Design, Control, and Interpretation of Tests for Bituminous Hot Mix Black Base Mixtures

by

Chester McDowell
Materials and Tests Soils Engineer

and

Avery W. Smith
Supervising Soils Engineer

conducted by

Materials and Tests Division, Soils Section
Texas Highway Department

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PREFACE

There is little doubt that a great need for newer techniques and conceptions for design of "Black Base" exists, and it is for this reason that we have been doing some research over a period of several years. During this investigation, many challenges were obvious; such as,

1. Development of compaction equipment and techniques capable of fabricating large size specimens containing aggregates up to 1-3/4 inch top sizes.

2. Development of density and voids concepts capable of being placed in use for control of construction.

3. Development of strength concepts involving the effect of water, voids, and rheological properties on the compressive strength of mixtures.

It is believed that we have developed some testing techniques involving the use of a large gyratory press and some engineering concepts based on voids and strengths, which are noteworthy at this time. We recognize that our techniques are new to many, and that our experience is limited so that this is essentially a progress report. It is believed that this report establishes the need for purchase of new testing equipment for most of our District and field laboratories. Inasmuch as it takes many months to purchase and manufacture the equipment necessary, and inasmuch as evidence for the need to purchase such equipment is necessary, it behooves us to report results of our findings a little sooner than we would like to.

TABLE OF CONTENTS

ABSTRACT

Out of the research conducted by the Texas Highway Department Materials and Tests Division comes a report which gives a fresh, if not new, look at hot mix black base construction. The paper is not as well documented as the Authors would prefer, but it takes a giant step in the evolution of mix design and construction controls based on the use of an absolute or total volume of voids concept. The Authors contend that the proposed system is more realistic than those based upon academic concepts consisting of estimating the extent to which external or internal voids are filled with asphalt. It is contended that the overall physical properties of the mix is the important thing and that the amount of absorption of asphalt in the stones is accounted for in the proposed processes of testing and evaluation. These procedures also take care of the effects of presence of aggregate sizes up to the 1-3/4 inch size. An important achievement reported involves the development of a large motorized gyratory press and accessories for compacting large size specimens in one layer. It is recommended that this equipment be made available to all Districts and major field laboratories.

The report takes a look at the detrimental effects of moisture absorption upon strength and its relation to total percent voids and concludes that mixtures containing less than 5 to 6 percent total voids will usually be uneffected by absorption of moisture. The key tool used in this investigation to obtain saturation in a minimum of time is the pressure pycnometer. A number of other proposed uses of this instrument are for determination of specific gravity of

total material (raw or mixed), volumes of cores and percent asphalt of road mixes thus eliminating the need for numerous extraction tests. If extraction tests must be run, the report warns against use of small samples.

An entirely new approach is made with respect to determination and interpretation of the unconfined compression test. The determination of the effect of rate of loading upon this test is a great contribution to the understanding of the failure of slow rate of loading tests to show the benefit of asphalt in stabilizing and strengthening of aggregate mixtures. The use of the high speed testing machine helped immensely in pointing this out. The report presents a method believed to enhance the interpretation and usefulness of the unconfined compressive strength tests by plotting strengths at slow versus fast rates of loading, and determining if the mix in question falls within group designations A, B, C, or D. By use of the group designation and a tabulation appearing in the report, the usefulness of the proposed mixture as base or subbase on light, medium, or heavy traffic may be determined.

LIST OF PHOTOGRAPHS

LIST OF TABLES

LIST OF FIGURES

OBJECTIVES

The need for the treatment of such a wide variety of mineral aggregates in Texas had a strong influence upon the objectives of this investigation which are briefly summarized as follows:

1. To discover a means of fabricating large "black base" specimens containing top size aggregate up to 1-3/4 inch. Said specimens to be free from excessive degradation, planes of weakness between layers, and to be uniform in density throughout. Density of such specimens to be reproducible and as high as might be expected from rolling and carrying traffic many years.

2. To develop asphalt-voids ratio curves capable of establishing ranges of asphalt and voids contents applicable to both design and construction control in the field.

3. To formulate a type of strength test which is applicable to engineering interpretation and which depicts advantages of asphalt over water as a stabilizing agent. It was desirable that such a strength test be useful in selecting acceptable mixtures and in choosing desirable asphalt contents for use.

SUMMARY OF INVESTIGATION CONDUCTED

A brief summary of our investigation is as follows:

1. Degree of reproducibility of saturated surface dry specific gravity and use of pressure pycnometer for determination of absolute specific gravity.

2. Equipment for heating, mixing, and molding of large specimens.

3. Best techniques for mixing base material and penetration grade asphalts.

4. Molding of large specimens by use of large gyratory press, which will be uniform in density.

5. Plotting of asphalt versus density and voids so as to evaluate significance of curves.

6. The feasibility of field control of "black base" on the basis of asphalt-voids ratio curves is explored and a method proposed. This involved the comparison of voids obtained from cores or blocks to those obtained in the gyratory press. This also includes a study of the limiting sample size for accurate extraction values for coarse graded mixtures.

7. Performance of conventional unconfined compression tests and effects of moisture absorption by use of the pressure pycnometer.

8. Purchase of testing machine capable of cross head travel of 36 in./min.

9. The effect of rate of loading upon unconfined compressive strengths.

10. Interpretation of unconfined compression strength test data. This includes theoretical minimum strengths for base and subbase necessary for three types of traffic when both slow and fast loading tests are used in this analysis.

CONCLUSIONS

The results of this investigation appear to justify the following conclusions:

1. The saturated surface dry specific gravity is not sufficiently reproducible or repeatable for use in calculating voids and that absolute gravities as determined on large samples by use of pressure pycnometer are adequately repeatable for this purpose. Although there is no data in the report to substantiate it the Authors believe that good reproducibility will be obtained by use of the pressure pycnometer because the element of human judgment is eliminated.

2. That a suitable gyratory press has been constructed and a procedure presented, which is capable of molding large size aggregate samples in one layer so as to produce six inch diameter by eight inch height specimens. These specimens appear to be uniform in density from top to bottom.

3. That a means for use of total voids concepts in the design and control of "black base" has been developed.

4. A field method for control of asphalt content and voids (density) has been developed which would aid in making the use of variable sources of local granular material safe for use in construction of hot mix asphalt "black base".

5. That care should be taken in selecting adequate size samples for extraction tests.

6. That mixtures containing less than 5.5 percent total voids probably will not lose strength due to absorption of moisture.

7. Unconfined compression strengths vary greatly with changes in rate of loading tests particularly for bituminous mixtures and that a fast rate of loading test should become a part of an analysis system for asphalt mixtures.

8. An engineering concept involving the use of various types of unconfined compression tests is proposed for different quality mix categories.

DISCUSSION

In order to utilize the benefits and economy of hot mix asphalt "black base", it was necessary to develop a significant means of measuring strength and voids characteristics, which is applicable to testing nonuniform materials. The economic advantage of "black base" over other hot mixes is usually dependent upon use of local base materials, which do not have to be washed and separated into a number of sizes before batching. This can amount to as much as three to four dollars per ton difference in costs. For strength measurements to be of much value they should show advantages of the cohesion of asphalt and also the lack of adhesion due to the hydrophilic nature of some materials. Therefore, the effect of absorbed moisture upon strength must be given close attention during preliminary testing. Methods for measurement of voids must be applicable to jobsite conditions due to the variations in the uniformity of base material aggregates.

