Iowa State Highway Commission

MATERIALS DEPARTMENT

SPECIAL INVESTIGATIONS

Report of R-223

EVALUATION OF COHESION AND SWELL CHARACTERISTICS OF ASPHALT TREATED BASE MIXTURES

IOWA STATE HIGHWAY COMMISSION

Department of Materials

Special Investigations

Report for

Research Project R-223

Evaluation of Cohesion and Swell Characteristics of Asphalt Treated Base Mixtures

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by

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and

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1.0 INTRODUCTION

This study was undertaken to evaluate the suitability of various stones which play an important role in the properties of compacted mixtures in asphalt treated bases. The determination of the effect of water temperature on the cohesion of the mixes is investigated. A number of stones were prepared for the test.

Attention is paid to the particular source of stone with the corresponding test results. A preliminary study of the effect of lime when added to mixed aggregate was also conducted.

2.0 PURPOSE

The purpose of this study is to provide needed information on the cohesive characteristics of asphalt treated bases using a wide range of stones. This study is also to evaluate the suitability of the various stone sources.

3.0 MATERIALS

The stones to be evaluated, for the asphalt treated bases, were from various projects throughout the state and have different characteristics from the geological point of view. The various sources of fine aggregate used in the study were from normally used sources. The location of the stones and the fine aggregates are listed in Table I.

The asphalt binders used were 136 penetration and 85 - 100 penetration.

Hydrated lime was used with two sources of aggregate for a short study of the effect of lime on the cohesive characteristics.

4.0 LABORATORY PROCEDURE

The asphalt treated base aggregates were combined in the ratio of seventy per cent of stone and thirty per cent of the pit run gravel, if the combination met with the current combined gradation requirement which is according to Sec. 4128.04, Class I, I.S.H.C. Specification of 1964. If not an adjustment in the individual gradation was made to meet the required combined gradation.

The test, "Effect of Water on Cohesion of Compacted Bituminous Mixtures", was according to AASHO-165. The method of compaction, molding temperature and period of soaking for wet strength determinations were sometimes modified from the AASHO-165 requirement, for particular samples. The modifications are listed in the remarks of Table I. Both four and five per cent of 136 penetration asphalt was used except for Lab. No's ABC7-415, 416 and 779 where four and a half per cent was used for study of the effect of soaking period on the wet strength. The 85 - 100 penetration asphalt was used in Lab. No's ABC7-77, 77A, 1085-1083 and 1084-1085 for the study of the effect of the type of asphalt used.

The hydrated lime was added to the aggregate for the test of Lab. No's ABC7-147-148 and into the specimens of Lab. No's ABC7-160-161 during mixing to study its effect on the cohesion test results.

The tabulation of laboratory trial mixes in conjunction with the study for some sources of the aggregate is shown in TABLE II.

5.0 INTERPRETATION OF THE TEST RESULTS

For this study, the evaluation of the suitability of individual stone sources was made mainly on the results of the test for the effect of water on cohesion of compacted mixes.

According to our past experience, the composite gradation is critical to the test result, thus the effect of the gradation is drawn to your attention for the study. The composite gradation of aggregates by the specification for the base materials is divided into four groups as shown in Fig. 1. The gradations of group 1 represent the finest materials while group 4 represents the coarsest material. The group of gradations are controlled by per cent passing of sieve 3/8", No. 8 and No. 30.

Referring to Table I, the individual analysis for each source of the coarse aggregate is made as follows:

5.1 CONCRETE MATERIAL COMPANY at LEGRAND QUARRY, CHAPIN

The effect of soaking period and soaking temperatures were determined. The results show that the specimens soaked for 48 hours at 120°F and the specimens soaked for 24 hours at 140°F gave nearly the same results in the retained strength, other conditions being the same, i.e. gradation group of composition, per cent of stone, per cent of fine aggregate and their sources. This is according to Lab. No's ABC7-42-43 and ABC7-42A-43A.

The effect of lime added to the aggregate before mixing and of molding temperatures were also investigated, (Lab. No's ABC7-217-218 and ABC7-147-148). The lime added should improve both pilot and wet strength of the mixes. But the results show that the pilot strength of the mixes of one per cent lime is lower

than that of the mixes without lime. This is because the effect of the molding temperature was also involved and more critical than that of one per cent lime added. When the molding temperature was increased from 255°F with one per cent lime added to 275°, the pilot strength was also increased by 1 and 13 per cent for 4 and 5 per cent asphalt mixes respectively. Thus, the per-cent increase indicates the difference between the two effects. Consequently, the mixes of one per cent lime give higher wet strength than that of the mixes without lime. Hence, the lime affects the wet strength more critically than the molding temperature by 45 and 23 per cent at 4 and 5 per cent asphalt respectively. And the two effects caused approximately 30% increase in the index of retained strength for both 4 and 5 per cent asphalt mixes.

