Iowa State Highway Commission

materials department

special investigations

research project

R-217

GRAVEL asphalt treated base mixtures with various percentages of crushed LIMESTONE

September 1968

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Report

Evaluation Study of Pit Run Gravel Asphalt Treated Base Mixtures with various Percentages of Crushed Limestone

Ames Laboratory

by

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1.0 Introduction

In November of 1966, an investigation of the rigid Class I asphalt treated base specification, requiring 70 per cent crushed limestone, was initiated. It was felt that it might be possible to modify the need for crushed particles, in the construction of bases on heavy duty roads, at a savings, by using more local materials, without sacrificing strength and/or durability.

2.0 Purpose

This is a short study on typical sources of pit run gravel, with various percentages of limestone. It is conducted with an eye open to the possibility that our specifications may be modified. The possibility that further investigation may be desirable is not ignored.

3.0 Materials

Crushed limestone from the Bradgate pit at Bradgate, Iowa, District Number two, was used for the Class I stone. A Buena Vista county gravel and Clay county gravel were used for the Class II samples. The agricultural lime portion of the Bradgate stone was used for a study of the effects of lime on the gravel mixes studied.

A comparison of the gradations of the crushed limestone and gravels is shown in figure one. Starting from the left, the gradation of the Bradgate stone is shown, followed by the

Buena Vista county gravel and the Clay county gravel, respectively. The gradations shown are plotted in comparison with the maximum three fourths inch density line as the straight line on each figure.

An asphalt with the penetration grade of 100 to 150 was to be used and the actual penetration was found to be 136.

4.0 Laboratory Procedure

The investigation was divided into two phases, a Class I study and a Class II study. The aggregates were initially graded to meet the requirements of their class specifications.

The Bradgate stone gradation was made to conform with the Class I specification while the gravel gradations were made to conform with the Class II gradation requirements. The Bradgate stone was adjusted from the field sample gradation to fall just inside the present Class II gradation requirements. Also, all of the pit run mixtures would comply with the Class I gradation requirements. The Bradgate stone was then combined with the gravels in the ratios of 7:3, 1:1, 3:7 while still keeping within the Class I specifications.

The Clay county gravel needed no adjustments to qualify with Class II gradation requirements under all conditions studied. The Buena Vista gravel needed a slight adjustment toward the coarser side to keep it inside the Class II gradation limits with the higher agricultural lime additions to the mix. The Class II gravels were mixed with ten and then twenty per cent agricultural lime. One sample of each initial gradation (stone or gravel) was also tested.

The Bradgate stone had one extra gradation built to conform as close as possible with the middle of the Class I specification.

The "A" freeze thaw and L. A. abrasion (B) tests were performed on each stone. Water absorption for each gradation and the 'Iowa' HRB specific gravity of the aggregates were determined. The specific gravity of asphalt was also determined to be 1.002.

Six specimens were molded for each asphalt content, with two asphalt contents for each gradation. The specimens were divided into two sets of three specimens and one set was used for cohesion tests. This was done according to AASHO T-165, alternate method.

The per cent of voids filled with asphalt was determined for the pilots with the per cent voids filled with asphalt and per cent voids filled with water being determined for the cohesion specimens.

The per cent strength retention, per cent swell by AASHO-T-101, per cent swell by volume change and average density were determined for each set.

The Marshall density and Hveem stability, side pressure, were determined for each asphalt content of each gradation.

The results of these tests are recorded on the accompanying data sheet.

5.0 Interpretation of Results

The Bradgate stone seems to have the gradation that is closest to the maximum density curve. When the Bradgate stone was mixed with the gravels, the Clay county gravel gives a better gradation than the Bradgate - Buena Vista mixture. The gradation comparisons for the mixtures are shown in figures two and three.

The Bradgate stone seems to be the most desirable stone, as was expected. It has a lower per cent loss in the "A" freeze and thaw, than the two gravels. The Bradgate stone also shows a lower percentage of water absorption. It is interesting to note that while leading in these desirable characteristics, the Bradgate stone has the highest per cent loss during the L. A. abrasion test.

With the mixture of the Bradgate stone and the Buena Vista county gravel the general trend, of the per cent strength retention decreasing as the per cent of Bradgate decreases, may be observed. The Bradgate stone and the Clay county gravel do not appear to follow the same trend.

The Bradgate-Clay mixture's strength retention at first increases then finally decreases as the percentage of Bradgate stone decreases. These observations may be made by referring to figures four and five.

The per cent volume change increases as the per cent of Bradgate stone decreases, for the Bradgate-Buena Vista mixture. On the Bradgate-Clay mixture there seems to be a reversal of this trend, particularly at the fifty per cent point. These trends hold for both the four and five per cent asphalt specimens as may be observed in figures six and seven.

From figures eight through eleven it may be observed that as the amount of Bradgate stone decreases the percentage of voids filled with water increases while the per cent of voids filled with asphalt decreases.

It may be observed from figure twelve that the addition of the agricultural lime does not greatly affect the per cent strength retention in any great manner. If it does anything it causes a slight increase in the per cent strength retention at the twenty per cent level. At the same time, the per cent strength retention decreases at the ten per cent level with the noticeable exception of the five per cent asphalt specimens of the Clay county gravel.

In figures thirteen through sixteen it may be noted that as the per cent of lime added increases (up to twenty per cent) the percentage of the aggregate voids filled with water and asphalt cement decreases. The only noticeable exception to this occurs at the four and five per cent asphalt, and ten per cent agricultural lime level in the Clay county gravel. Generally speaking the per cent of voids filled with asphalt shows a steady increase as the per cent of lime is increased.

No definite relationship could be established, graphically, between the per cent strength retention and the per cent voids filled with asphalt and water.

The per cent swell was determined according to A.A.S.H.O. T-101 and also it was determined for the cohesion specimens on a volume basis. The per cent swell by A.A.S.H.O. T-101 consistently yields a lower numerical value of swell than the results obtained from computing the swell on a volume basis. Generally, the per cent swell by volume does not often yield numerical values of less than one per cent. The Bradgate stone, at the five per cent asphalt level, is the only set of specimens that yields a value, of per cent swell by volume, of less than one. At the same time it should be pointed out that the per cent swell by A.A.S.H.O. T-101 only exceeds the one per cent value for one asphalt content.

These observations may be studied by referring to Figure Seventeen.