TABLE I

Inaccuracy of Saturated Surface Dry Specific Gravities

	Saturated Surface Dry Specific Gravities	
Lab. No.	Section A	Section E
62-Un-R	2.36	2.36
	2.34	2.36
60-177-R	2.37	2.33
61-151-R	2.44	2.40
	2.42	2.40
60-204-R	2.45	2.44
	2.46	2.44
62-69-R	2.69	2.70
	2.72	2.70
61-95-R	2.34	2.33
	2.30	2.33
60-222-R	2.43	2.41
	2.41	2.41
60-223-R	1.68	1.71
	1.76	1.71
	1.83	1.71
60-86-R	2.52	2.50
	2.49	2.50
60-200-R	2.60	2.52
60-277-R	2.64	2.58
61-177-R	2.58	2.58
60-174-R	2.38	2.38
61-477-R	2.37	2.02
	2.24	2.02
60-215-R	1.87	1.69
60-397-R	2.46	2.47
60-198-R	2.55	2.50

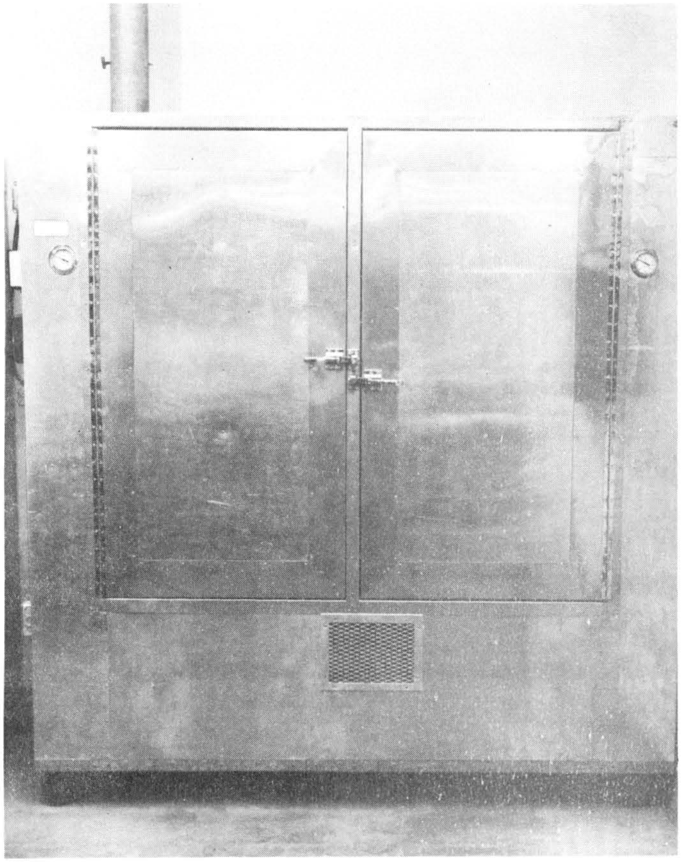
Due to the variable nature of flexible base materials, it appeared that an accurate reproducible means of measuring specific gravity was necessary. The widely used method for determination of saturated surface dry specific gravities was used in determination of the values shown in Table I by a number of operators in two sections of our laboratory.

Results of above tests indicated that we could not depend upon the reproducibility or repeatability of the saturated surface dry specific gravity test for the purpose of calculation of percent voids for black base mix design. We have used the pressure pycnometer for many years to determine the "absolute" specific gravity of soil materials containing large amounts of large aggregate. Data given in Table II illustrates repeatability of "absolute" specific gravities obtained by use of pressure pycnometer.

TABLE II

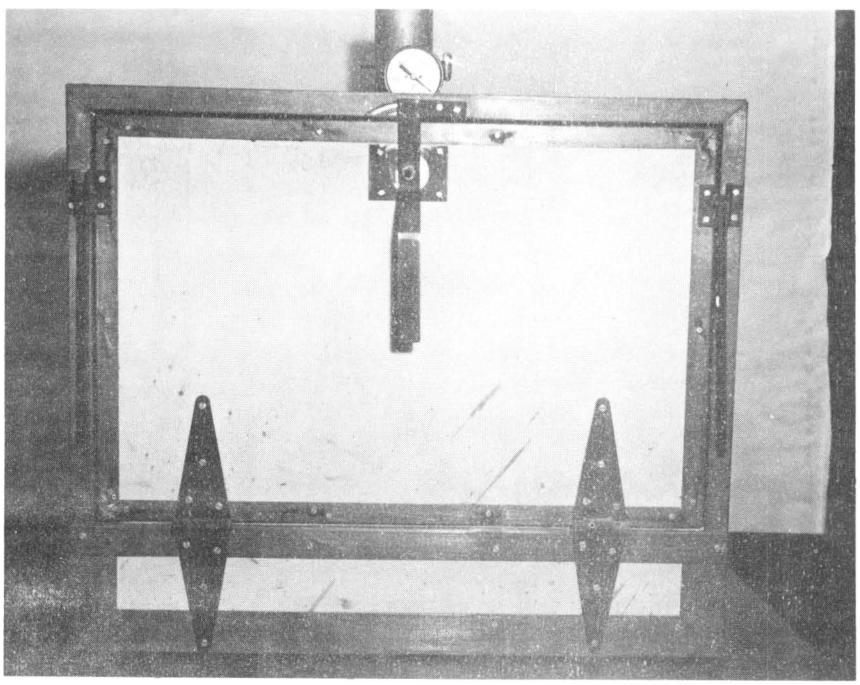
Repeatability of Absolute Specific Gravities
Determined by Use of Pressure Pycnometer

Lab. No.	Trial No.	Sp. Gr.	Sp. Gr. Used
66-154-R	1	2.747	2.74
	2	2.741	
	3	2.743	
61-154-R	1	2.715	2.72
	2	2.723	
	3	2.719	
50/50 Mixture	1	2.728	2.73
66-154-R	2	2.730	
61-154-R	3	2.730	



