33.24	33.22	33.24	
Wt.w/ beads & bkt.(2) kg	33.26	33.26	33.22	33.24	
Wt.w/ beads & bkt.(3) kg	33.26	33.24	33.20	33.24	
Wt.w/ beads & bkt.(avg)	33.23	33.25	33.21	33.24	
Bucket wt.	8.7041	8.7041	8.7041	8.7041	
Wt. of beads, g	19466.4	19473.2	19444.2	19463.5	
Volume of beads, cm^3	11819.2	11823.3	11805.7	11817.4	
Pill vol = bkt vol - bead vol	2260.3	2256.2	2273.8	2262.1	Range
G_{mb} pill	2.215	2.221	2.204	2.213	0.018
G_{mm}	2.549	2.549	2.549	2.549	
Air Voids	13.10	12.86	13.55	13.19	0.7
		Avg air voids		13.17	

Bucket Wt. (Empty)	8.7041	kg		
Bucket Volume	14079.5	cm^3		
Beads and Bucket	1	2	3	
	31.88	31.90	31.90	kg
Avg. (beads and bucket)	31.89	kg		
Avg. minus bucket wt.	23.19	kg		
G_{mb} of beads	1.647			

N_{max} dimensional method

Ht @ N_{max}, mm	117.8	120.1	118.4	118.1
Area, cm^2	176.7	176.7	176.7	176.7
Volume, cm^3	2081.7	2122.3	2092.3	2087.0
Dry wt.	5004.7	4998.0	5002.6	5009.6
G_{mb}	2.404	2.355	2.391	2.400
G_{mb} corr. fact.	1.024	1.023	1.024	1.023

Gmb, Nmax	Dens(pcf)	Ht, Nmax	Mass	Dens(pcf)
2.461	153.6	117.8	5004.7	153.6
2.410	150.4	120.1	4998.0	150.4
2.449	152.8	118.4	5002.6	152.8
2.455	153.2	118.1	5009.6	153.2

N_{des} dimensional method

Ht @ N_{des}, mm	119.6	121.9	120.3	119.9	
Area, cm^2	176.7	176.7	176.7	176.7	
Volume, cm^3	2113.5	2154.2	2125.9	2118.8	
Dry wt.	5004.7	4998.0	5002.6	5009.6	
G_{mb}	2.368	2.320	2.353	2.364	Range
G_{mb} * CF	2.424	2.374	2.410	2.418	0.050
G_{mm}	2.549	2.549	2.549	2.549	
Air Voids (corr)	4.91	6.85	5.44	5.12	1.9
		Avg air voids, corr		5.58	

Summary, 71A - 12.5 Granite	N_{des}	N_{ini}	
Average air voids, back calculated	5.58	15.37	15.37
Average air voids actual, SSD	5.76	12.81	NA
Average air voids actual, beads	NA	NA	13.17
Difference (back calculated-actual)	-0.18	2.56	2.19

N_{ini} dimensional method

Ht @ N_{ini}, mm	133.3	135.7	134.4	134.0	
Area, cm^2	176.7	176.7	176.7	176.7	
Volume, cm^3	2355.6	2398.0	2375.0	2368.0	
Dry wt.	5004.7	4998.0	5002.6	5009.6	
G_{mb}	2.125	2.084	2.106	2.116	Range
G_{mb} * CF	2.175	2.133	2.157	2.164	0.042
G_{mm}	2.549	2.549	2.549	2.549	
Air Voids (corr)	14.68	16.32	15.36	15.10	1.6
		Avg air voids, corr		15.37	

Calculations for Mix 17B-19.0 GR (Including Outliers)

N_{max} SSD method

Sample ID	A	B	C	D	Range	
Dry Wt.	4868.9	4861.8	4885.6	4880.3	23.8	
Wt. In $H_2$0	2897.3	2881.5	2901.1	2896.1		
SSD Wt.	4875.6	4868.9	4895.4	4891.6		
Volume	1978.3	1987.4	1994.3	1995.5		St. Dev.
G_{mb}	2.461	2.446	2.450	2.446	0.016	0.007
G_{mm}	2.525	2.525	2.525	2.525		
Air Voids	2.53	3.12	2.98	3.14	0.6	
		Avg air voids		2.94		

N_{des} SSD method

Sample ID	E	F	G	H	Range	
Dry Wt.	4886.1	4888.6	4874.3	4878.3	14.3	
Wt. In $H_2$0	2871.7	2895.3	2877.6	2875.3		
SSD Wt.	4902.0	4901.5	4887.9	4893.6		
Volume	2030.3	2006.2	2010.3	2018.3		St. Dev.
G_{mb}	2.407	2.437	2.425	2.417	0.030	0.013
G_{mm}	2.525	2.525	2.525	2.525		
Air Voids	4.69	3.50	3.97	4.28	1.2	
		Avg air voids		4.11		

N_{ini} SSD method

Sample ID	I	J	K	L	Range	
Dry Wt.	4869.2	4885.0	4891.3	4878.8	22.1	
Wt. In $H_2$0	2831.9	2828.7	2835.6	2833.9		
SSD Wt.	4961.2	4965.9	4976.8	4963.4		
Volume	2129.3	2137.2	2141.2	2129.5		St. Dev.
G_{mb}	2.287	2.286	2.284	2.291	0.007	0.003
G_{mm}	2.525	2.525	2.525	2.525		
Air Voids	9.44	9.48	9.53	9.27	0.3	
		Avg air voids		9.43		