From this it appears that the per cent of swell of Cohesion Specimens, tested by alternate method (140°F), and based on volume change, gives a wider range and a more critical point that correlates better to per cent of strength retention than when using the standard AASHO-T-101 swell testing procedure. There are two possible reasons for this. One is that the temperature differential in the testing procedure may cause this. The other is that the restriction of the mold and the shorter length of specimen may account for it.

7.0 Summary

The results of this investigation do not necessarily uphold the seventy per cent crushed particle requirement of the specifications. Just what effect the different gradations of aggregates has on the test results is a matter for some discussion. If it were possible to control the gravel gradations more closely, better results using gravel might be obtained.

While the per cent strength retention of gravel mixes containing agricultural lime is not significantly improved, it is quite evident that both wet and dry strength is increased substantially and should be seriously considered for improving the load bearing characteristics of Class II bases.

The fact that the Bradgate stone shows less absorption and less loss in the "A" freeze thaw while still showing a higher per cent loss on the L. A. abrasion shows that the hardest stone is not necessarily the most desirable one.

The Bradgate stone adjusted to the centerline gradation limits of Class I Specifications shows definitely that this gradation is the nearest to perfect due to the fact that the Marshall Specimens are past the critical point at 5% Asphalt Content as evidenced by the loss in stability.

The study, while not making any break-through in the study of asphalt mixes, does supplement the information and data necessary to make sound engineering judgment based on fact, concerning the characteristics of asphaltic concrete. It should be used as an aid in adding to valuable insight as to the expected characteristics of asphaltic concrete bases.

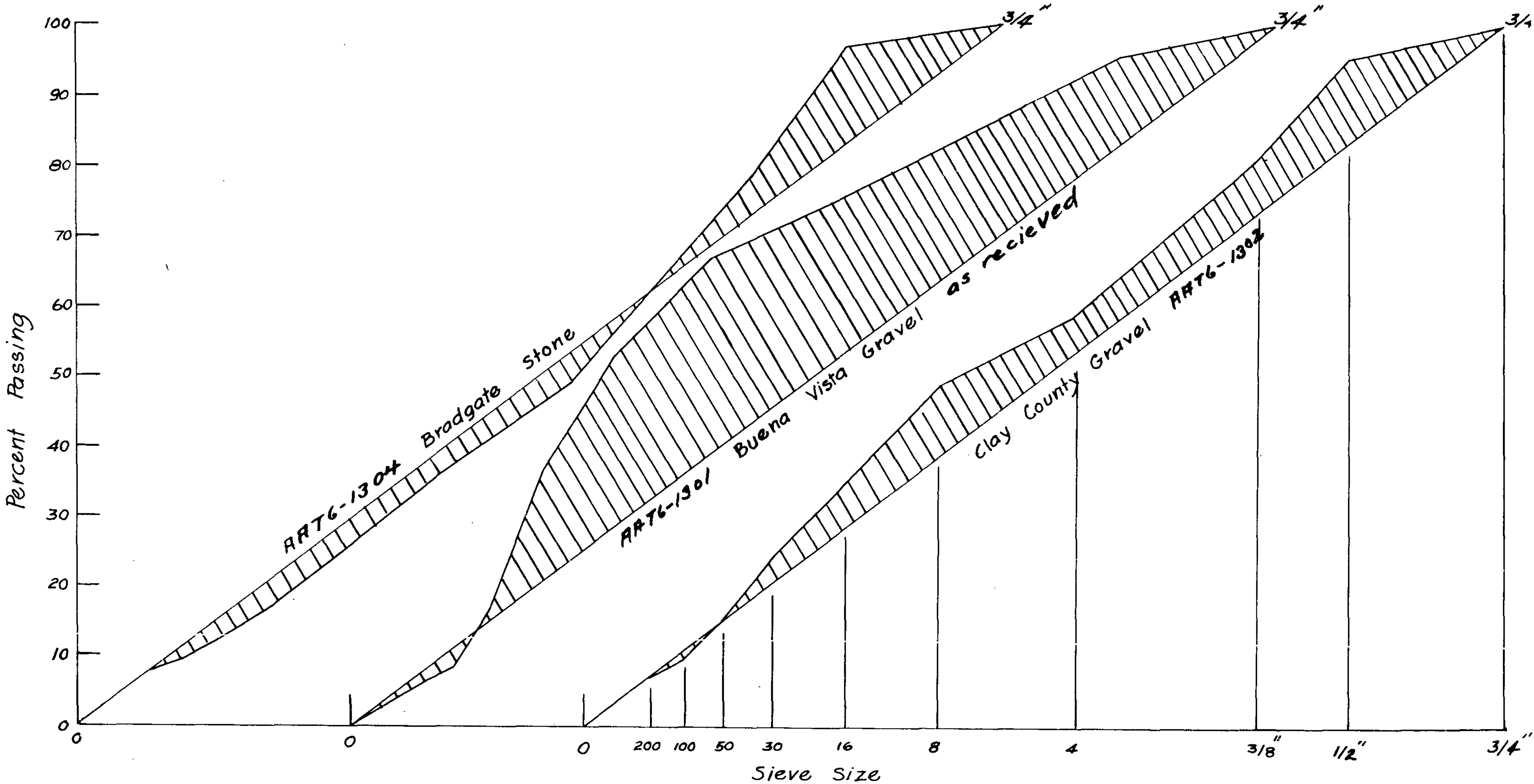
R-217 DATA SHEET

These gradations are actual tests of built-up samples of mixes made for check tests during batching process.