Photograph 1

Large Electric Drying Oven

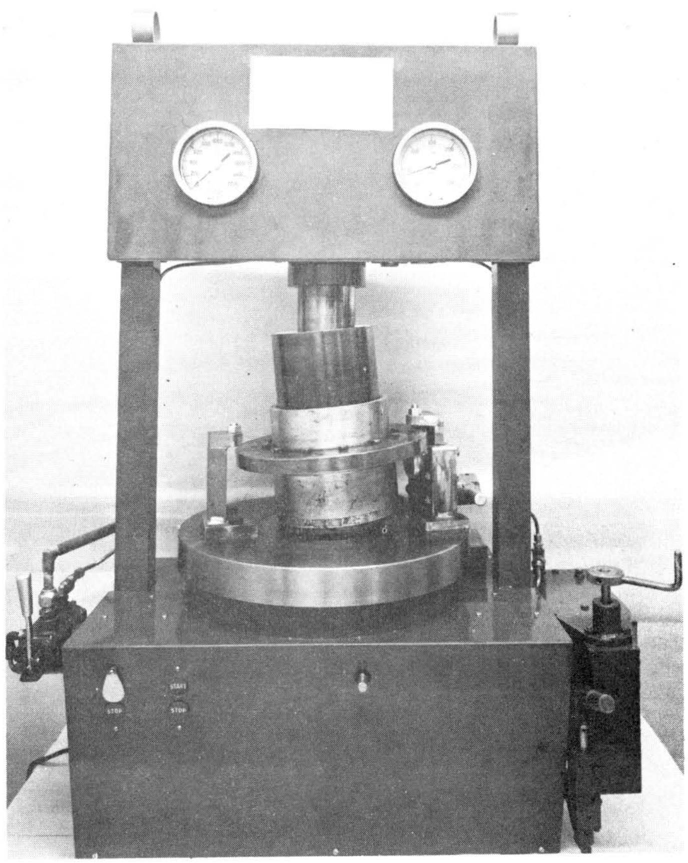


Photograph 2

Small Electric Drying Oven

Photograph 3

Large Size
Hotplate



Photograph 4

Motorized Gyratory Press
and 6 x 12 Mold

Thus it was hoped that we might be able to establish certain usable information by plotting curves relating density and total voids to percent asphalt. Before being able to utilize density and/or total voids concept, it was necessary to obtain equipment for heating, mixing, and molding of large specimens. (See photographs 1, 2, 3, and 4.) We soon found that hand made laboratory mixes differed in appearance from comparable field mixtures until we learned to add asphalt to the plus No. 10 aggregate first, and then blend in the minus No. 10 fines after the asphalt has had a chance to coat the large stones. This coating is hampered in the hand mixing of laboratory mixes because the fines blot up too much asphalt before it can be distributed on the stones. Most "black base" plant mixers do not experience much of this difficulty because the asphalt is added to a tumbling action of a well dispersed mixture of aggregate and fines.

The Texas Highway Department Materials and Tests Division requested the T H D Equipment and Procurement Division to revise existing motorized gyratory press and molds to be capable of compacting large size specimens. The success of the operation of this press is largely due to the excellent efforts and cooperation of shop personnel of the Equipment and Procurement Division.

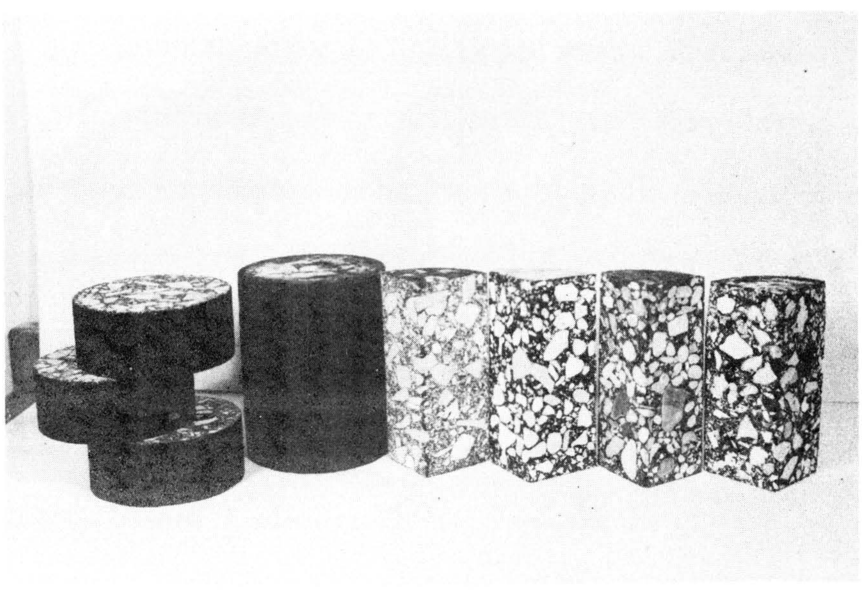
Specimens six inches in diameter by eight inches in height were molded in one layer by use of the gyratory press. (See photographs 5 and 6.) Some specimens were sawed in layers to obtain uniformity of density. (See photographs 7 and 8 for closeup views of sawed surfaces.) Data given in Table III illustrates that uniform density was obtained in all sections of specimens.

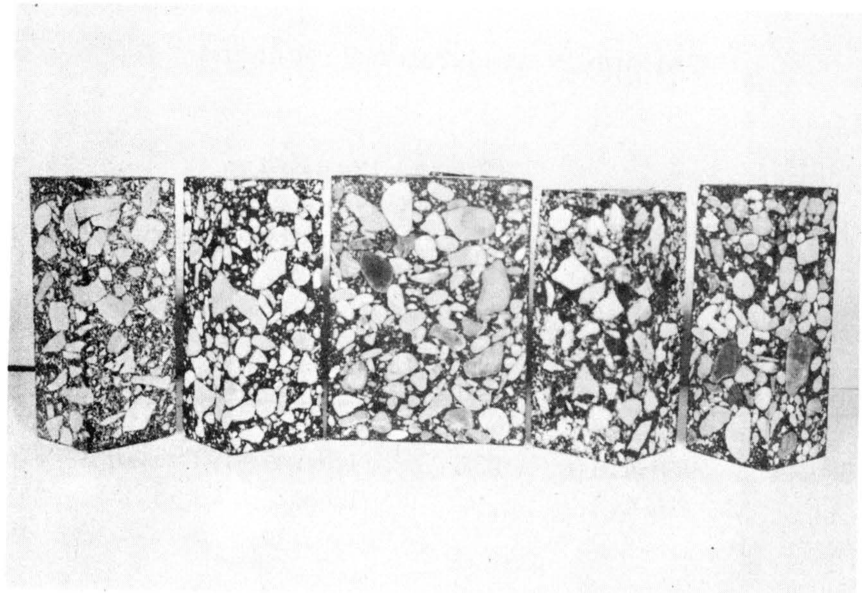
Photograph 5

Showing one of many large collections of specimens prior to discarding.

Photograph 6

Showing one whole specimen and several sawed sections of specimens.





Photographs 7 and 8 Showing close ups of sawed faces.

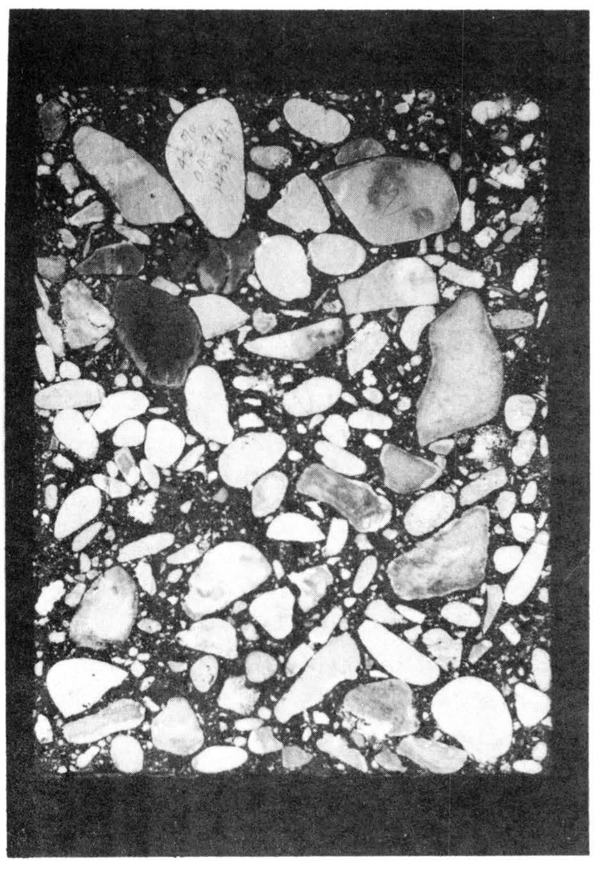


TABLE III

Uniformity of Gyrated Specimens

Lab. No.	Spec.	No.	% Asphalt	Average Density #/cf.	Paraffin Dipped Density of Sawed Spec. #/cf.**	Pressure Pycnometer Density of Sawed Specimen*	Location in Specimen
61-154-R	5	T	4.1	156.3	155.4	156.6	Top third
		M	4.1		154.3	156.2	Middle third
		B	4.1		154.8	156.1	Bottom third
61-154-R	6	T	4.1	156.2	154.7	156.5	Top third
		M	4.1		154.4	156.1	Middle third
		B	4.1		154.6	156.0	Bottom third

Molding of the above specimens and subsequent specimens shown in this report were compacted in accordance with the test procedures given in the Appendix. All indications are that we have selected a rather high compactive effort for use. This was done purposely for the following reasons:

1. High compaction efficiency produces density and voids conditions, which are more accurately reproducible in the laboratory. Application to field conditions will be discussed subsequently.