N_{ini} - Glass Beads tested by Bryan Cawley

Sample ID	I	J	K	L	
Dry Wt.	4869.2	4885.0	4891.3	4878.8	
Wt. partial wet	4886.5	4899.0	4905.8	4891.3	
Wt.w/ beads & bkt.(1) kg	33.26	33.30	33.30	33.24	
Wt.w/ beads & bkt.(2) kg	33.26	33.28	33.28	33.18	
Wt.w/ beads & bkt.(3) kg	33.22	33.32	33.30	33.24	
Wt.w/ beads & bkt.(avg)	33.25	33.30	33.29	33.22	
Bucket wt.	8.7041	8.7041	8.7041	8.7041	
Wt. of beads, g	19656.1	19696.9	19683.4	19624.6	
Volume of beads, cm^3	11917.2	11941.9	11933.8	11898.1	
Pill vol = bkt vol - bead vol	2162.3	2137.6	2145.7	2181.4	Range
G_{mb} pill	2.252	2.285	2.280	2.237	0.049
G_{mm}	2.525	2.525	2.525	2.525	
Air Voids	10.82	9.49	9.72	11.42	1.9
		Avg air voids		10.36	

Bucket Wt. (Empty)	8.7041	kg		
Bucket Volume	14079.5	cm^3		
Beads and Bucket	1	2	3	
	31.92	31.94	31.92	kg
Avg. (beads and bucket)	31.93	kg		
Avg. minus bucket wt.	23.22	kg		
G_{mb} of beads	1.649			

N_{max} dimensional method

Ht @ N_{max}, mm	116.7	116.7	118.1	119.3
Area, cm^2	176.7	176.7	176.7	176.7
Volume, cm^3	2062.3	2062.3	2087.0	2108.2
Dry wt.	4868.9	4861.8	4885.6	4880.3
G_{mb}	2.361	2.358	2.341	2.315
G_{mb} corr. fact.	1.042	1.038	1.046	1.056

Gmb, Nmax	Dens(pcf)	Ht, Nmax	Mass	Dens(pcf)
2.461	153.6	116.7	4868.9	153.6
2.446	152.6	116.7	4861.8	152.6
2.450	152.9	118.1	4885.6	152.9
2.446	152.6	119.3	4880.3	152.6

N_{des} dimensional method

Ht @ N_{des}, mm	118.3	118.4	119.7	120.9	
Area, cm^2	176.7	176.7	176.7	176.7	
Volume, cm^3	2090.5	2092.3	2115.3	2136.5	
Dry wt.	4868.9	4861.8	4885.6	4880.3	
G_{mb}	2.329	2.324	2.310	2.284	Range
G_{mb} * CF	2.428	2.411	2.417	2.413	0.017
G_{mm}	2.525	2.525	2.525	2.525	
Air Voids (corr)	3.85	4.51	4.28	4.42	0.7
		Avg air voids, corr.		4.26	

Summary, 17B - 19.0 Granite	N_{des}	N_{ini}	
Average air voids, back calculated	4.26	13.68	13.68
Average air voids actual, SSD	4.11	9.43	NA
Average air voids actual, beads	NA	NA	10.36
Difference (back calculated-actual)	0.16	4.26	3.32

N_{ini} dimensional method

Ht @ N_{ini}, mm	130.8	132.0	132.6	134.0	
Area, cm^2	176.7	176.7	176.7	176.7	
Volume, cm^3	2311.4	2332.6	2343.2	2368.0	
Dry wt.	4868.9	4861.8	4885.6	4880.3	
G_{mb}	2.106	2.084	2.085	2.061	Range
G_{mb} * CF	2.196	2.163	2.182	2.177	0.033
G_{mm}	2.525	2.525	2.525	2.525	
Air Voids (corr)	13.04	14.35	13.59	13.77	1.3
		Avg air voids corr.		13.68	

Calculations for Mix 176A-9.5 LR (Excluding Outliers)

N_{max} SSD method

Sample ID	A	B	C	D	Range
Dry Wt.	4509.1	4499.7	4506.8		9.4
Wt. In H_20	2499.8	2501.6	2502.7		
SSD Wt.	4513.2	4502.6	4508.8		
Volume	2013.4	2001.0	2006.1		
G_{mb}	2.240	2.249	2.247		0.009
G_{mm}	2.311	2.311	2.311		
Air Voids	3.09	2.69	2.79		0.4
		Avg air voids		2.86	

N_{max} dimensional method

Ht @ N_{max}, mm	115.4	114.4	114.8	
Area, cm^2	176.7	176.7	176.7	
Volume, cm^3	2039.3	2021.6	2028.7	
Dry wt.	4509.1	4499.7	4506.8	
G_{mb}	2.211	2.226	2.222	
G_{mb} corr. fact.	1.013	1.010	1.011	

N_{des} dimensional method

Ht @ N_{des}, mm	117.6	116.6	117.0		
Area, cm^2	176.7	176.7	176.7		
Volume, cm^3	2078.2	2060.5	2067.6		
Dry wt.	4509.1	4499.7	4506.8		
G_{mb}	2.170	2.184	2.180		Range
G_{mb} * CF	2.198	2.206	2.204		0.009
G_{mm}	2.311	2.311	2.311		
Air Voids (corr)	4.90	4.53	4.62		0.4
		Avg air voids, corr		4.68	