R-217 DATA SHEET	Bradgate Stone AAT6-1304		Buena Vista Gravel AAT6-1301 (A)		Clay Co. Gravel AAT6-1302		70% - 1304 30% - 1301		50% - 1304 50% - 1301		30% - 1304 70% - 1301		70% - 1304 30% - 1302		50% - 1304 50% - 1302		30% - 1304 70% - 1302		90% - 1301 10% - Lime (A)		80% - 1301 20% - Lime (A)		90% - 1302 10% - Lime		80% - 1302 20% - Lime		1304 to meet the middle of Class I	
Gradation 3/4"	100.0		100.0	100.0	100.0		100.0		100.0		100.0		100.0		100.0		100.0		100.0		100.0		100.0		100.0		100.0	
1/2"	97.0		91.7	95.8	92.7		95.6		95.3		94.9		94.9		95.3		93.9		94.0		93.6		92.7		92.2		96.0	
3/8"	78.7		84.3	89.0	84.2		81.0		85.3		86.6		83.0		82.1		82.6		85.8		87.1		85.7		87.1		77.0	
No. 4	49.4		69.3	75.9	67.9		58.7		64.1		68.9		56.2		58.8		63.3		72.5		75.7		73.3		75.1		59.0	
No. 8	36.2		59.2	67.3	52.3		49.1		53.1		59.9		41.8		45.0		48.3		60.7		64.9		58.7		62.9		48.0	
No. 16	25.1		45.3	53.4	34.8		35.2		42.3		45.9		27.6		30.0		32.1		48.7		48.1		42.6		45.7		35.0	
No. 30	16.8		31.6	37.4	19.2		24.8		29.8		32.1		16.5		18.2		17.9		34.7		32.3		26.0		28.6		26.0	
No. 50	12.3		14.8	17.6	8.1		15.3		16.6		16.1		9.8		10.3		8.9		17.8		17.1		12.9		14.9		18.0	
No. 100	9.6		7.0	8.5	4.8		9.7		9.8		8.7		7.1		7.1		5.9		9.8		10.1		8.2		9.7		15.0	
No. 200	7.7		5.7	6.6	4.0		8.0		7.6		6.7		5.8		5.7		4.8		7.5		7.8		6.5		7.6		10.5	
Freeze & Thaw Water-Alcohol % Loss	4.2		8.1		6.3																							
Los Angeles Abrasion (B) % Loss	34		27		24																							
Water Absorption % by weight	0.27		0.95		0.94		0.40		0.54		0.87		0.33		0.27		0.67											
H.R.B. Specific Gravity Dry Agg.	2.707	2.707	2.660	2.660	2.703	2.703	2.704	2.704	2.701	2.701	2.678	2.678	2.711	2.711	2.710	2.710	2.697	2.697	2.655	2.655	2.665	2.665	2.698	2.698	2.695	2.695	2.703	2.703
Percent Asphalt	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00
Theoretical Solid Sp.Gr.	2.534	2.495	2.495	2.457	2.531	2.492	2.532	2.492	2.529	2.489	2.510	2.471	2.538	2.498	2.537	2.497	2.526	2.487	2.491	2.453	2.499	2.461	2.527	2.487	2.524	2.485	2.531	2.491
Pilot Specimens: Average Dry Wt. of Specimen Gms.	1849.8	1852.4	1740.5	1747.9	1772.2	1767.2	1857.3	1857.6	1798.0	1799.3	1759.3	1777.2	1899.3	1856.1	1847.2	1853.9	1849.0	1830.5	1741.3	1763.4	1750.2	1774.5	1800.0	1810.7	1799.2	1818.6	1879.1	1910.8
Average Specimen Volume in C.C.	809.0	799.3	819.3	810.3	815.1	804.9	824.3	812.6	815.7	805.5	818.8	818.1	816.4	806.9	820.7	816.0	830.2	817.3	817.3	814.1	817.2	816.2	823.0	818.0	814.8	813.0	801.1	799.1
Volume of Aggregate in C.C.	656.0	650.1	628.2	624.2	629.4	621.1	659.4	652.6	639.1	632.8	630.9	630.4	654.9	650.4	654.4	649.9	656.4	649.8	629.6	631.0	630.5	632.6	640.5	637.6	640.9	641.1	667.4	671.6
Voids in Mineral Aggregate in C.C.	153.0	149.2	191.1	186.1	185.7	183.8	164.9	160.0	176.6	172.7	187.9	187.7	161.5	156.5	166.3	166.1	173.8	172.5	187.7	183.1	186.7	183.6	182.5	180.4	173.9	171.9	133.7	127.5
Weight of Asphalt in Specimen in Gms.	73.99	92.62	69.62	87.40	70.90	88.40	74.29	92.90	71.92	89.98	70.40	88.68	73.97	92.81	73.89	92.70	73.76	91.53	69.70	88.20	70.10	88.70	72.00	90.50	72.00	90.90	75.20	95.50
Volume of Asphalt in Specimen in C.C.	73.84	92.44	69.48	87.20	70.80	88.20	74.14	92.70	71.78	89.80	70.26	88.68	73.82	92.62	73.74	92.51	73.61	91.35	69.50	88.00	70.00	88.50	71.90	90.40	71.90	90.70	75.00	95.30
Agg. Voids filled with Asphalt in %	48.26	61.96	36.36	46.86	38.12	48.00	45.00	57.90	40.60	52.00	37.40	47.20	45.70	59.20	44.30	55.70	42.40	53.00	37.00	48.10	37.50	48.20	39.40	50.10	41.30	52.80	56.10	74.70
Percent Voids in Pilots	9.60	6.91	15.04	12.32	14.03	11.81	10.95	8.19	12.81	10.28	14.38	12.06	10.83	8.00	11.57	9.12	12.17	10.04	14.42	11.59	14.32	11.63	13.56	11.08	12.38	10.16	7.15	3.98
Average Load P.S.I. (Pilot)	266	243	148	168	155	136	260	237	263	245	221	213	241	223	219	208	205	188	186	190	207	211	192	176	231	235	363	309
Average Density	2.287	2.318	2.124	2.157	2.175	2.196	2.253	2.286	2.206	2.234	2.149	2.172	2.265	2.300	2.246	2.272	2.222	2.240	2.131	2.166	2.142	2.174	2.187	2.214	2.208	2.237	2.349	2.391