*Unless filled with paraffin or other suitable material, the side voids from imperfections, slaked or missing aggregates will not be included in the volume of specimen. This should be done to avoid too high values. Not done in this case, except specimen 5M which had a slightly rough periphery and a density of 157.2 p.c.f. uncoated. Side voids, filled with paraffin, should be trimmed smooth, leaving a minimum of paraffin.

** AASHO T-166.

2. The use of high efficiency compaction procedures helps avoid selection of mixtures which may produce rutting under traffic.

A typical plotting of density in pounds per cubic foot versus percent asphalt is shown in the upper portion of Figure 1 and the shape of a typical curve relating percent asphalt to percent total voids is shown in the lower portion of Figure 1.

Linear Portions A of the curves in top and bottom of Figure 1 show that voids are being reduced by compaction and by addition of asphalt. The B portions represents a condition where increases in asphalt are reducing voids but no change in density of aggregate occurs. The C portion of the curves represents a condition of overlubrication inasmuch as density of aggregates are decreasing. Figure 2 shows the results of molding many specimens for a number of widely varying materials, such as gravel, crushed stone, caliche, and sandy soil. (See Table IV for gradation and soil constants.) It may be noted that the asphalt-voids ratio (AVR) curves for each material consist of similar shapes but occupy different positions on the chart. It may be noted that the fifty-fifty blending of 66-154-R and 61-154-R produced an AVR curve situated half way between individual AVR curves. An overlubrication base line drawn at an angle of 45° with the horizontal through the "fat point" of the AVR curve separates most low strength specimens usually below 45 psi from the stronger ones appearing higher to the left on the chart. As evidence of the sensitivity of the AVR curves, we have noted a shift of the curve when small changes of amount of fines occurs. The two left hand curves in Figure 2 are separated by