N_{ini} dimensional method

Ht @ N_{ini}, mm	133.1	131.4	132.4		
Area, cm^2	176.7	176.7	176.7		
Volume, cm^3	2352.1	2322.0	2339.7		
Dry wt.	4509.1	4499.7	4506.8		
G_{mb}	1.917	1.938	1.926		Range
G_{mb} * CF	1.942	1.958	1.948		0.016
G_{mm}	2.311	2.311	2.311		
Air Voids (corr)	15.98	15.28	15.71		0.7
		Avg air voids corr.		15.66	

N_{des} SSD method

Sample ID	E	F	G	H	Range
Dry Wt.	4503.7	4506.5	4501.7	4500.2	6.3
Wt. In H_20	2440.4	2446.4	2460.9	2454.2	
SSD Wt.	4514.3	4512.3	4508.9	4508.5	
Volume	2073.9	2065.9	2048.0	2054.3	
G_{mb}	2.172	2.181	2.198	2.191	0.026
G_{mm}	2.311	2.311	2.311	2.311	
Air Voids	6.03	5.61	4.89	5.21	1.1
		Avg air voids		5.43	

Gmb, Nmax	Dens(pcf)	Ht, Nmax	Mass	Dens(pcf)
2.240	139.7	115.4	4509.1	139.7
2.249	140.3	114.4	4499.7	140.3
2.247	140.2	114.8	4506.8	140.2

Summary, 176A - 9.5 Limerock	N_{des}	N_{ini}	
Average air voids, back calculated	4.68	15.66	15.66
Average air voids actual, SSD	5.43	15.73	NA
Average air voids actual, beads	NA	NA	15.16
Difference (back calculated-actual)	-0.75	-0.07	0.50

N_{ini} SSD method

Sample ID	I	J	K	L	Range
Dry Wt.	4510.2	4502.1	4508.0	4516.4	14.3
Wt. In H_20	2380.2	2396.5	2389.7	2392.1	
SSD Wt.	4679.2	4727.4	4681.1	4733.4	
Volume	2299.0	2330.9	2291.4	2341.3	
G_{mb}	1.962	1.931	1.967	1.929	0.038
G_{mm}	2.311	2.311	2.311	2.311	
Air Voids	15.11	16.42	14.87	16.53	1.7
		Avg air voids		15.73	

N_{ini} - Glass Beads tested by Brian Cawley

Sample ID	I	J	K	L	
Dry Wt.	4510.2	4502.1	4508.0	4516.4	
Wt. partial wet	4557.5	4556.5	4565.2	4575.4	
Wt.w/ beads & bkt.(1) kg	32.80	32.70	32.84	32.76	
Wt.w/ beads & bkt.(2) kg	32.80	32.72	32.80	32.74	
Wt.w/ beads & bkt.(3) kg	32.80	32.70	32.82	32.68	
Wt.w/ beads & bkt.(avg)	32.80	32.71	32.82	32.73	
Bucket wt.	8.7041	8.7041	8.7041	8.7041	
Wt. of beads, g	19538.4	19446.1	19550.7	19447.2	
Volume of beads, cm^3	11805.2	11749.4	11812.6	11750.1	
Pill vol = bkt vol - bead vol	2274.3	2330.1	2266.9	2329.4	Range
G_{mb} pill	1.983	1.932	1.989	1.939	0.056
G_{mm}	2.311	2.311	2.311	2.311	
Air Voids	14.19	16.39	13.95	16.10	2.4
		Avg air voids		15.16	

Bucket Wt. (Empty)	8.7041	kg		
Bucket Volume	14079.5	cm^3		
Beads and Bucket	1	2	3	
	32.02	32.02	31.98	kg
Avg. (beads and bucket)	32.01	kg		
Avg. minus bucket wt.	23.30	kg		
G_{mb} of beads	1.655			

Calculations for Mix 177A-12.5 LR (Excluding Outliers)

N_{max} SSD method

Sample ID	A	B	C	D	Range
Dry Wt.	4538.5	v	4549.7	4546.1	11.2
Wt. In H_20	2544.9	o	2547.6	2537.4	
SSD Wt.	4543.5	l	4553.7	4551.1	
Volume	1998.6	d	2006.1	2013.7	
G_{mb}	2.271		2.268	2.258	0.013
G_{mm}	2.322		2.322	2.322	
Air Voids	2.20		2.33	2.77	0.6
		Avg air voids		2.44	

N_{max} dimensional method

Ht @ N_{max}, mm	114.8	v	115.2	115.9
Area, cm^2	176.7	o	176.7	176.7
Volume, cm^3	2028.7	l	2035.8	2048.1
Dry wt.	4538.5	d	4549.7	4546.1
G_{mb}	2.237		2.235	2.220
G_{mb} corr. fact.	1.015		1.015	1.017

N_{des} dimensional method

Ht @ N_{des}, mm	117.2	v	117.5	118.2	
Area, cm^2	176.7	o	176.7	176.7	
Volume, cm^3	2071.1	l	2076.4	2088.8	
Dry wt.	4538.5	d	4549.7	4546.1	
G_{mb}	2.191		2.191	2.176	Range
G_{mb} * CF	2.224		2.224	2.214	0.011
G_{mm}	2.322		2.322	2.322	
Air Voids (corr)	4.21		4.24	4.67	0.5
		Avg air voids, corr.		4.37	

N_{ini} dimensional method

Ht @ N_{ini}, mm	132.8	v	133.6	133.7	
Area, cm^2	176.7	o	176.7	176.7	
Volume, cm^3	2346.8	l	2360.9	2362.7	
Dry wt.	4538.5	d	4549.7	4546.1	
G_{mb}	1.934		1.927	1.924	Range
G_{mb} * CF	1.963		1.956	1.957	0.007
G_{mm}	2.322		2.322	2.322	
Air Voids (corr)	15.46		15.78	15.72	0.3
		Avg air voids corr.		15.65	