Percent Swell (A.A.S.H.O. T-101)	0.74	0.51	0.78	0.83	0.48	0.29	0.70	0.71	0.27	0.59	0.69	0.64	0.32	0.23	0.34	0.27	0.44	0.23	1.04	0.58	0.79	0.45	0.40	0.36	0.42	0.33	0.10	0.05
Cohesion Specimens: Average Wet Weight in Gms.	1900.5	1878.5	1858.0	1843.2	1865.5	1822.7	1932.2	1906.7	1876.8	1858.7	1840.3	1861.0	1904.3	1891.0	1903.0	1894.2	1913.7	1885.5	1859.2	1849.3	1847.5	1854.2	1887.5	1873.5	1876.4	1872.1	1929.9	1933.6
Average Original Dry Weight in Gms.	1851.0	1850.7	1738.2	1747.7	1778.0	1754.9	1859.8	1856.7	1797.5	1799.8	1743.0	1778.3	1849.0	1856.5	1847.6	1853.0	1845.2	1831.1	1749.7	1763.2	1750.4	1775.7	1800.0	1809.6	1800.6	1818.6	1880.5	1911.1
Absorbed water in gms.	49.5	27.8	119.8	95.5	87.5	67.8	72.4	50.0	89.3	58.9	97.3	82.7	55.3	34.5	55.4	41.2	68.5	54.4	109.5	86.1	97.1	78.5	87.5	63.9	75.8	53.5	49.4	22.5
Average volume in C.C. (After treatment)	820.2	805.2	864.3	852.0	839.5	817.3	853.3	834.5	844.2	830.3	848.0	856.3	833.7	832.3	837.0	828.2	850.0	833.5	866.5	853.2	856.8	857.8	841.9	835.1	834.7	827.6	816.7	807.1
Average Original Dry Volume in C.C.	809.5	797.8	818.3	810.0	817.8	799.4	852.2	812.2	815.5	805.7	811.0	818.0	815.8	807.0	822.6	815.5	831.2	817.5	820.8	813.2	817.4	816.7	821.9	818.0	815.0	812.2	800.8	798.9
Gain in Volume in C.C.	10.7	7.4	46.0	42.0	21.7	17.9	28.1	22.3	28.7	24.6	37.0	38.3	17.9	15.3	14.4	12.7	18.8	16.0	45.7	40.0	39.4	41.1	20.0	17.1	19.7	15.4	15.9	8.2
Percent Volume Change (Cohesion Specimen)	1.30	0.93	5.62	5.19	2.65	2.24	3.41	2.75	3.52	3.05	4.56	4.68	2.19	1.90	1.75	1.56	2.26	1.96	5.57	4.92	4.82	5.03	2.43	2.09	2.42	1.90	1.99	1,03
Average Volume in C.C.	820.2	805.2	864.3	852.0	839.5	817.3	853.3	834.5	844.2	830.3	848.0	856.3	833.7	822.3	837.0	828.2	850.0	833.5	866.5	853.2	856.8	857.8	841.9	835.1	834.7	827.6	816.7	807.1
Volume of Aggregate in C.C.	656.5	649.5	627.3	624.2	631.5	616.8	660.3	652.3	638.9	633.0	624.8	630.8	654.7	650.6	654.5	649.6	656.8	645.0	632.7	630.9	630.5	633.0	640.5	637.2	641.4	641.1	667.9	671.4
Aggregate Voids in C.C.	163.7	155.7	237.0	227.8	208.0	200.5	193.0	182.2	205.3	197.3	223.2	225.5	179.0	171.7	182.5	178.6	193.2	188.5	233.8	222.3	226.3	224.8	201.4	197.9	193.3	186.5	148.8	135.4
Volume of Asphalt in C.C.	73.9	92.4	69.4	87.2	71.0	87.6	74.24	92.65	71.60	89.81	69.60	88.7	73.81	92.64	73.75	92.47	73.66	91.38	69.90	88.00	69.90	88.60	71.90	90.40	71.90	90.70	75.00	95.40
Volume of Water in C.C.	49.5	27.8	119.8	95.5	87.5	67.8	72.40	50.00	89.30	58.90	97.30	82.70	55.30	34.50	55.40	41.20	68.50	54.40	109.50	86.10	97.10	78.50	87.50	63.90	75.80	53.50	49.40	22.50
Agg. Voids filled with water in %	30.24	17.85	50.50	41.90	42.10	33.8	37.51	27.44	43.50	29.85	43.60	36.70	30.90	20.10	30.40	23.10	35.50	28.90	46.80	38.70	42.90	34.90	43.40	32.30	39.20	28.70	33.20	16.60
Agg. Voids filled with Asphalt in %	45.14	59.34	29.30	38.30	34.10	43.7	38.47	50.85	35.00	45.52	31.20	39.30	41.20	54.00	40.40	51.80	38.10	48.50	29.90	39.60	30.90	39.40	35.70	45.70	37.20	48.60	50.40	70.50
Agg. Voids filled with A.C. & H_2O	75.38	77.19	79.80	80.20	76.20	77.50	75.98	78.29	78.50	75.37	74.80	76.00	72.10	74.10	70.80	74.90	73.60	77.40	76.70	78.30	73.80	74.30	79.10	78.0	76.40	77.30	83.60	87.10
Average Load in P.S.I.	191	200	42	59	91	94	135	144	111	132	79	91	186	188	173	172	136	140	52	61	68	85	110	130	145	176	163	218
Percent Strength Retention	71.8	82.3	28.4	35.1	58.7	69.6	51.9	60.8	42.2	53.9	35.7	42.7	77.2	84.3	79.0	82.7	66.3	74.5	28.0	32.1	32.9	40.3	57.3	73.9	62.8	74.9	44.9	70.6
Average Marshall Density	2.338	2.321	2.147	2.181	-	-	2.249	2.318	2.220	2.241	2.146	2.195	2.320	2.349	2.301	2.308	2.272	2.297	2.156	2.217	-	-	2.232	2.251	2.219	2.277	2.409	2.435
Hveem Stability	31	44	56	55	51	54	37	44	51	46	46	47	35	36	35	38	42	40	51	52	46	55	54	56	52	54	39	81
Calc. % Voids Hveem Spec.	7.59	6.79	14.12	11.34	-	-	11.11	6.91	12.23	10.00	14.50	11.13	8.66	6.04	9.41	7.68	10.20	7.75	13.41	9.51	-	-	11.78	9.60	11.94	8.55	4.78	2.21