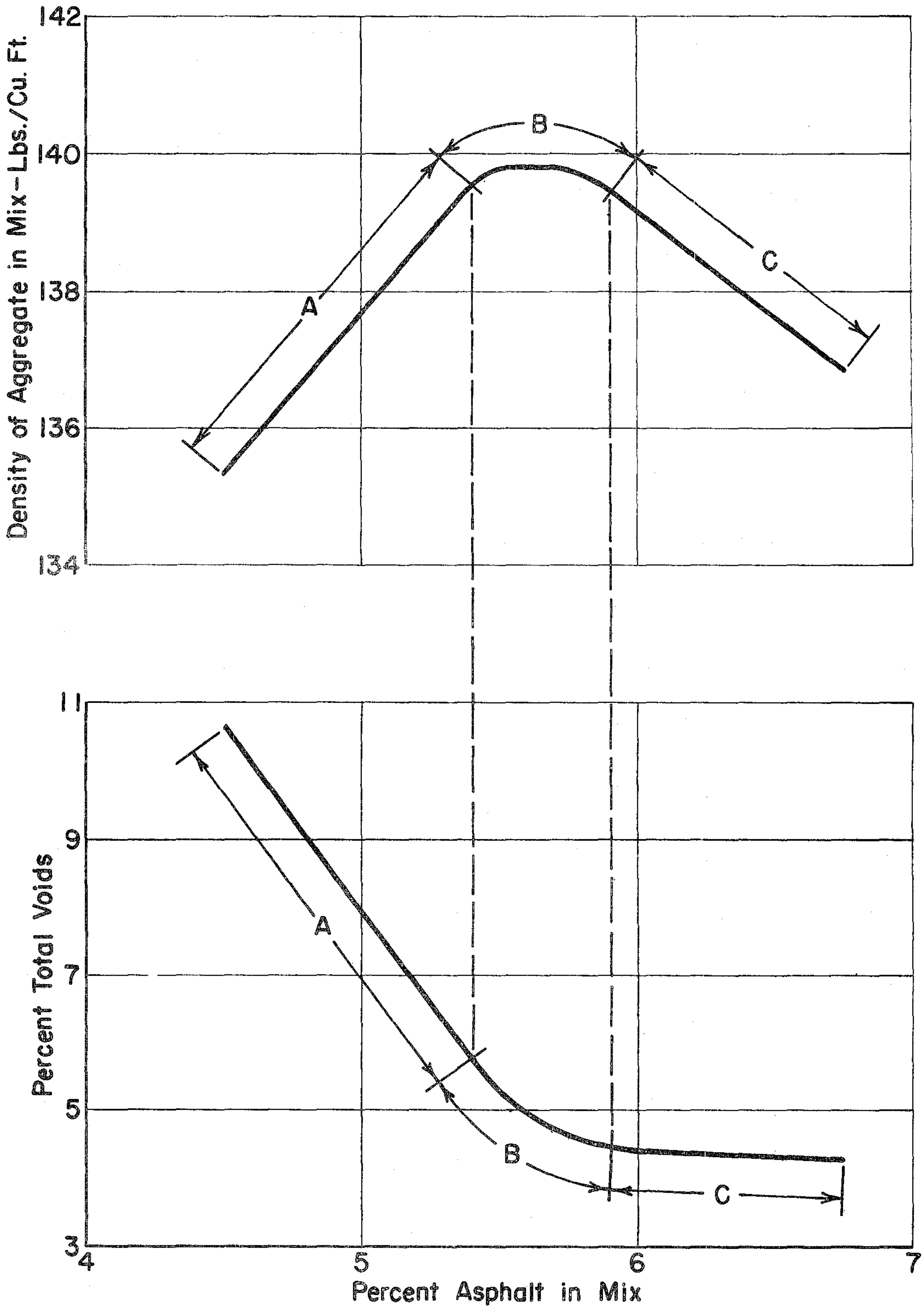


Figure 1, Compaction Characteristics of Hot Mix Black Base Mixtures

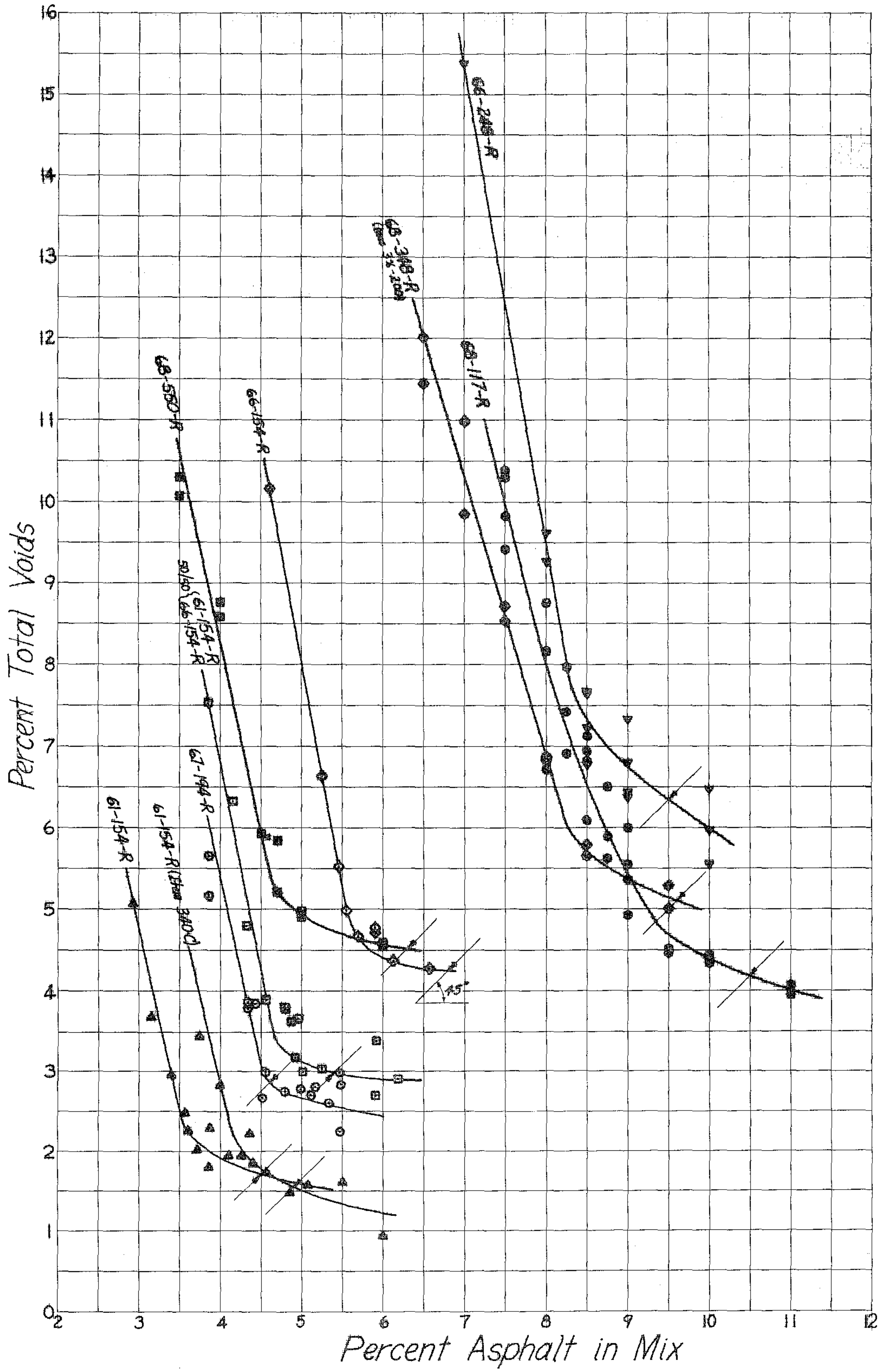


Figure 2
Typical Asphalt-Voids Ratio Curves for Several Types of Soil-Aggregate Materials

approximately 1/2 of one percent asphalt because removal of some fines from good aggregate made room for more asphalt. Other AVR curves run on caliches containing high amounts of fines caused the AVR curve of the gradation containing only three percent less minus No. 200 to be shifted to the left approximately 1/2 percent asphalt rather than to the right as mentioned above.

In order to compare the void contents obtained in the gyratory press with those obtained from rolling, a few cores or blocks were taken from completed sections after rolling. These results are shown in Figure 3, and it appears that good field rolling on the average may be expected to produce anywhere from zero to five percent more voids than are obtained by use of the gyratory press.

PROPOSED USE OF AVR CURVES

In order to obtain best use of AVR curves, the following procedure is proposed:

1. By use of procedures shown in the Appendix, run out a curve relating percent total voids to percent asphalt. As an example, see solid line curve as shown in Figure 4.

2. By use of unconfined strength test, evidence of flushing, slump, etc., choose the "fat point" or maximum percent asphalt (6.4% in this case), then on the basis of a tolerance of 5% additional voids, choose a minimum of 4.8% asphalt.

TABLE IV

Soil Constants and Gradations of Raw Soil-Aggregate Materials

Lab. No.	LL	PI	SL	LS	SR	Soil Binder	W B M % Loss
SOILS TESTED FOR SATURATED SURFACE DRY GRAVITIES							
60-86-R	29	10	18.8	5.6	1.80	28	40
60-174-R	28	9	19.6	4.3	1.73	23	36
60-177-R	20	4	16.8	2.4	1.83	19	36
60-198-R	25	4	20.0	2.6	1.67	37	-
60-200-R	23	4	21.0	.9	1.62	39	-
60-204-R	26	5	21.0	2.7	1.65	33	49
60-215-R	40	5	31.4	3.4	1.39	31	58
60-222-R	23	5	17.0	3.3	1.78	19	31
60-223-R	48	18	34.0	6.1	1.35	34	60
60-277-R	28	14	14.6	7.1	1.91	19	26
60-397-R	24	9	16.4	4.1	1.89	18	30
61-95-R	24	7	16.5	4.3	1.85	26	40
61-151-R	25	6	17.6	4.1	1.76	27	41
61-177-R	32	17	13.0	9.6	1.93	28	37
61-477-R	33	6	24.0	4.2	1.55	19	31
62-69-R	15	2	12.8	1.8	1.85	47	-
GYRATED SOIL MATERIALS							
61-154-R	25	12	14.3	6.3	1.94	21	29
66-154-R	21	4	18.6	2.2	1.83	27	37
66-248-R	25	5	20.8	2.3	1.69	96	-
67-194-R	20	5	15.7	2.2	1.85	22	32
68-117-R	35	8	28.1	3.2	1.55	26	45
68-348-R	37	10	27.9	4.5	1.54	19	-
68-550-R	30	12	20.7	4.8	1.73	24	-

PERCENT RETAINED ON

Laboratory No.	Round Opening Screens, Opening in Inches									Square Mesh Sieves, Sieve Numbers						Grain Diam. In Millimeters			Spec. Grav.	Material
	3½	3	2½	2	1½	1	¾	½	¼	10	20	40	60	100	200	.05	.005	.001		
60-86-R				0	4	15	25	37	50	62	68	72	74	76	78	79	89	96	2.80	Crushed Stone
60-174-R				0	11	30	39	48	59	69	74	77	79	81	89	90	95	97	2.71	Crushed Stone
60-177-R			0	3	12	29	39	50	64	75	78	81	83	85	87	88	94	99	2.72	Crushed Stone
60-198-R				0	3	8	13	19	32	49	58	63	-	-	-	-	-	-	-	Sand-Shell
60-200-R				0	2	7	11	17	30	49	58	61	-	-	-	-	-	-	-	Sand-Shell
60-204-R			0	3	8	28	36	43	53	62	65	67	68	69	88	89	94	97	2.69	Crushed Stone
60-215-R			0	2	10	23	30	40	52	63	66	69	71	80	90	91	97	98	2.70	Crushed Stone
60-222-R			0	4	14	33	41	49	61	73	77	80	82	85	90	91	96	98	2.71	Crushed Stone
60-223-R			0	2	8	19	27	39	52	61	64	66	69	76	87	88	94	96	2.69	Crushed Stone
60-277-R				0	1	9	21	35	47	66	76	81	84	86	88	89	94	97	2.73	Crushed Stone
60-397-R				0	13	31	36	44	57	69	77	82	84	87	89	90	94	97	2.69	Crushed Stone
61-95-R				0	8	18	27	38	52	65	70	74	76	78	81	82	91	97	2.70	Crushed Stone
61-151-R			0	1	19	42	51	58	63	68	71	73	74	76	89	90	95	-	2.67	Crushed Stone
61-177-R				0	9	31	41	50	59	66	70	72	74	76	79	80	88	94	2.66	Cr. Stone Sub-base