5.2 SCHILDBERG AT MENLO QUARRY, MENLO

There were four tests run on this stone and the composite gradations of all mixing aggregates fall in group 2. This is according to Lab. No's ABC7-77 and 7-265, the index of retained strength of 5 per cent, 85-100 penetration asphalt mixes is more than 15 per cent higher, while the pilot strength is more than 20 per cent higher than those of the mixes of 5 per cent, 136 penetration asphalt, other conditions being the same.

The same phenomena took place when comparing the tests results of Lab. No's ABC7-77A and 7-266. A general conclusion can be drawn that the index of retained strength depends primarily upon the type of asphalt. The mixes containing harder asphalt give higher strength and index of retained strength.

5.3 KASER CONSTRUCTION COMPANY AT GRANT QUARRY, GRANT

Regarding Lab. No's ABC7-66-67 and 7-103-104, the coarser composite gradation (Group 4) of Lab. No's ABC7-103-104 gave higher pilot strength but lower wet strength and index of retention than that of the finer composite gradation (Group 3) of Lab. No's ABC7-66-67. This is probably due to the greater amount of voids in the coarser mix (See Table II). The coarser grade has a tendency of having higher voids than the finer one. Quality of stone may be reflected also in cohesion strength retention test.

5.4 FORT DODGE LIMESTONE AT GILMORE CITY

From the test results of Lab. No's ABC 7-70-71 and 7-1082-1083, conclusions can be made similar to those given for the Menlo Quarry stone, i.e., the effect of the asphalt type on the test results.

5.5 SCHILDBERG AT CRESCENT

For this study, an attempt was made to investigate the suitability of each ledge. The Hertha ledge stone is compared to the Bethany ledge stone. The results of Lab. No's ABC7-83-84 (Hertha ledge) and ABC-87-88 (Bethany ledge) show that no significance in the difference between the Hertha ledge and the Bethany ledge concerning the effect of water on cohesion. When comparing the results of Lab. No's ABC7-83-84 to Lab. No's ABC-1086-1087, the conclusion is the same as those of the Menlo Quarry stone, i.e., the effect of the asphalt type on the test results.

5.6 MUTT PLACE AT SOUTH DAKOTA

Regarding Lab. No's ABC7-158-159, this mix gives low pilot

and cohesion strength at both 4 and 5 per cent asphalt content. A further test was carried on by adding one per cent of hydrated lime during mixing (Lab. No. ABC7-160), the pilot strength and the wet strength were increased, i.e., the pilot and the wet strength are increased by approximately 300 and 400 per cent respectively at five per cent asphalt content. This is because:

1. A chemical reaction took place between the lime and the aggregates and improved the cohesive test characteristics of the mixes. Evidently the pit run gravel source contained a detrimental clay that was changed in character by the addition of lime.

2. The lime particles which are very fine stayed in between the aggregate particles and possibly caused less voids in the mixes, this probably improved the cohesive test characteristics.

A further study was carried on. By adding two per cent water together with one per cent of hydrated lime and curing 24 hours before mixing (Lab. No. ABC7-161), the pilot strength and the wet strength were less than those of the mixes without the two per cent water treatment. Per cent strength retention dropped also.

There is some doubt as to the validity of these particular test results. Since it is contrary to some previous work on lime addition to soils.

5.7 SCHILDBERG AT ATLANTIC

The effect of the soaking period, at room temperature, on the wet strength was investigated. The wet strength was increased for Lab. No's ABC7-415 but decreased for Lab. No's ABC7-416 and 7-779 when the period of soaking was increased. The

results are inconclusive and no general conclusion can be drawn, thus further study is needed. The results of this study are shown in Figs. 2 - 4.

The effect of curing period, in air at room temperature, on the pilot strength was also investigated. The pilot strength decreased when the curing period was increased, this is shown by Fig. 5. The available data is not adequate to make a general statement. A further study is needed.

The rest of the results of the project are the individual investigations to evaluate each source of stone under particular methods and are not discussed in this report.