N_{des} SSD method

Sample ID	E	F	G	H	Range
Dry Wt.	4554.7		4546.5	4540.5	14.2
Wt. In H_20	2480.0		2458.3	2470.9	
SSD Wt.	4570.7		4565.7	4553.4	
Volume	2090.7		2107.4	2082.5	
G_{mb}	2.179		2.157	2.180	0.023
G_{mm}	2.322		2.322	2.322	
Air Voids	6.18		7.09	6.10	1.0
		Avg air voids		6.46	

Gmb, Nmax	Dens(pcf)	Ht, Nmax	Mass	Dens(pcf)
2.271	141.7	114.8	4538.5	141.7
2.268	141.5	115.2	4549.7	141.5
2.258	140.9	115.9	4546.1	140.9

Summary, 177A - 12.5 Limerock	N_{des}	N_{ini}	
Average air voids, back calculated	4.37	15.65	15.65
Average air voids actual, SSD	6.46	14.36	NA
Average air voids actual, beads	NA	NA	14.51
Difference (back calculated-actual)	-2.09	1.29	1.14

N_{ini} SSD method

Sample ID	I	J	K	L	Range
Dry Wt.	4550.0	4545.8	4555.2	4547.7	9.4
Wt. In H_20	2459.4	2456.9	2452.1	2452.3	
SSD Wt.	4736.3	4752.4	4735.4	4748.8	
Volume	2276.9	2295.5	2283.3	2296.5	
G_{mb}	1.998	1.980	1.995	1.980	0.018
G_{mm}	2.322	2.322	2.322	2.322	
Air Voids	13.94	14.72	14.08	14.72	0.8
		Avg air voids		14.36	

N_{ini} - Glass Beads tested by Bryan Cawley

Sample ID	I	J	K	L	
Dry Wt.	4550.0	4545.8	4555.2	4547.7	
Wt. partial wet	4594.8	4593.1	4601.1	4587.5	
Wt.w/ beads & bkt.(1) kg	32.77	32.66	32.72	32.74	
Wt.w/ beads & bkt.(2) kg	32.74	32.69	32.74	32.70	
Wt.w/ beads & bkt.(3) kg	32.77	32.68	32.73	32.71	
Wt.w/ beads & bkt.(avg)	32.76	32.68	32.73	32.72	
Bucket wt.	8.7041	8.7041	8.7041	8.7041	
Wt. of beads, g	19461.1	19379.5	19424.8	19425.1	
Volume of beads, cm^3	11810.8	11761.3	11788.8	11789.0	
Pill vol = bkt vol - bead vol	2268.7	2318.2	2290.7	2290.5	Range
G_{mb} pill	2.006	1.961	1.989	1.985	0.045
G_{mm}	2.322	2.322	2.322	2.322	
Air Voids	13.63	15.55	14.36	14.49	1.9
		Avg air voids		14.51	

Bucket Wt. (Empty)	8.7041	kg		
Bucket Volume	14079.5	cm^3		
Beads and Bucket	1	2	3	
	31.89	31.93	31.89	kg
Avg. (beads and bucket)	31.90	kg		
Avg. minus bucket wt.	23.20	kg		
G_{mb} of beads	1.648			

Calculations for Mix 178A-19.0 LR (Excluding Outliers)

N_{max} SSD method

Sample ID	A	B	C	D	Range
Dry Wt.		4572.1	4578.7	4581.6	9.5
Wt. In H_20		2531.0	2517.7	2532.8	
SSD Wt.		4585.2	4595.0	4597.5	
Volume		2054.2	2077.3	2064.7	
G_{mb}		2.226	2.204	2.219	0.022
G_{mm}		2.341	2.341	2.341	
Air Voids		4.92	5.85	5.21	0.9
		Avg air voids		5.33	

N_{max} dimensional method

Ht @ N_{max}, mm		118.1	119.6	119.2
Area, cm^2		176.7	176.7	176.7
Volume, cm^3		2087.0	2113.5	2106.4
Dry wt.		4572.1	4578.7	4581.6
G_{mb}		2.191	2.166	2.175
G_{mb} corr. fact.		1.016	1.017	1.020

N_{des} dimensional method

Ht @ N_{des}, mm		120.5	122.1	121.6	
Area, cm^2		176.7	176.7	176.7	
Volume, cm^3		2129.4	2157.7	2148.8	
Dry wt.		4572.1	4578.7	4581.6	
G_{mb}		2.147	2.122	2.132	Range
G_{mb} * CF		2.181	2.159	2.175	0.022
G_{mm}		2.341	2.341	2.341	
Air Voids (corr)		6.82	7.77	7.08	1.0
		Avg air voids, corr		7.22	

N_{ini} dimensional method

Ht @ N_{ini}, mm		135.9	138.9	138.0	
Area, cm^2		176.7	176.7	176.7	
Volume, cm^3		2401.6	2454.6	2438.7	
Dry wt.		4572.1	4578.7	4581.6	
G_{mb}		1.904	1.865	1.879	Range
G_{mb} * CF		1.934	1.898	1.917	0.036
G_{mm}		2.341	2.341	2.341	
Air Voids (corr)		17.38	18.93	18.12	1.6
		Avg air voids corr.		18.14	