Note: (A) Adjusted to stay within grading requirements.

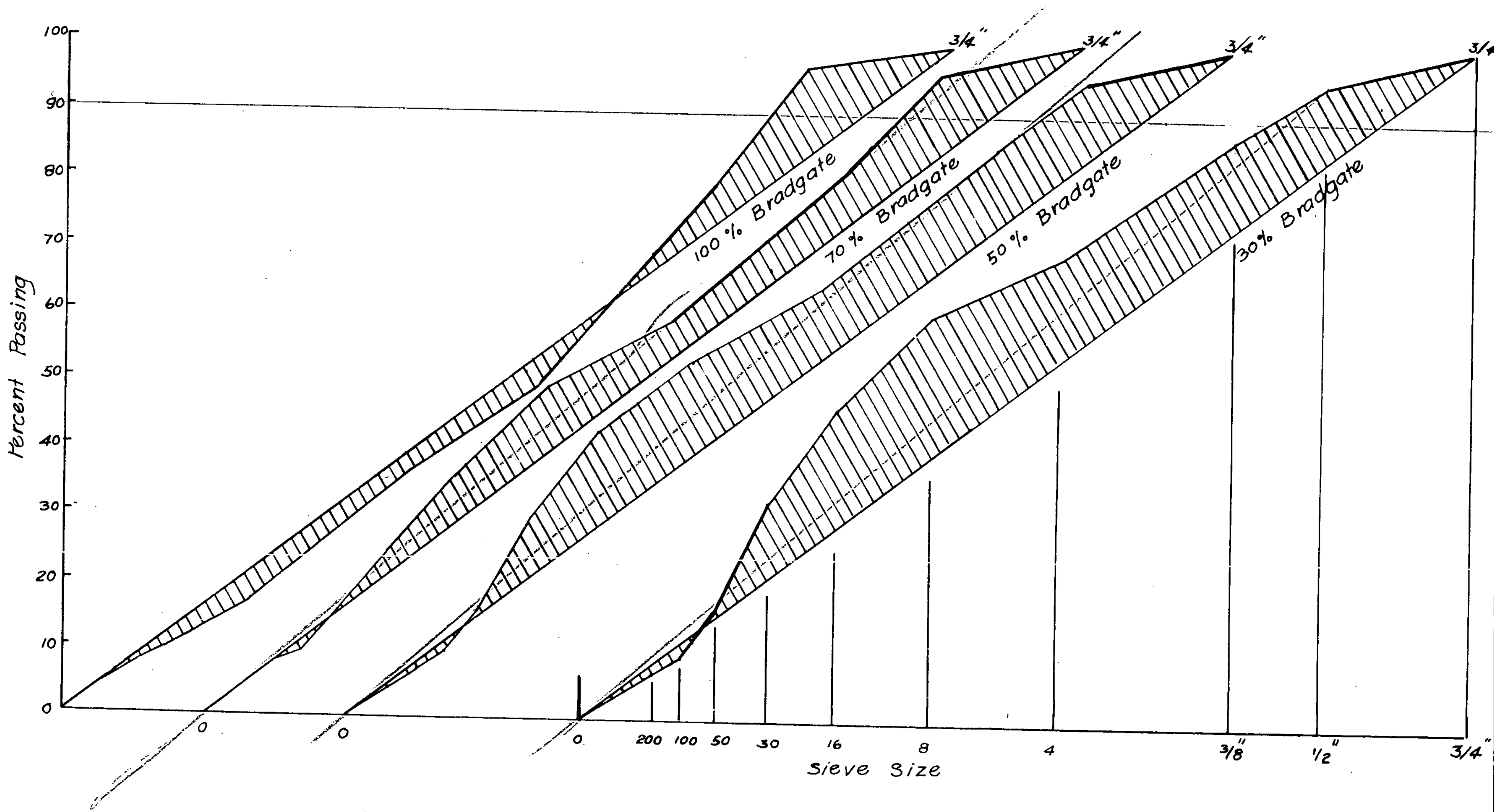
FIGURE 1.



Comparison of sieve analysis of Bradgate Stone, Buena Vista Gravel and Clay County Gravel

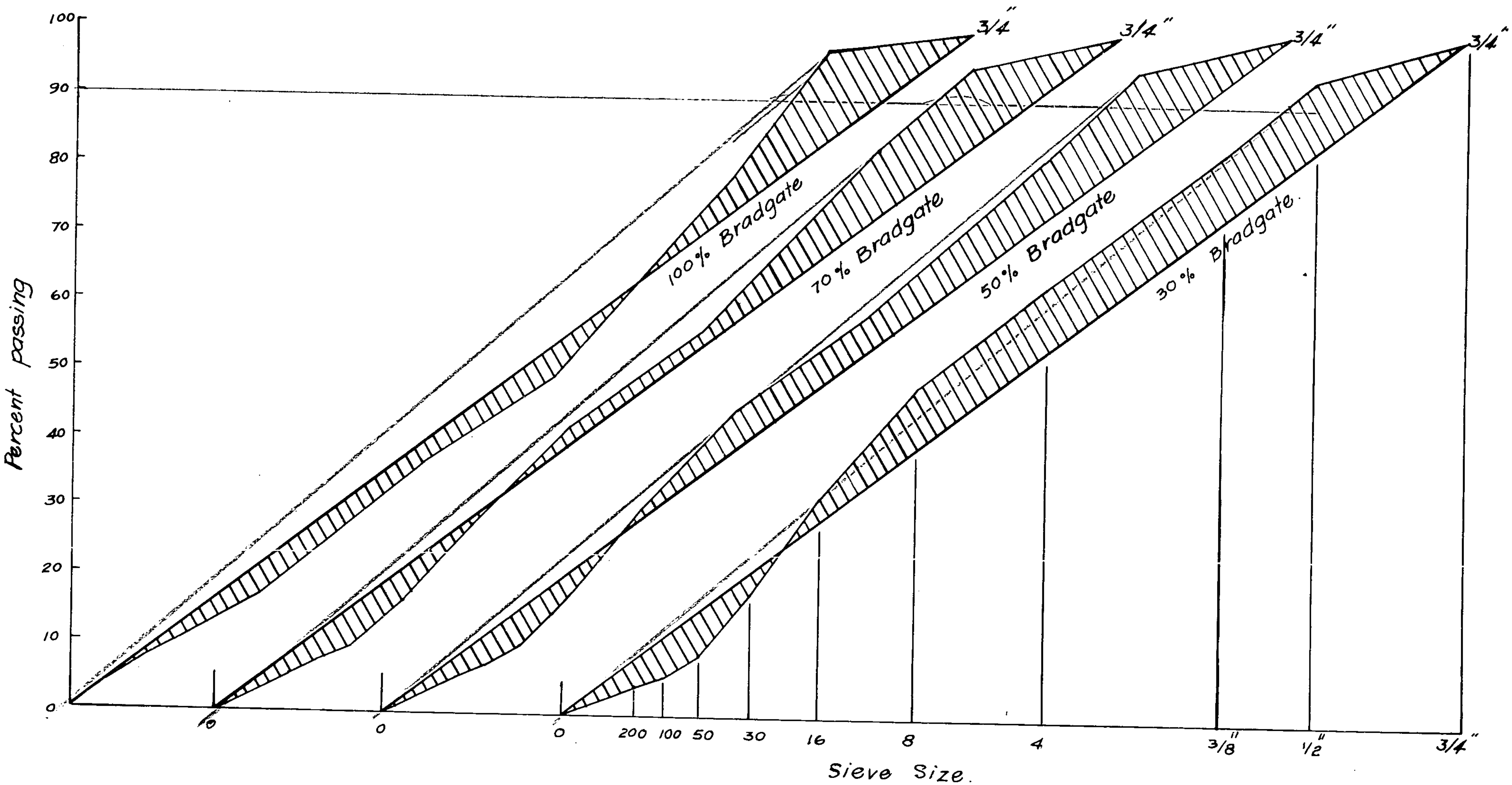
(Plotted with straight line 0.45 power.)