6.0 CONCLUSION

The results of the tests indicate the following:

1. The type of asphalt affects the pilot strength. The mixes containing low penetration asphalt always have higher pilot strengths and wet strengths than those containing higher penetration asphalt, while having the same amount of asphalt.

2. The increase of molding temperature from 255° to 275°F improved the pilot strength of the mix.

3. The lime added in the aggregates before mixing improve wet strength.

4. The lime added during mixing improves the cohesive test characteristics of the mix.

5. The coarser composite gradations of aggregates (high voids content) gives higher pilot strength but lower wet strength and index of retention than those of the finer composite gradations (low voids content).

6. The increase in the per cent of index of retention of the mixes from 4 to 5 per cent 136 penetration asphalt are 5.4, 5.3, 8.6 and 5.4 for the composite gradation groups 1, 2, 3 and 4 respectively.

7. This study was conducted to obtain some information concerning the cohesive characteristics of the aggregate combinations as outlined in the I.S.H.C. Spec., Div. II 607, February 28, 1967, and for a preliminary study of the effect of various features, thus the results are applicable only to the aggregates studied herein.

IOWA STATE HIGHWAY COMMISSION

DATA SHEET

Table I

R-223

Evaluation of Asphalt Treated Base

Cohesion and Swell Tests

LAB. NO.	COARSE AGGREGATE	PERCENT COARSE AGG.	FINE AGGREGATE	PERCENT FINE AGG.	GRADATION GROUP OF COMPOSITE AGG.	4 PERCENT ASPHALT: PILOT STRENGTH P.S.I.	4 PERCENT ASPHALT: WET STRENGTH P.S.I.	4 PERCENT ASPHALT: % RET.	4 PERCENT ASPHALT: % SWELL	5 PERCENT ASPHALT: PILOT STRENGTH P.S.I.	5 PERCENT ASPHALT: WET STRENGTH P.S.I.	5 PERCENT ASPHALT: % RET.	5 PERCENT ASPHALT: % SWELL	REMARKS — Cohesion Test AASHO-165 (USED ALTERNATE PROCEDURE). Used 136 Penetration Asphalt Cement unless otherwise noted.
ABC7-42-43	Conc.Matls.@ LeGrand Qr.,Chapin	60	Marshall Co. Pit Run	40	2	220	162	73.6	0.03	223	186	83.[illegible]	0.14	AASHO-165
ABC7-42A-43A	"	60	"	40	2	220	170	77.3	--	223	181	81.2	--	AASHO-165 but specimens soaked 48 Hrs. @ 120° F.
ABC7-217-218	"	70	Conc.Matls. @ Marshalltown	30	3	272	190	69.9	--	293	234	80.0	--	AASHO-165 But molded @ 275° F.
ABC7-147-148	"	70	"	30	3	269	276	102.6	0.14	259	287	110.8	0.14	AASHO-165 & 1% hydrated lime added