Laboratory No.	Square Mesh Sieves, Opening in Inches								Square Mesh Sieves, Sieve Numbers							Grain Diam. In Millimeters			Spec. Grav.	Material
	3	2½	2	1¾	1¼	7/8	6/8	3/8	4	10	20	40	60	100	200	.05	.005	.001		
61-477-R				0	4	14	24	39	57	74	78	81	83	87	91	92	96	-	2.60	Crushed Caliche
62-69-R								5	33	49	50	53	59	69	82	85	95	96	2.59	Iron Ore
61-154-R				0	11	19	27	38	50	61	73	79	82	84	86	88	95	97	2.72	Cr.St.flex ba.
66-154-R				0	10	18	26	37	51	63	70	73	75	78	80	82	95	98	2.81	Cr.St.flex ba.
66-248-R										0	1	4	25	68	77	79	84	87	2.67	Subgrade Soil
67-194-R				0	9	21	36	52	63	69	73	78	83	87	90	90	95	99	2.71	Cr.gravel flex ba
68-117-R					0	19	26	38	53	61	69	74	77	81	88	90	96	99	2.67	Cr.Caliche fl.ba.
*68-348-R				0	5	22	35	47	61	70	77	81	84	88	92	92	97	98	2.64	Cr.Stone flex ba.
68-550-R					0	2	12	27	45	61	71	76	79	81	83	84	93	97	2.68	Cr.Stone flex ba.
61-154-R Item 340·Type C						0	2	25	45	63	-	75	-	-	96					Cr.Stone

* 3% of weight total material removed from -200 before gyration.