N_{des} SSD method

Sample ID	E	F	G	H	Range
Dry Wt.		4588.8	4583.1	4586.7	5.7
Wt. In H_20		2524.6	2522.6	2515.9	
SSD Wt.		4609.7	4601.3	4610.5	
Volume		2085.1	2078.7	2094.6	
G_{mb}		2.201	2.205	2.190	0.015
G_{mm}		2.341	2.341	2.341	
Air Voids		5.99	5.82	6.46	0.6
		Avg air voids		6.09	

Gmb, Nmax	Dens(pcf)	Ht, Nmax	Mass	Dens(pcf)
0.000	0.0	0.0	0.0	0.0
2.226	138.9	118.1	4572.1	138.9
2.204	137.5	119.6	4578.7	137.5
2.219	138.5	119.2	4581.6	138.5

Summary, 178A - 19.0 Limerock	N_{des}	N_{ini}	
Average air voids, back calculated	7.22	18.14	18.14
Average air voids actual, SSD	6.09	15.06	NA
Average air voids actual, beads	NA	NA	16.24
Difference (back calculated-actual)	1.13	3.09	1.90

N_{ini} SSD method

Sample ID	I	J	K	L	Range
Dry Wt.	4588.3	4588.2	4591.4	4589.9	3.2
Wt. In H_20	2497.4	2512.2	2504.1	2511.8	
SSD Wt.	4790.5	4837.2	4815.2	4814.8	
Volume	2293.1	2325.0	2311.1	2303.0	
G_{mb}	2.001	1.973	1.987	1.993	0.027
G_{mm}	2.341	2.341	2.341	2.341	
Air Voids	14.53	15.70	15.14	14.87	1.2
		Avg air voids		15.06	

N_{ini} - Glass Beads tested by Bryan Cawley

Sample ID	I	J	K	L	
Dry Wt.		4588.2	4591.4	4589.9	
Wt. partial wet		4660.8	4652.0	4654.0	
Wt.w/ beads & bkt.(1) kg		32.68	32.72	32.70	
Wt.w/ beads & bkt.(2) kg		32.68	32.72	32.72	
Wt.w/ beads & bkt.(3) kg		32.68	32.74	32.70	
Wt.w/ beads & bkt.(avg)		32.68	32.73	32.71	
Bucket wt.		8.7041	8.7041	8.7041	
Wt. of beads, g		19315.1	19370.6	19348.6	
Volume of beads, cm^3		11720.6	11754.2	11740.9	
Pill vol = bkt vol - bead vol		2358.9	2325.3	2338.6	Range
G_{mb} pill		1.945	1.975	1.963	0.030
G_{mm}		2.341	2.341	2.341	
Air Voids		16.91	15.65	16.16	1.3
		Avg air voids		16.24	

Bucket Wt. (Empty)	8.7041	kg		
Bucket Volume	14079.5	cm^3		
Beads and Bucket	1	2	3	
	31.84	31.92	31.96	kg
Avg. (beads and bucket)	31.91	kg		
Avg. minus bucket wt.	23.20	kg		
G_{mb} of beads	1.648			

Calculations for Mix 108A-9.5 GR (Excluding Outliers)

N_{max} SSD method

Sample ID	A	B	C	D	Range
Dry Wt.		5001.3	4997.4	4981.5	19.8
Wt. In H_20		2960.2	2958.1	2954.6	
SSD Wt.		5003.2	4999.8	4983.9	
Volume		2043.0	2041.7	2029.3	
G_{mb}		2.448	2.448	2.455	0.007
G_{mm}		2.515	2.515	2.515	
Air Voids		2.66	2.68	2.39	0.3
		Avg air voids		2.58	

N_{max} dimensional method

Ht @ N_{max}, mm		117.1	117.1	116.4
Area, cm^2		176.7	176.7	176.7
Volume, cm^3		2069.3	2069.3	2057.0
Dry wt.		5001.3	4997.4	4981.5
G_{mb}		2.417	2.415	2.422
G_{mb} corr. fact.		1.013	1.014	1.014

N_{des} dimensional method

Ht @ N_{des}, mm		118.7	118.6	117.9	
Area, cm^2		176.7	176.7	176.7	
Volume, cm^3		2097.6	2095.8	2083.5	
Dry wt.		5001.3	4997.4	4981.5	
G_{mb}		2.384	2.384	2.391	Range
G_{mb} * CF		2.415	2.417	2.424	0.009
G_{mm}		2.515	2.515	2.515	
Air Voids (corr)		3.98	3.91	3.64	0.3
		Avg air voids, corr		3.84	

N_{ini} dimensional method

Ht @ N_{ini}, mm		131.3	131.1	130.3	
Area, cm^2		176.7	176.7	176.7	
Volume, cm^3		2320.3	2316.7	2302.6	
Dry wt.		5001.3	4997.4	4981.5	
G_{mb}		2.155	2.157	2.163	Range
G_{mb} * CF		2.183	2.186	2.193	0.010
G_{mm}		2.515	2.515	2.515	
Air Voids (corr)		13.19	13.07	12.81	0.4
		Avg air voids, corr		13.02	

N_{des} SSD method

Sample ID	E	F	G	H	Range
Dry Wt.	4978.9	4979.1	4975.1	4976.3	4.0
Wt. In H_20	2929.2	2927.4	2928.0	2930.5	
SSD Wt.	4982.3	4982.2	4978.2	4979.5	
Volume	2053.1	2054.8	2050.2	2049.0	
G_{mb}	2.425	2.423	2.427	2.429	0.005
G_{mm}	2.515	2.515	2.515	2.515	
Air Voids	3.58	3.65	3.51	3.43	0.2
		Avg air voids		3.54	