ABC7-77	Schildberg @ Menlo Qr., Menlo	75	Brayton Pit @ Audubon Co.	25	2	--	--	--	--	692	697	100.9	--	Marshall Compaction @ 275°F,Type B Field Mix, 85-100 Pen. A.C.
ABC7-77A	"	75	"	25	2	--	--	--	--	468	430	92.0	--	AASHO-165,Type B Field Mix; 85-100 Pen. A.C.
ABC7-265	"	75	"	25	2	--	--	--	--	576	487	84.5	--	Marshall Compaction @ 275° F.
ABC7-266	"	75	"	25	2	--	--	--	--	349	265	75.9	--	AASHO-165
ABC7-66-67	Kaser Constr. Co.@ Grant Qr.,Grant	80	Brayton Pit @ Audubon Co.	20	3	327	65	19.9	0.36	320	106	33.2	0.41	AASHO-165
ABC7-103-104	"	100	--	--	4	442	39	8.8	0.41	372	47	12.6	0.32	AASHO-165
ABC7-70-71	Ft.Dodge Lmst. @ Gilmore City	70	Egland Farm @ Story Co.	30	2	275	210	76.4	0.23	281	247	88.0	0.19	AASHO-165
ABC7-1949-1950	"	70	"	30	2	482	492	102.1	--	436	474	108.7	--	Marshall Compaction @ 275° F., 3 Days Soaked @ 110° F.
ABC7-1082-1083	"	70	"	30	2	433	415	95.8	--	430	415	96.5	--	AASHO-165, 85-100 Pen. A.C.
ABC7-83-84	Schildberg @ Crescent (Hertha)	70	Crescent Qr. @ Pott. Co.	30	3	271	13	4.8	0.40	296	25	8.4	0.36	AASHO-165
ABC7-87-88	" (Bethany)	70	"	30	3	298	10	3.4	0.45	293	23	7.8	0.40	AASHO-165
ABC7-176-177	" (Bethany)	70	"	30	--	323	51	15.8	0.45	327	48	14.7	0.41	AASHO-165 but molded @ 275° F.
ABC7-1953-1954	" (Bethany)	70	Egland Farm @ Story Co.	30	3	504	237	47.0	--	531	337	63.5	--	Marshall Compaction @ 275° F., 3 Days Soaked @ 110° F.
ABC7-1086-1087	" (Bethany)	70	Crescent Qr. @ Pott. Co.	30	3	398	85	21.4	--	368	130	35.3	--	AASHO-165 , 85 Pen. A.C.
ABC7-158-159	Mutt Place @ S. Dakota	50	1. Mutt Place @ S. Dakota	40										
	"		2. Blow Sand @ Blenco, Monona Co.	10	3	137	94	69.0	0.00	143	98	69.0	0.09	AASHO-165
ABC7-160	"	50	"	"	3	--	--	--	--	576	487	84.5	--	AASHO-165, 1 % Hydrated lime added during mixing
ABC7-161	"	50	"	"	3	--	--	--	--	349	265	75.9	--	AASHO-165,1 % hyd. lime & 2% Water added then cured 24 hours before mixing aggregate.
ABC7-131-132	Schildberg @ Atlantics	70	Egland Farm @ Story Co.	30	3	323	66	20.4	0.32	375	110	29.3	0.28	AASHO-165
ABC7-415	"	70	"	30	4	435	451	103.7	--	--	--	--	--	Marshall Compaction @ 275° F, 4.5% A.C., Soaked @ room temp. for 3 da
"	"	70	"	30	4	435	464	106.7	--	--	--	--	--	" " " " " " " " " 5 "
"	"	70	"	30	4	435	496	114.0	--	--	--	--	--	" " " " " " " " " 7 "
ABC7-416	"	70	"	30	4	314	297	94.6	--	--	--	--	--	AASHO-165, but soaked @ room temp. for 3 days., 4.5% A.C.
"	"	70	"	30	4	314	287	91.4	--	--	--	--	--	" " " " " " 5 " " "