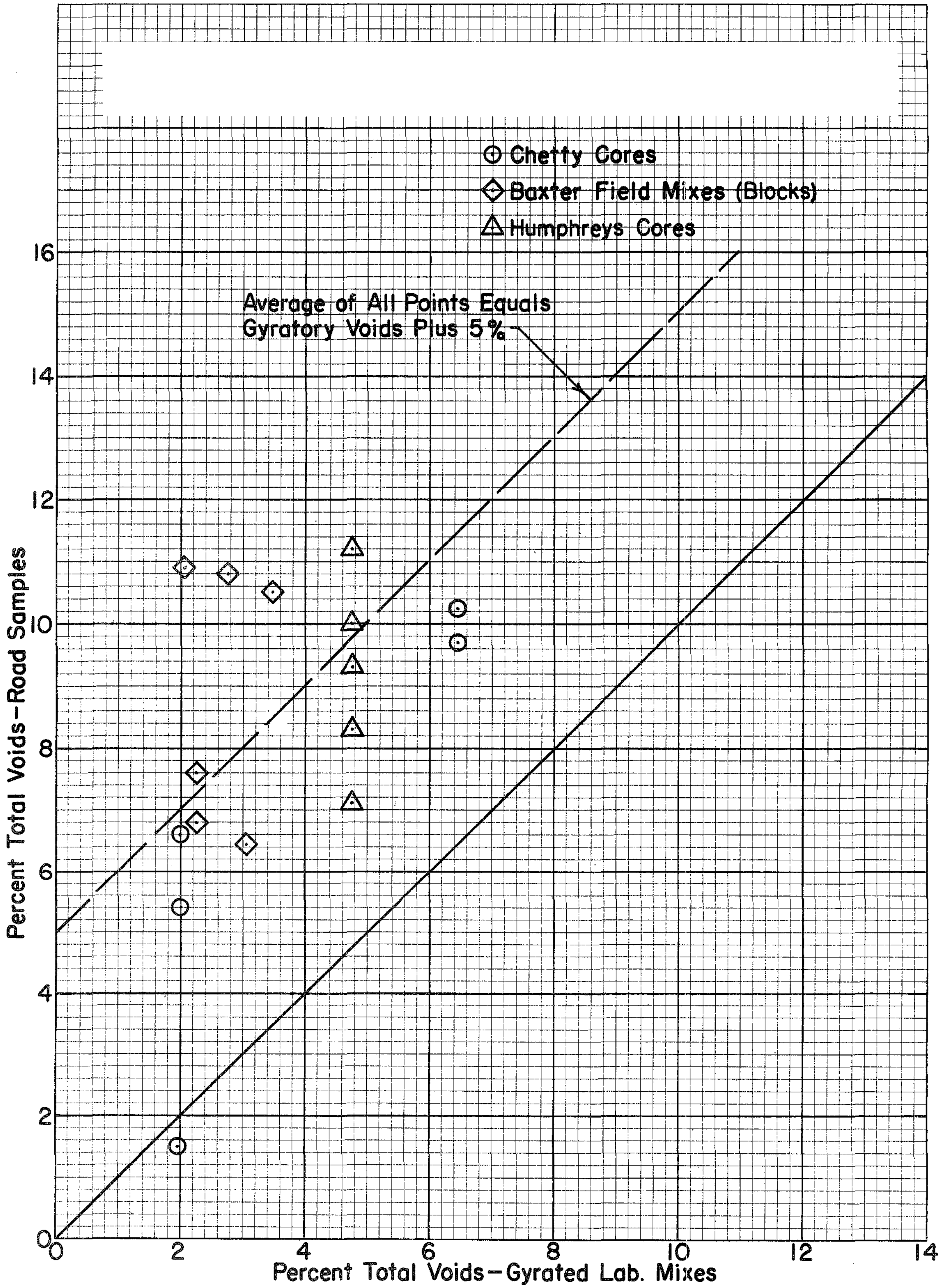


Figure 3, Comparison of Total Voids of Gyrated Mixtures with Road Sample Voids

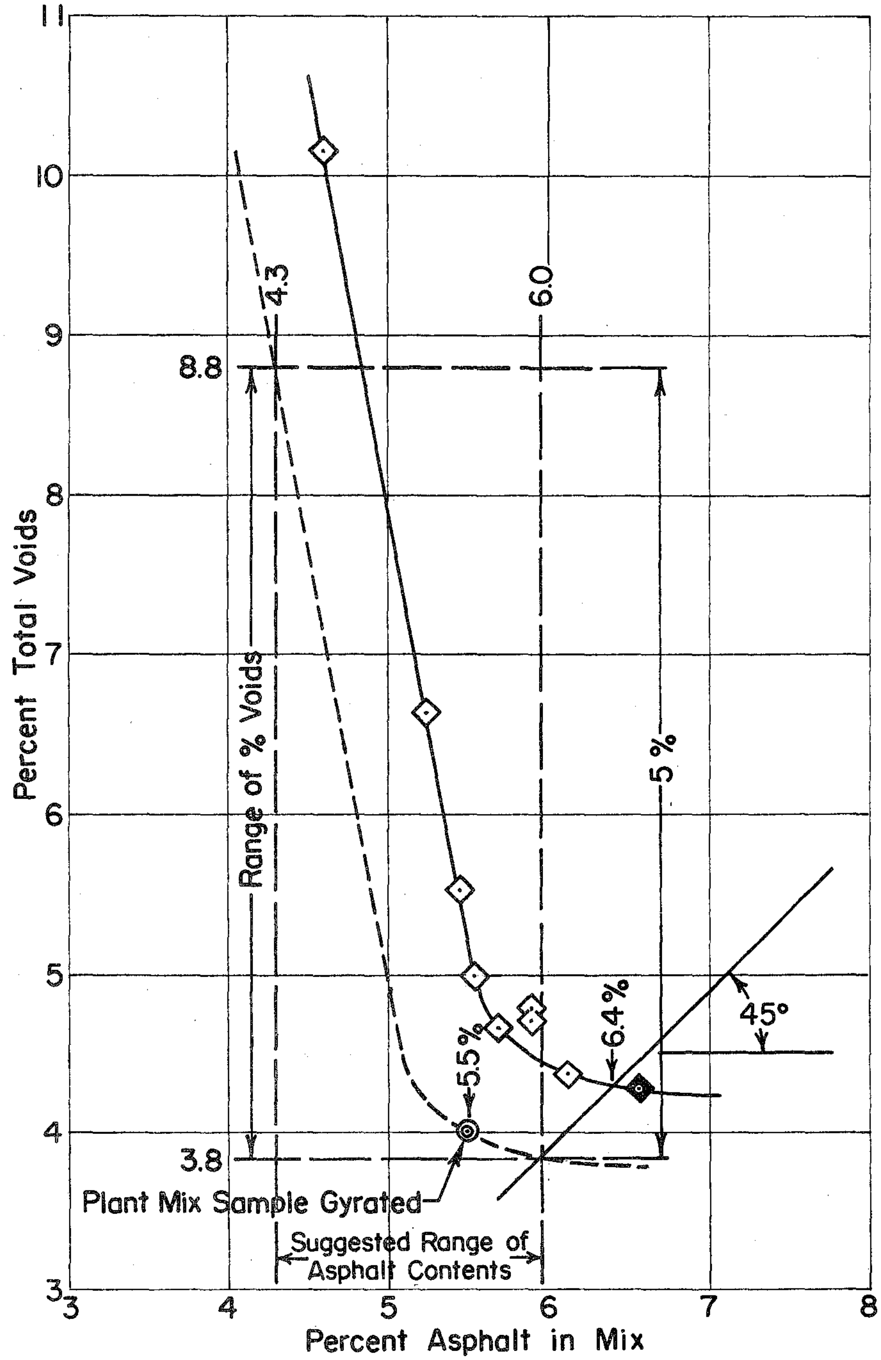


Figure 4, Asphalt-Voids Ratio Curve for Mixture and Voids Control

3. Let us assume that a contractor believes his material will be some cleaner than the sample tested to obtain original AVR curve and that he should start using 5.5% asphalt.

4. Take a sample from the plant mix, keep it hot, and mold in the gyratory press using procedure shown in Part IV of the Appendix.

5. By use of previously known specific gravities, calculate percent total voids and plot on Figure 4. Note, if specific gravity of the mix is unknown, it can be determined by use of the pressure pycnometer using the procedures set forth in Part III of the Appendix. Delete step 2. If percent asphalt is unknown, it may be necessary to perform other tests. (See notes at conclusion of this chapter.)

6. Construct another AVR curve parallel to the preliminary design AVR curve and passing through the point obtained in step 5. See Figure 4.

7. Construct an overlubrication base line 45 degrees with the horizontal and passing through the maximum percent for use (6.4% asphalt on the preliminary AVR curve in this example).

8. Where the new AVR curve (dashed line) intercepts the overlubrication base line, draw a vertical line extending upward to 5 percent voids above the intersection mentioned. It appears that the range of voids in the road in this instance should be between 3.8 and 8.8 percent. (See subsequent notes relative to obtaining percent voids in roadway.)

9. In the example in Figure 4, a horizontal line is drawn at the voids content of the overlubrication base line intersection plus 5 (8.8% in this case) until it intersects the new dashed AVR curve. This intersection is believed to represent the minimum percentage of asphalt practical for use.* If this minimum percentage contains over 5.5% voids, it should be checked by running strength tests on pressure wetted samples. See subsequent chapter on strength of "black base" mixtures. If the lean mixtures are hydrophilic, it might be that the minimum asphalt content shown would have to be increased and the maximum allowable percent voids lowered.

NOTES: There are perhaps several ways in which roadway voids or densities might could be obtained but perhaps coring is one of the methods usually preferred. For black base we prefer to work with smooth six inch diameter cores. The volume of such cores can be determined by use of the pressure pycnometer on cores which have been pressure wetted previously with the pressure pycnometer. Steps 4 through 15 of Part III in the Appendix should be used for this volume determination, and the use of a plastic bag will not be helpful. If large voids in the vertical faces of cores are apparent, the pressure pycnometer displacement volume may need to be supplemented in an amount obtained by filling void holes of the vertical walls with paraffin. If the percent of road mixtures is uncertain, the percent asphalt may have to be determined by extraction, or if specific gravities of separate ingredients are known, the percent asphalt may be determined by obtaining specific gravity of the mixture and calculating it by use of the following formula.

*See Recommendation No. 9.

$$\text{Percent Asphalt} = \frac{100\, G_2\, (G_1 - CG)}{CG\, (G_1 - G_2)}$$

Where: G_1 = Specific gravity of soil

G_2 = Specific gravity of asphalt

G_3 = Specific gravity of combined materials.

If extraction tests are to be used, cores should be taken to extract enough material to be representative. When we encountered this problem, we decided to extract split portions of a large sample of known asphalt content until all of the known batch was extracted. The following results were obtained and are given in Table V.

From Table V data, it can be seen that for materials containing large size aggregate, the extraction values for the normal size samples can be terribly erratic.

In the case of Figure 4, it is believed that the adjusted AVR dashed line will usually shift to the left of the original preliminary AVR curve but it is possible for it to go either left or right. It is also believed that most roadway voids values from rolling will fall to the right of the adjusted dashed AVR curves. Within a limited range of asphalt, percent voids and percent asphalt are interchangable.

TABLE V

Variability in Asphalt Content Obtained from Extracting Small Portions of Samples Containing Coarse Aggregates

Lab. No.	Field Mix. No.	Sta. No.	Spec. No.	Incre-ment No.	% Asphalt Extracted	% Asphalt in Mix**
67-194-R	1	739 + 00	2	1	3.7	4.8
				2	5.2	4.8
				3	4.4	4.8
				4	6.4	4.8
				5	4.5	4.8
67-194-R	2	737 + 00	2	1	4.2	4.4
				2	3.7	4.4
				3	8.0	4.4
				4	3.0	4.4
				5	2.9	4.4
67-194-R	3	736 + 00	1	1	4.2	4.5
				2	6.0	4.5
				3	4.2	4.5
				4	4.1	4.5
				5	4.4	4.5
67-194-R	4	717 + 17	1	1	6.5	4.6
				2	4.5	4.6
				3	4.1	4.6
				4	3.7	4.6
67-194-R	5	716 + 00	1	1	6.0	4.6
				2	4.9	4.6
				3	3.7	4.6
				4	3.2	4.6
67-194-R	6	715 + 43	1	1	5.7	5.0
				2	5.8	5.0
				3	4.2	5.0
				4	4.4	5.0
67-194-R*	Lab. Mix				5.0	4.5 (Added)

Field mixes 1 through 6 molded into 6" x 8" specimens, broken up and sampled in either 4 or 5 "equal" samples for extraction.