Gmb, Nmax	Dens(pcf)	Ht, Nmax	Mass	Dens(pcf)
0.000	0.0	0.0	0.0	0.0
2.448	152.8	117.1	5001.3	152.8
2.448	152.7	117.1	4997.4	152.7
2.455	153.2	116.4	4981.5	153.2

Summary, 108A - 9.5 Granite	N_{des}	N_{ini}	
Average air voids, back calculated	3.84	13.02	13.02
Average air voids actual, SSD	3.54	11.66	NA
Average air voids actual, beads	NA	NA	11.55
Difference (back calculated-actual)	0.30	1.37	1.48

N_{ini} SSD method

Sample ID	I	J	K	L	Range
Dry Wt.	4978.9	4977.4	4976.7	4976.3	2.6
Wt. In H_20	2808.5	2806.1	2822.7	2801.7	
SSD Wt.	5062.7	5068.7	5038.9	5030.0	
Volume	2254.2	2262.6	2216.2	2228.3	
G_{mb}	2.209	2.200	2.246	2.233	0.046
G_{mm}	2.515	2.515	2.515	2.515	
Air Voids	12.18	12.53	10.71	11.20	1.8
		Avg air voids		11.66	

N_{ini} - Glass Beads tested by Greg Sholar

Sample ID	I	J	K	L	
Dry Wt.	4978.9	4977.4		4976.3	
Wt. partial wet	5029.1	5030.7		5005.4	
Wt.w/ beads & bkt.(1) kg	33.24	33.24		33.26	
Wt.w/ beads & bkt.(2) kg	33.26	33.26		33.26	
Wt.w/ beads & bkt.(3) kg	33.26	33.24		33.20	
Wt.w/ beads & bkt.(avg)	33.25	33.25		33.24	
Bucket wt.	8.7041	8.7041		8.7041	
Wt. of beads, g	19520.1	19511.9		19530.5	
Volume of beads, cm^3	11841.6	11836.6		11847.9	
Pill vol = bkt vol - bead vol	2237.9	2242.9		2231.6	Range
G_{mb} pill	2.225	2.219		2.230	0.011
G_{mm}	2.515	2.515		2.515	
Air Voids	11.54	11.76		11.34	0.4
		Avg air voids		11.55	

Bucket Wt. (Empty)		8.7041	kg		
Bucket Volume		14079.5	cm^3		
Beads and Bucket		1	2	3	
		31.86	31.94	31.94	kg
Avg. (beads and bucket)		31.91	kg		
Avg. minus bucket wt.		23.21	kg		
G_{mb} of beads		1.648			

Calculations for Mix 71A-12.5 GR (Excluding Outliers)

N_{max} SSD method

Sample ID	A	B	C	D	Range
Dry Wt.	5004.7		5002.6	5009.6	7.0
Wt. In H_20	2978.2		2967.3	2976.8	
SSD Wt.	5011.8		5010.1	5017.1	
Volume	2033.6		2042.8	2040.3	
G_{mb}	2.461		2.449	2.455	0.012
G_{mm}	2.549		2.549	2.549	
Air Voids	3.45		3.93	3.67	0.5
		Avg air voids		3.68	

N_{max} dimensional method

Ht @ N_{max}, mm	117.8		118.4	118.1
Area, cm^2	176.7		176.7	176.7
Volume, cm^3	2081.7		2092.3	2087.0
Dry wt.	5004.7		5002.6	5009.6
G_{mb}	2.404		2.391	2.400
G_{mb} corr. fact.	1.024		1.024	1.023

N_{des} dimensional method

Ht @ N_{des}, mm	119.6		120.3	119.9	
Area, cm^2	176.7		176.7	176.7	
Volume, cm^3	2113.5		2125.9	2118.8	
Dry wt.	5004.7		5002.6	5009.6	
G_{mb}	2.368		2.353	2.364	Range
G_{mb} * CF	2.424		2.410	2.418	0.014
G_{mm}	2.549		2.549	2.549	
Air Voids (corr)	4.91		5.44	5.12	0.5
		Avg air voids, corr.		5.16	

N_{ini} dimensional method

Ht @ N_{ini}, mm	133.3		134.4	134.0	
Area, cm^2	176.7		176.7	176.7	
Volume, cm^3	2355.6		2375.0	2368.0	
Dry wt.	5004.7		5002.6	5009.6	
G_{mb}	2.125		2.106	2.116	Range
G_{mb} * CF	2.175		2.157	2.164	0.017
G_{mm}	2.549		2.549	2.549	
Air Voids (corr)	14.68		15.36	15.10	0.7
		Avg air voids, corr.		15.05	

N_{des} SSD method

Sample ID	E	F	G	H	Range
Dry Wt.		5009.5	5010.0	5003.8	6.2
Wt. In H_20		2962.8	2958.0	2925.1	
SSD Wt.		5022.2	5022.3	5018.6	
Volume		2059.4	2064.3	2093.5	
G_{mb}		2.433	2.427	2.390	0.042
G_{mm}		2.549	2.549	2.549	
Air Voids		4.57	4.79	6.23	1.7
		Avg air voids		5.20	

Gmb, Nmax	Dens(pcf)	Ht, Nmax	Mass	Dens(pcf)
2.461	153.6	117.8	5004.7	153.6
0.000	0.0	0.0	0.0	0.0
2.449	152.8	118.4	5002.6	152.8
2.455	153.2	118.1	5009.6	153.2