"	"	70	"	30	4	314	289	92.0	--	--	--	--	--	" " " " " " 7 " " "
ABC7-779	"	70	"	30	4	562	--	--	--	--	--	--	--	Marshall Compaction @ 275°F.,4.5% A.C.,cured in air for 1 day.
"	"	70	"	30	4	460	479	85.2	--	--	--	--	--	" " " " 4.5% & soaked @ room temp. for 3 days,
"	"	70	"	30	4	435	415	73.9	--	--	--	--	--	" " " " " " " " " 5 "
"	"	70	"	30	4	502	378	67.3	--	--	--	--	--	" " " " " " " " " 7 "
ABC7-1951-1952	"	70	"	30	3	482	492	102.1	--	436	474	108.7	--	Marshall compaction @ 275° F., 3 days soaked @ 110° F.
ABC7-1084-1085	"	70	"	30	4	422	161	38.2	--	432	214	49.5	--	AASHO-165, 85-100 Pen. A.C.
ABC7-303-304	Greene Lmst. @ Lubben Qr.,Packard	70	Greene Lmst. @ Butler, Co.	30	2	217	60	27.6	0.73	207	76	36.7	0.33	AASHO-165 but molded @ 275° F. for 3 min.
ABC7-127-128	"	70	"	30	2	303	53	17.5	1.21	293	77	26.3	1.08	" " " " " " "
ABC7-46-47	Grupp Constr. Co. @ Howard Co.	70	Egland Farm @ Story Co.	30	4	264	37	14.0	1.09	266	40	15.0	1.00	AASHO-165
ABC7-92-93	Welp & McCarten @ Leland	40	Leland Pit @ Winnebago Co.	60	1	224	104	46.4	0.49	242	115	47.5	0.50	AASHO-165
ABC7-94-95	Conc. Matls. @ Fertile	40	"	60	2	229	50	21.8	0.85	231	57	24.7	0.67	AASHO-165
ABC7-101-102	1. Mutt Place,3/8"Cr.Rock@ S.Dak.	36	1. Pit Run Gr.,Mutt Place @ S.Dak.	45										
	2. " " 3/4" " " " "	12	2. Fine Sand,Midwest Pav.,@ Monona	5										
			3. Fine Lime,P&M Stone @ Humboldt	2	2	179	90	50.3	0.23	177	88	53.1	0.28	AASHO-165
ABC7-133-134	Paul Niemann @ Eldorado	70	Egland Farm @ Story Co.	30	3	274	111	40.5	0.25	261	210	80.5	0.20	AASHO-165
ABC7-156-157	Waverly S & Gr. @ Shellrock	70	Waverly S & Gr. @ Butler Co.	30	2	202	48	23.8	0.45	234	56	23.9	0.59	AASHO-165, but molded @ 275° F.
ABC7-169-170	Conc. Matls. @ Yokum Qr.,Finchford	70	Brooks S.& Gr. @ Shellrock	30	1	254	34	13.4	0.45	217	26	12.0	0.45	AASHO-165 but molded @ 275° F.
ABC7-174-175	Kaser Constr. @ Thurman	70	J.Stanley & Bartlett @ Fremont Co.	30	3	262	205	78.3	0.27	253	221	87.4	0.32	AASHO-165, but molded @ 275° F.
ABC7-186	Clark Lmst. @ Logan	70	1.Clark Lmst. @ Logan (Sand)	20										
			2.Clark Lmst. @ Logan (Cr. Grav.)	10	2	230	109	47.4	0.45	--	--	--	--	AASHO-165
ABC7-244-245	Conc. Matls. @ Frederika	70	Waverly S.& Gr. @ Shellrock	30	1	296	235	79.4	0.09	301	290	96.3	0.14	AASHO-165, but molded @ 275° F.
ABC7-785-786	Greene Lmst. @ Eagle Qr.	70	NE¼ 1-92-16, Butler Co.	30	2	251	182	72.5	0.18	279	241	86.1	0.09	AASHO-165, but molded @ 275° F. for 3 min.