FIGURE 2



Comparison between Gradation of 100 % Bradgate Stone and various percentages of Buena Vista Gravel.
(Plotted with straight line 0.45 power)

FIGURE 3



Comparison between Gradation of 100% Bradgate stone and various Percentage of Clay County Gravel. 1302

(Plotted with straight line 0.45 power)

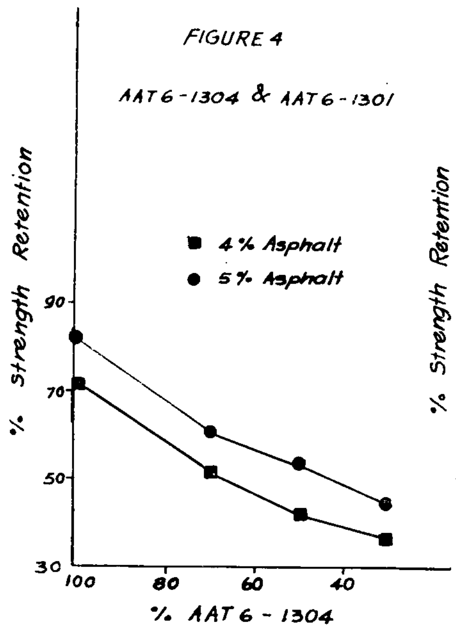


FIGURE 4
AAT6-1304 & AAT6-1301
% Strength Retention
4% Asphalt
5% Asphalt
% AAT6-1304