Summary, 71A - 12.5 Granite	N_{des}	N_{ini}	
Average air voids, back calculated	5.16	15.05	15.05
Average air voids actual, SSD	5.20	12.59	NA
Average air voids actual, beads	NA	NA	13.17
Difference (back calculated-actual)	-0.04	2.46	1.87

N_{ini} SSD method

Sample ID	I	J	K	L	Range
Dry Wt.	5006.7	5011.4	5010.6		4.7
Wt. In H_20	2921.6	2916.9	2918.7		
SSD Wt.	5172.1	5165.3	5165.1		
Volume	2250.5	2248.4	2246.4		
G_{mb}	2.225	2.229	2.231		0.006
G_{mm}	2.549	2.549	2.549		
Air Voids	12.72	12.56	12.50		0.2
		Avg air voids		12.59	

N_{ini} - Glass Beads tested by Mike Berkowitz

Sample ID	I	J	K	L	
Dry Wt.	5006.7	5011.4	5010.6	5005.8	
Wt. partial wet	5062.8	5069.4	5065.0	5072.4	
Wt.w/ beads & bkt.(1) kg	33.18	33.24	33.22	33.24	
Wt.w/ beads & bkt.(2) kg	33.26	33.26	33.22	33.24	
Wt.w/ beads & bkt.(3) kg	33.26	33.24	33.20	33.24	
Wt.w/ beads & bkt.(avg)	33.23	33.25	33.21	33.24	
Bucket wt.	8.7041	8.7041	8.7041	8.7041	
Wt. of beads, g	19466.4	19473.2	19444.2	19463.5	
Volume of beads, cm^3	11819.2	11823.3	11805.7	11817.4	
Pill vol = bkt vol - bead vol	2260.3	2256.2	2273.8	2262.1	Range
G_{mb} pill	2.215	2.221	2.204	2.213	0.018
G_{mm}	2.549	2.549	2.549	2.549	
Air Voids	13.10	12.86	13.55	13.19	0.7
		Avg air voids		13.17	

Bucket Wt. (Empty)		8.7041	kg		
Bucket Volume		14079.5	cm^3		
Beads and Bucket		1	2	3	
		31.88	31.90	31.90	kg
Avg. (beads and bucket)		31.89	kg		
Avg. minus bucket wt.		23.19	kg		
G_{mb} of beads		1.647			

Calculations for Mix 17B-19.0 GR (Excluding Outliers)

N_{max} SSD method

Sample ID	A	B	C	D	Range
Dry Wt.		4861.8	4885.6	4880.3	23.8
Wt. In H_20		2881.5	2901.1	2896.1	
SSD Wt.		4868.9	4895.4	4891.6	
Volume		1987.4	1994.3	1995.5	
G_{mb}		2.446	2.450	2.446	0.004
G_{mm}		2.525	2.525	2.525	
Air Voids		3.12	2.98	3.14	0.2
		Avg air voids		3.08	

N_{max} dimensional method

Ht @ N_{max}, mm		116.7	118.1	119.3
Area, cm^2		176.7	176.7	176.7
Volume, cm^3		2062.3	2087.0	2108.2
Dry wt.		4861.8	4885.6	4880.3
G_{mb}		2.358	2.341	2.315
G_{mb} corr. fact.		1.038	1.046	1.056

N_{des} dimensional method

Ht @ N_{des}, mm		118.4	119.7	120.9	
Area, cm^2		176.7	176.7	176.7	
Volume, cm^3		2092.3	2115.3	2136.5	
Dry wt.		4861.8	4885.6	4880.3	
G_{mb}		2.324	2.310	2.284	Range
G_{mb} * CF		2.411	2.417	2.413	0.006
G_{mm}		2.525	2.525	2.525	
Air Voids (corr)		4.51	4.28	4.42	0.2
		Avg air voids, corr.		4.40	

N_{ini} dimensional method

Ht @ N_{ini}, mm		132.0	132.6	134.0	
Area, cm^2		176.7	176.7	176.7	
Volume, cm^3		2332.6	2343.2	2368.0	
Dry wt.		4861.8	4885.6	4880.3	
G_{mb}		2.084	2.085	2.061	Range
G_{mb} * CF		2.163	2.182	2.177	0.019
G_{mm}		2.525	2.525	2.525	
Air Voids (corr)		14.35	13.59	13.77	0.8
		Avg air voids corr.		13.90	

N_{des} SSD method

Sample ID	E	F	G	H	Range
Dry Wt.	4886.1	4888.6	4874.3	4878.3	14.3
Wt. In H_20	2871.7	2895.3	2877.6	2875.3	
SSD Wt.	4902.0	4901.5	4887.9	4893.6	
Volume	2030.3	2006.2	2010.3	2018.3	
G_{mb}	2.407	2.437	2.425	2.417	0.030
G_{mm}	2.525	2.525	2.525	2.525	
Air Voids	4.69	3.50	3.97	4.28	1.2
		Avg air voids		4.11	

Gmb, Nmax	Dens(pcf)	Ht, Nmax	Mass	Dens(pcf)
0.000	0.0	0.0	0.0	0.0
2.446	152.6	116.7	4861.8	152.6
2.450	152.9	118.1	4885.6	152.9
2.446	152.6	119.3	4880.3	152.6

Summary, 17B - 19.0 Granite	N_{des}	N_{ini}	
Average air voids, back calculated	4.40	13.90	13.90
Average air voids actual, SSD	4.11	9.43	NA
Average air voids actual, beads	NA	NA	10.36
Difference (back calculated-actual)	0.29	4.47	3.54