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DATA SHEET

TABLE II

R-223

Tabulation of Laboratory Trial Mixes Made in Conjunction With Cohesion Tests From Same Sources as Shown in Table I
(Marshall Compaction, Hveem Side Pressure, Gradation, etc.)

Laboratory Numbers	Coarse Aggregate Source	%	Fine Aggregate or Sand Source	%	Gradation Group Composite Agg.	Gradation Agg. - % Passing Sieve 3/4"	1/2"	3/8"	#4	#8	#30	#50	#100	#200	4% Asphalt Cement: Hveem Side Press @ 400# Vert. Load PSI	Dens.	I.H.R.B. Sp.Gr. Calculated Solid Dens.	Air Voids	Agg. Voids Filled w/AC %	Abs. %	5% Asphalt Cement: Hveem Side Press. @ 400# Vert. Load PSI	Dens. Spec. Marsh. Comp.	I.H.R.B. Calc. Solid Sp. Gr.	Calc. Air Voids in Speci. - %	Agg. Voids Filled w/A.C. %	Water Absor. Agg. - %
ABC7-40 - 41	Conc.Matls.@LeGrand Q.,Chapin	60	Marshall Co. Pit-Run	40	2	100	--	80	64	51	30	--	--	6.1	31	2.29	2.504	8.6		1.05	33	2.33	2.465	5.5		1.05
ABC7-219 - 220	" " "	70	Conc. Matls. Marshalltown	30	3	100	88	76	54	44	22	14	9.0	6.1	26	2.31	2.523	8.4		0.65	29	2.34	2.483	5.8		0.65
ABC7-145 - 146	" " "	70	" " Plus 1% Hyd. Lime	30	3										29	2.31	2.511	8.0		1.00	37	2.36	2.472	4.5		1.00
ABC7-68 - 69	Kaser Const., Grant Qr., - Montgomery Co.	80	Brayton Pit - Audubon Co.	20	3	99	90	78	57	42	21	14	11	8.9	37	2.27	2.509	9.5		0.80	36	2.31	2.470	6.5		0.80
ABC7-105	" " "	100			4	99	90	77	53	36	17	14	12	10	43	2.21	2.512	12.0		1.19	--	--	--	--		--
ABC7-85 - 86	Crescent Qr., Pott. Co., Hertha Ledge	70	Crescent Qr. - Pott. Co.	30	3	100	--	74	55	43	24	--	--	11	42	2.16	2.470	12.6	40.8	1.33	36	2.23	2.433	8.3	57.3	1.33
ABC7-89 - 90	" Bethany Falls Ledge	70	" "	30	3	100	--	73	55	43	24	--	--	12	42	2.21	2.489	11.2	44.2	1.26	35	2.25	2.451	8.2	57.9	1.26
ABC7-178 - 179	" " Beds 35-40	70	" "	30											33	2.25	2.483	9.4		1.85	33	2.28	2.445	6.8		1.85
ABC7-158 - 159	Mutt Place - So. Kakota	50	1. Mutt Place - So. Dakota 2. Blow Sd. Blenco, Monona Co	40 10	3	100	89	77	62	47	23	--	--	4.0	52	2.30	2.528	9.0		0.76	58	2.33	2.488	6.4		0.76
ABC7-129 - 130	Schildberg - Atlantic	70	Egland Farm - Story City	30	3	98	87	75	56	41	19	14	11	9.4	33	2.30	2.463	6.6		1.39	41	2.35	2.426	3.1		1.39
ABC7-125 - 126	Greene Lmst. - Lubben Qr. Packard	70	Greene Lmst. - Butler Co.	30	2	99	96	87	68	52	24	14	10	9.1	44	2.26	2.528	10.6		0.33	39	2.31	2.488	7.2		0.33
ABC7-46 - 47	Davis Corners - Howard Co.	70	Egland Farm - Story City	30	4	99	--	70	46	31	15	--	--	7.7	45	2.15	2.473	11.1	39.7	2.69	50	2.19	2.435	10.1	52.1	2.69
ABC7-103 - 104	Mutt Place 3/8" Cr. Rock - So. Dakota	36	Pit-Run Gr.-Mutt Place,S. Dak.	45																						
	~~Mutt Place 3/4" " " "~~	12	Fine Sd. Midw.Pav. - Monona Co Fine Lime,P&M Stone-Humboldt	5 2	2	100	93	83	64	48	23	14	7.0	5.5	39	2.32	2.521	8.0		0.27	43	2.33	2.482	6.1		0.27
ABC7-133 - 134	County Qr. - Fayette Co.	70	Egland Farm - Story City	30	3	99	--	74	55	41	22	--	--	10.0	36	2.42	2.533	4.5		0.33	63	2.43	2.492	2.5		0.33
ABC7-156 - 157	Shell Rock Qr. - Butler Co.	70	Waverly Sd&Gr. - Butler Co.	30	2	100	94	85	64	50	28	16	13	11.0	34	2.27	2.527	10.2		1.06	37	2.28	2.487	8.3		1.07
ABC7-167 - 168	Yokum Qr. - Black Hawk Co.	70	Brooks Sd&Gr. - Shell Rock	30	1	100	95	87	71	57	30	17	11	8.6	45	2.13	2.500	14.8		0.77	45	2.19	2.461	11.0		0.77
ABC7-172 - 173	Thurman Qr. - Fremont Co.	70	J.Stanley(Stockpile)Fremont Co	30	3	100	--	76	61	48	24	--	--	6.7	30	2.28	2.469	7.7		1.06	37	2.30	2.493	7.7		1.06