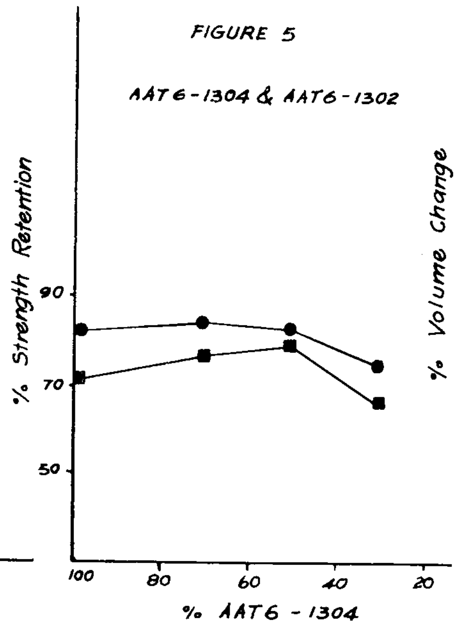


FIGURE 5
AAT6-1304 & AAT6-1302
% Strength Retention
% AAT6-1304

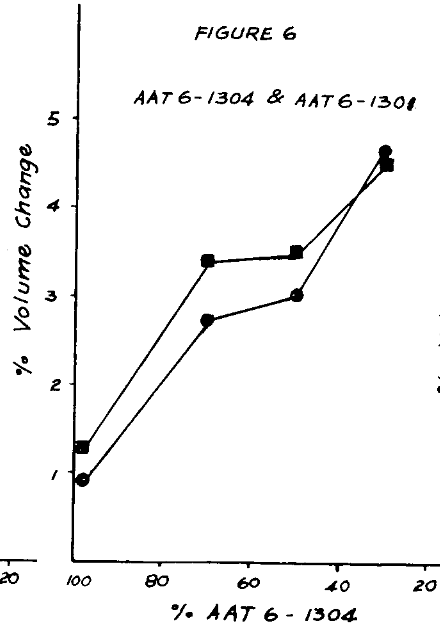


FIGURE 6
AAT6-1304 & AAT6-1301
% Volume Change
% AAT6-1304

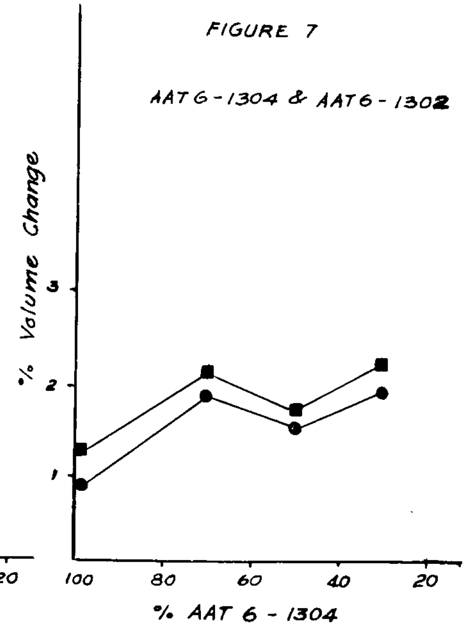


FIGURE 7
AAT6-1304 & AAT6-1302
% Volume Change
% AAT6-1304

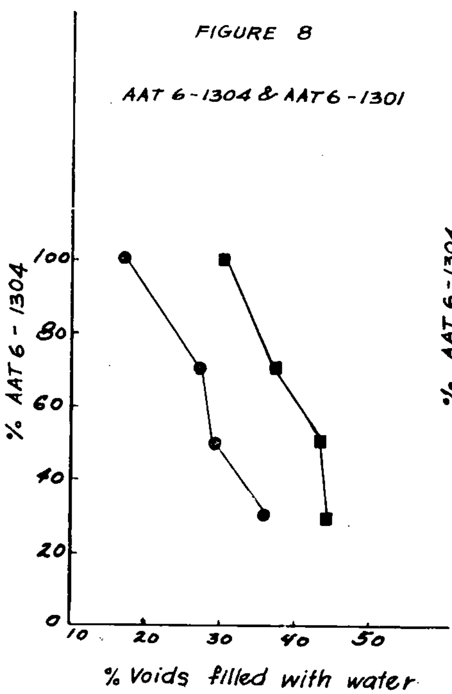


FIGURE 8
AAT6-1304 & AAT6-1301
% AAT6-1304
% Voids filled with water

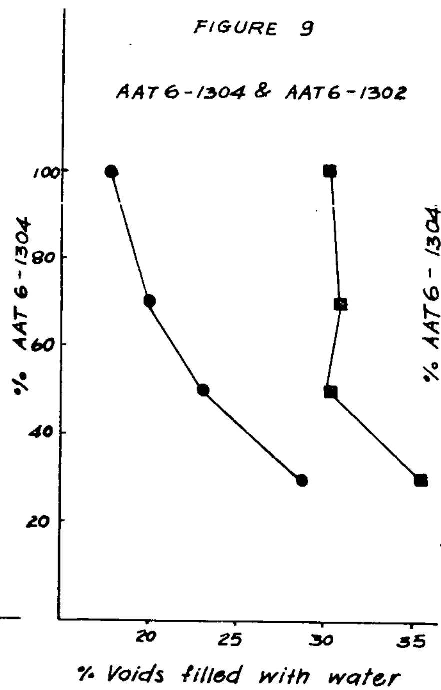


FIGURE 9
AAT6-1304 & AAT6-1302
% AAT6-1304
% Voids filled with water

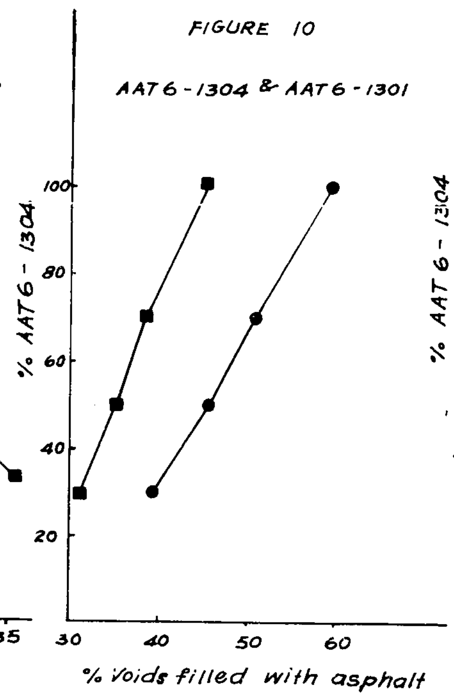


FIGURE 10
AAT6-1304 & AAT6-1301
% AAT6-1304
% Voids filled with asphalt

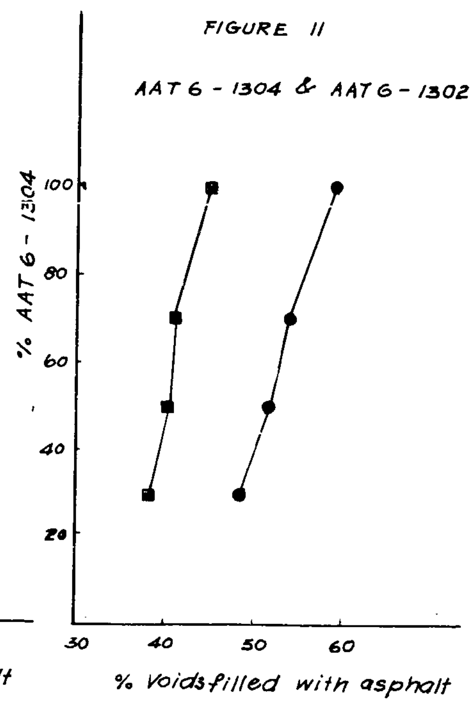


FIGURE 11
AAT6-1304 & AAT6-1302