N_{ini} SSD method

Sample ID	I	J	K	L	Range
Dry Wt.	4869.2	4885.0	4891.3	4878.8	22.1
Wt. In H_20	2831.9	2828.7	2835.6	2833.9	
SSD Wt.	4961.2	4965.9	4976.8	4963.4	
Volume	2129.3	2137.2	2141.2	2129.5	
G_{mb}	2.287	2.286	2.284	2.291	0.007
G_{mm}	2.525	2.525	2.525	2.525	
Air Voids	9.44	9.48	9.53	9.27	0.3
		Avg air voids		9.43	

N_{ini} - Glass Beads tested by Bryan Cawley

Sample ID	I	J	K	L	
Dry Wt.	4869.2	4885.0	4891.3	4878.8	
Wt. partial wet	4886.5	4899.0	4905.8	4891.3	
Wt.w/ beads & bkt.(1) kg	33.26	33.30	33.30	33.24	
Wt.w/ beads & bkt.(2) kg	33.26	33.28	33.28	33.18	
Wt.w/ beads & bkt.(3) kg	33.22	33.32	33.30	33.24	
Wt.w/ beads & bkt.(avg)	33.25	33.30	33.29	33.22	
Bucket wt.	8.7041	8.7041	8.7041	8.7041	
Wt. of beads, g	19656.1	19696.9	19683.4	19624.6	
Volume of beads, cm^3	11917.2	11941.9	11933.8	11898.1	
Pill vol = bkt vol - bead vol	2162.3	2137.6	2145.7	2181.4	Range
G_{mb} pill	2.252	2.285	2.280	2.237	0.049
G_{mm}	2.525	2.525	2.525	2.525	
Air Voids	10.82	9.49	9.72	11.42	1.9
		Avg air voids		10.36	

Bucket Wt. (Empty)		8.7041	kg		
Bucket Volume		14079.5	cm^3		
Beads and Bucket		1	2	3	
		31.92	31.94	31.92	kg
Avg. (beads and bucket)		31.93	kg		
Avg. minus bucket wt.		23.22	kg		
G_{mb} of beads		1.649			

Outlier Determination; FDOT method

Mix ID	Gmb @ Nmax A	B	C	D	Avg.	Range	Avg + R/2	Avg - R/2	Outlier
176A-9.5 LR	2.240	2.249	2.247	2.196	2.233	0.053	2.259	2.206	D
177A-12.5 LR	2.271		2.268	2.258	2.265	0.013	2.272	2.259	None
178A-19.0 LR	2.249	2.226	2.204	2.219	2.224	0.045	2.247	2.202	A
108A-9.5 GR	2.426	2.448	2.448	2.455	2.444	0.029	2.458	2.430	A
71A-12.5 GR	2.461	2.410	2.449	2.455	2.444	0.051	2.469	2.418	B
17B-19.0 GR	2.461	2.446	2.450	2.446	2.451	0.016	2.458	2.443	A

Mix ID	Gmb @ Ndes E	F	G	H	Avg.	Range	Avg + R/2	Avg - R/2	Outlier
176A-9.5 LR	2.172	2.181	2.198	2.191	2.185	0.026	2.199	2.172	None
177A-12.5 LR	2.179	2.247	2.157	2.180	2.191	0.089	2.235	2.146	F
178A-19.0 LR	2.164	2.201	2.205	2.190	2.190	0.040	2.210	2.170	E
108A-9.5 GR	2.425	2.423	2.427	2.429	2.426	0.005	2.429	2.423	None
71A-12.5 GR	2.359	2.433	2.427	2.390	2.402	0.074	2.439	2.365	E
17B-19.0 GR	2.407	2.437	2.425	2.417	2.421	0.030	2.436	2.406	None*

*Include 2.437 even though 0.001 high

Mix ID	Gmb @ Nini (SSD method) I	J	K	L	Avg.	Range	Avg + R/2	Avg - R/2	Outlier
176A-9.5 LR	1.962	1.931	1.967	1.929	1.947	0.038	1.967	1.928	None
177A-12.5 LR	1.998	1.980	1.995	1.980	1.988	0.018	1.998	1.979	None
178A-19.0 LR	2.001	1.973	1.987	1.993	1.989	0.027	2.002	1.975	None
108A-9.5 GR	2.209	2.200	2.246	2.233	2.222	0.046	2.245	2.199	None
71A-12.5 GR	2.225	2.229	2.231	2.206	2.223	0.025	2.235	2.210	L
17B-19.0 GR	2.287	2.286	2.284	2.291	2.287	0.007	2.290	2.284	None

Mix ID	Gmb @ Nini (Glass Beads method) I	J	K	L	Avg.	Range	Avg + R/2	Avg - R/2	Outlier
176A-9.5 LR	1.983	1.932	1.989	1.939	1.961	0.056	1.989	1.932	None
177A-12.5 LR	2.006	1.961	1.989	1.985	1.985	0.045	2.007	1.963	None
178A-19.0 LR	2.008	1.945	1.975	1.963	1.973	0.063	2.004	1.941	I
108A-9.5 GR	2.225	2.219	2.258	2.230	2.233	0.039	2.252	2.214	K
71A-12.5 GR	2.215	2.221	2.204	2.213	2.213	0.018	2.222	2.204	None
17B-19.0 GR	2.252	2.285	2.280	2.237	2.263	0.049	2.288	2.239	None