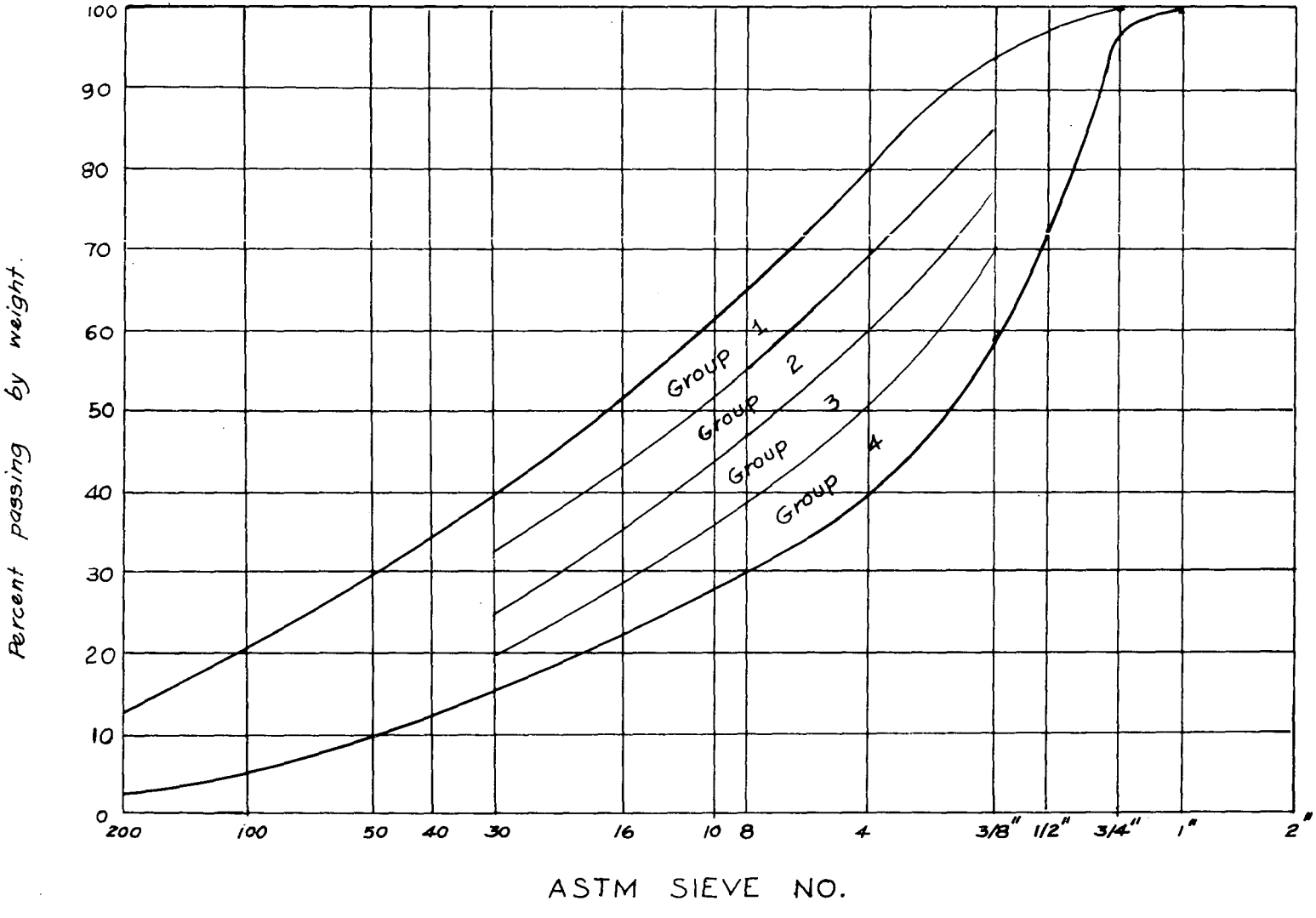

Figure 1 : Grading bands, showing the gradation bands for the various groups within the specification limits.