% AAT6-1304
% Voids filled with asphalt

FIGURE 12

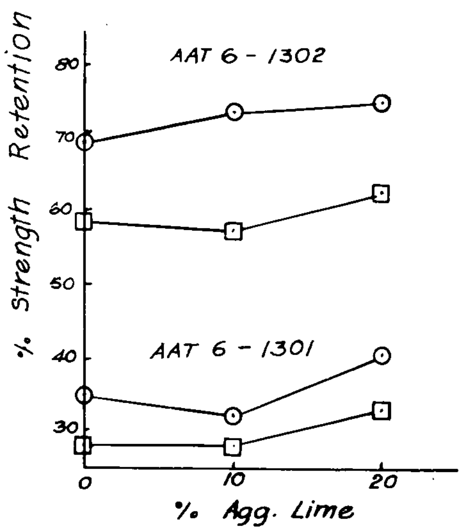


FIGURE 13

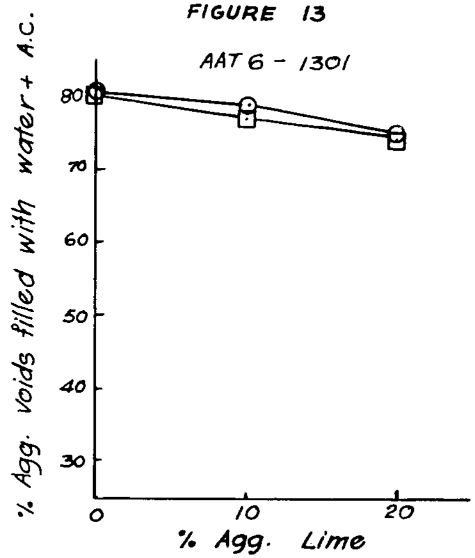


FIGURE 14

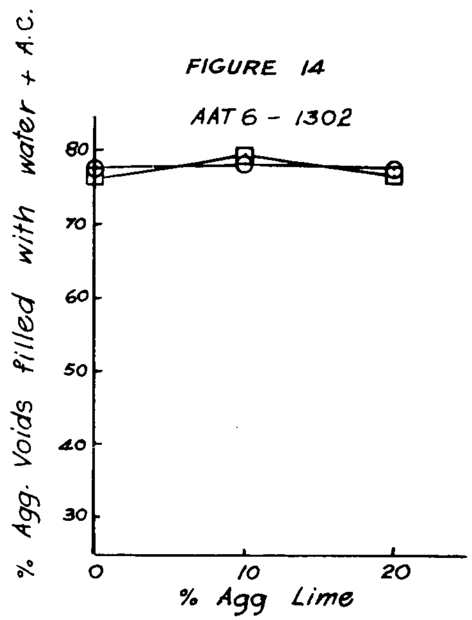


FIGURE 15

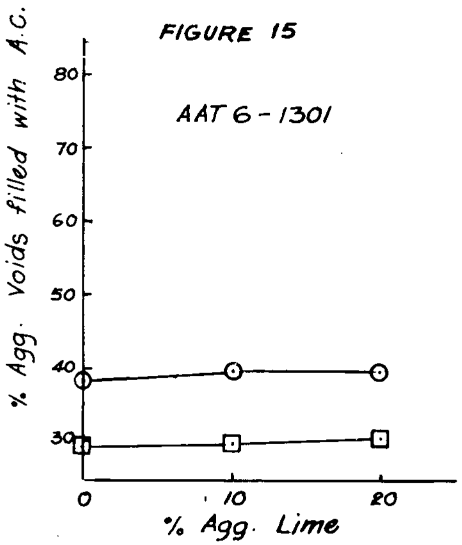
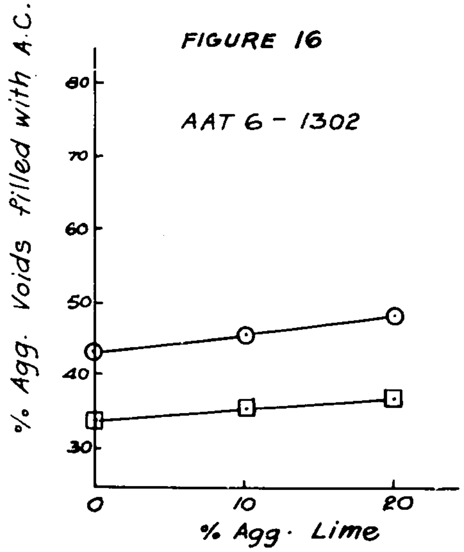


FIGURE 16



Class II Study
of
Pit Run Gravels with Bradgate
minus No. 8 Aggricultural Lime

□ 4 % Asphalt
○ 5 % Asphalt

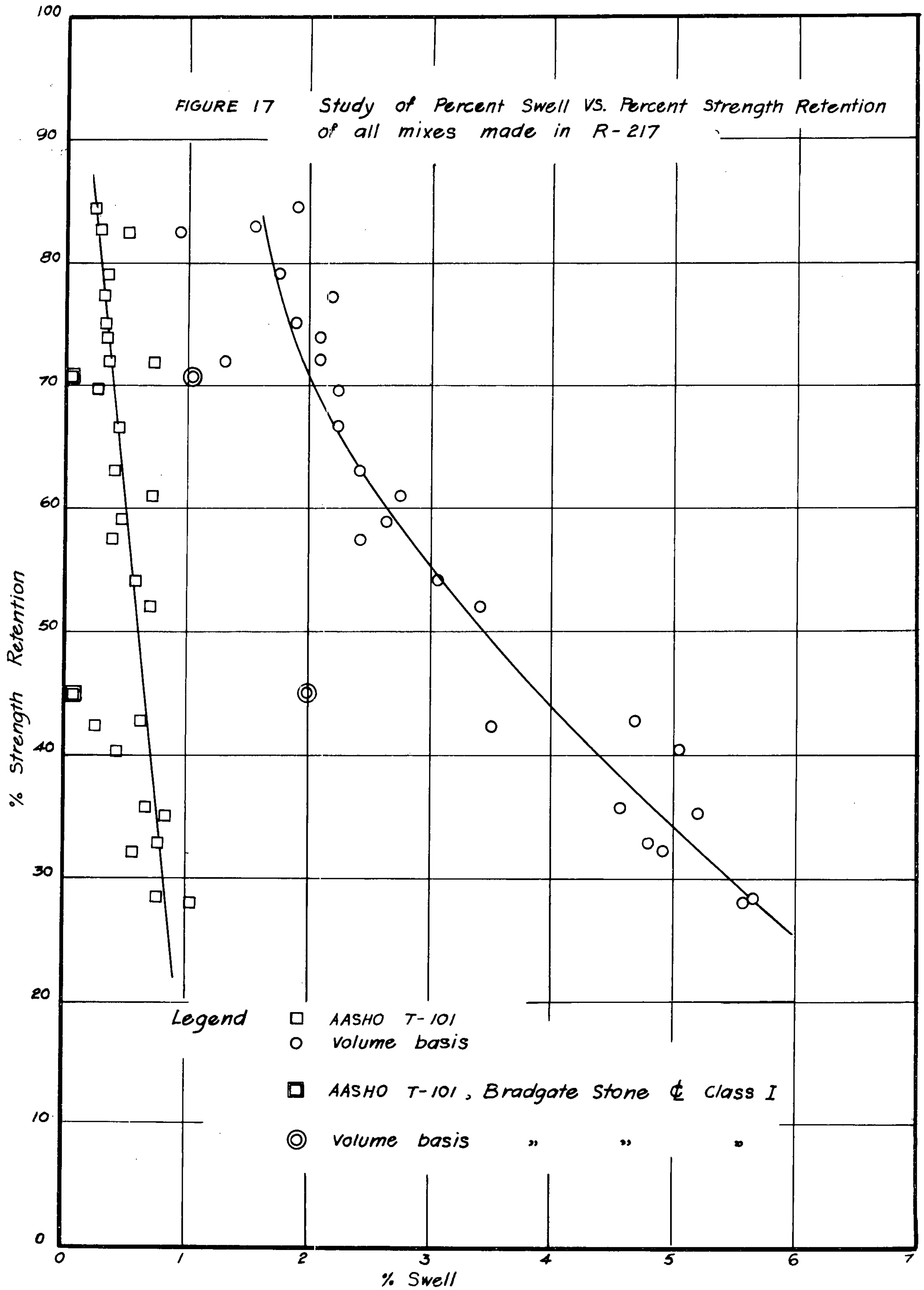


FIGURE 17 Study of Percent Swell VS. Percent Strength Retention of all mixes made in R-217
% Strength Retention
% Swell
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5
6
7
Legend
AASHO T-101
Volume basis
AASHO T-101, Bradgate Stone ¢ Class I
Volume basis " " "