FIGURE 2

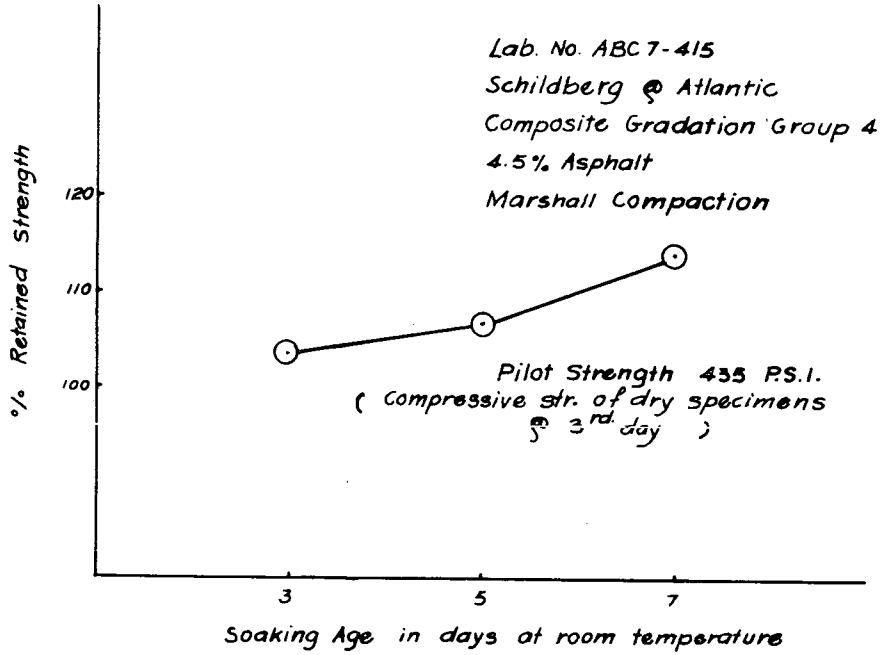

FIGURE 3

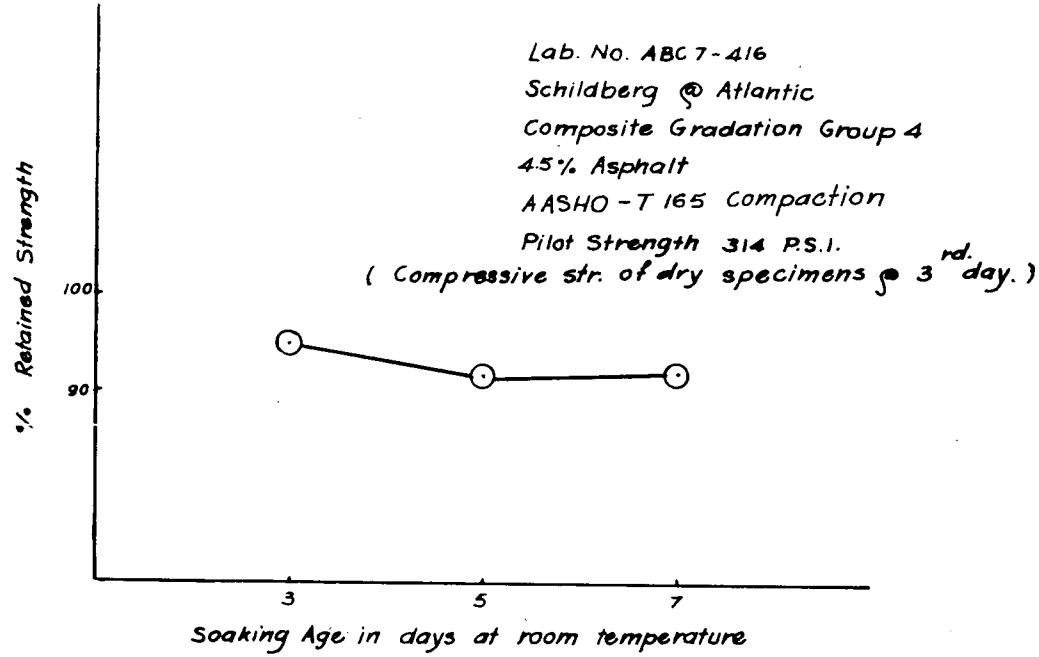

FIGURE 4

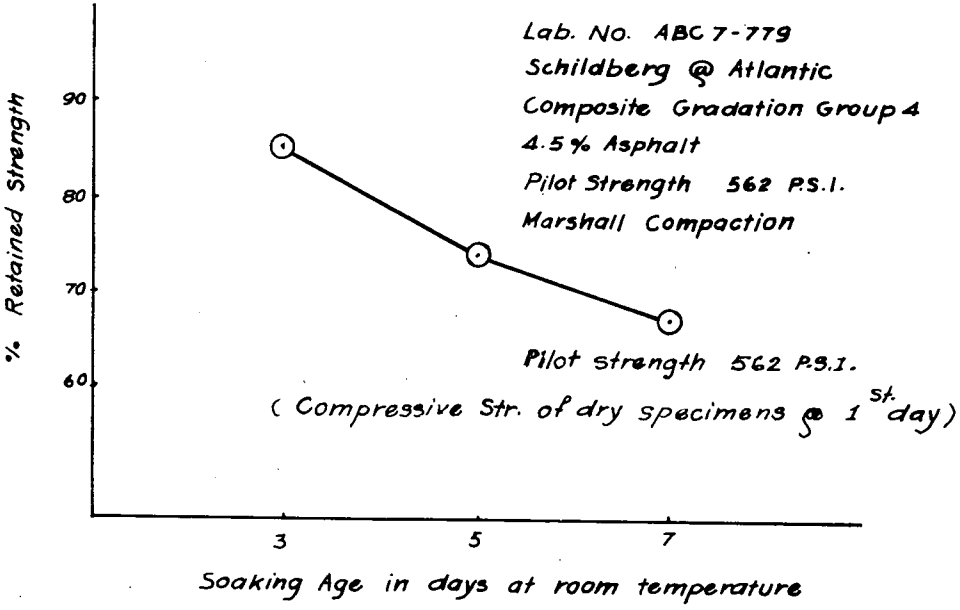

FIGURE 5