*Specimen broken up and sampled with sample splitter for extraction.

**On basis of total specimen extracted.

Control checks of voids in the compacted roadway probably should be made daily or as often as the properties of the mix are changed. It may be that cutting of cores will not be the only means of control. We understand that the State Highway Department of Washington has used air meters for similar control indicator tests.[1]

STRENGTH TESTS FOR BLACK BASE MIXTURES

In this investigation, every effort was made to examine strength properties in conjunction with the void characteristics discussed in previous portions of this report. This is because we do not believe that voids alone are sufficient information upon which to base many necessary engineering judgments. Since the unconfined compression test has been used successfully in conjunction with triaxial control of production of base materials, and inasmuch as it is fairly simple to perform, it was selected for use in this investigation. This test was used to help determine the fat point or maximum percent asphalt, the effect of moisture, and the effect of rate of loading.

For most materials, the fat point can be determined by the combined use of the shape of AVR curves, and an unconfined compressive strength of 45 psi; however, there are some harsh aggregate mixes containing high percentages of asphalt that will not drop to 45 psi, but they will show evidence of flushing and/or slumping under their own weight at 140^{o} F.

[1] "Washington's Experience on Thick Lift Construction of Asphalt Concrete with Pneumatic Breakdown Compaction" by R. V. LeClerc. Published in Volume 36 Proceedings of the Association of Asphalt Paving Technologists.

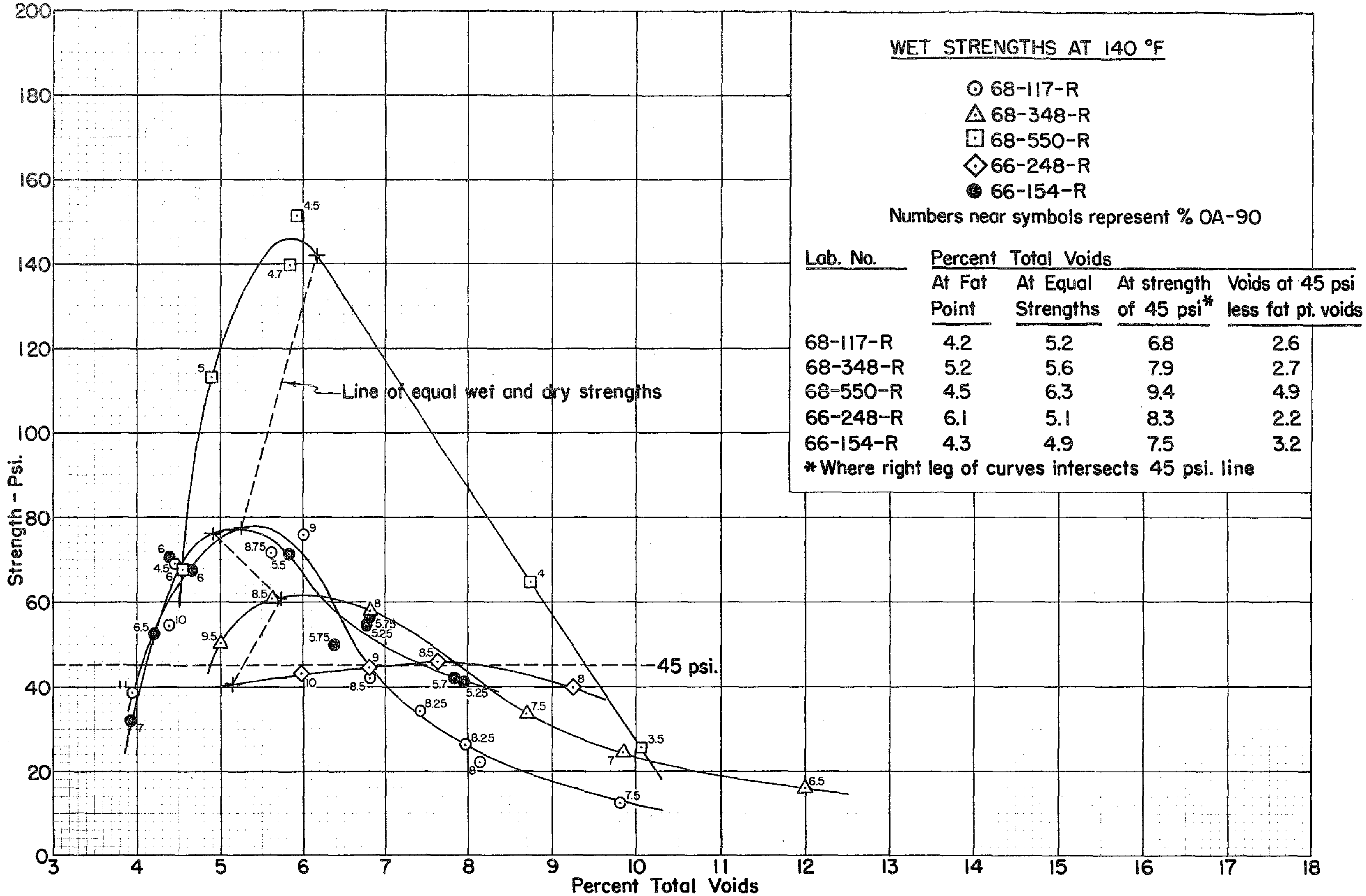


Figure 5, Relation on Percent Voids to Effect the Absorption on Strength

To be economical in the use of black base, it is necessary to use many types of base and soil materials; therefore, it is essential that we guard against the use of mixtures that are poorly waterproofed. To do this within a reasonable time, we have selected the pressure pycnometer for wetting unconfined compressive strength specimens. By testing both wetted and nonwetted specimens in compression, the loss of strength due to wetting can be observed. The method for pressure wetting of specimens is given in Part III of the Appendix. Figure 5 shows the effect of pressure wetting upon several different materials combined with various percentages of asphalt. It may be noted that the data shown in Figure 5 indicate that mixtures containing less than 5 to 6 percent total voids are little effected by absorbed water, and that some of the lean mixtures have less than 45 psi compressive strength when wetted.

All points for mixtures appearing to the left of the heavy dashed line in Figure 5 (containing less than 4.9 to 6.3% voids) were not effected detrimentally by absorption of moisture. Dry strengths of duplicate mixes are shown in Figure 6. Figure 5 indicates that mixtures may contain from 6.8 to 9.4 percent voids before strengths drop to 45 psi, due to the effects of absorbed moisture, depending upon the type of each mineral aggregate used. Generally mixtures containing less than 5.5% voids probably do not need to be investigated for the effects of moisture upon strength. The tabulated data in Figure 5 indicate that the total voids content may be from 2.2 to 4.9 percent higher than those of the "fat point" before questionable strengths at 140^{O} F. are obtained. Since road bases seldom, if ever, reach 140^{O} F. the extra 5 percent voids tolerance proposed earlier in this report is reasonable; however, this should be verified for

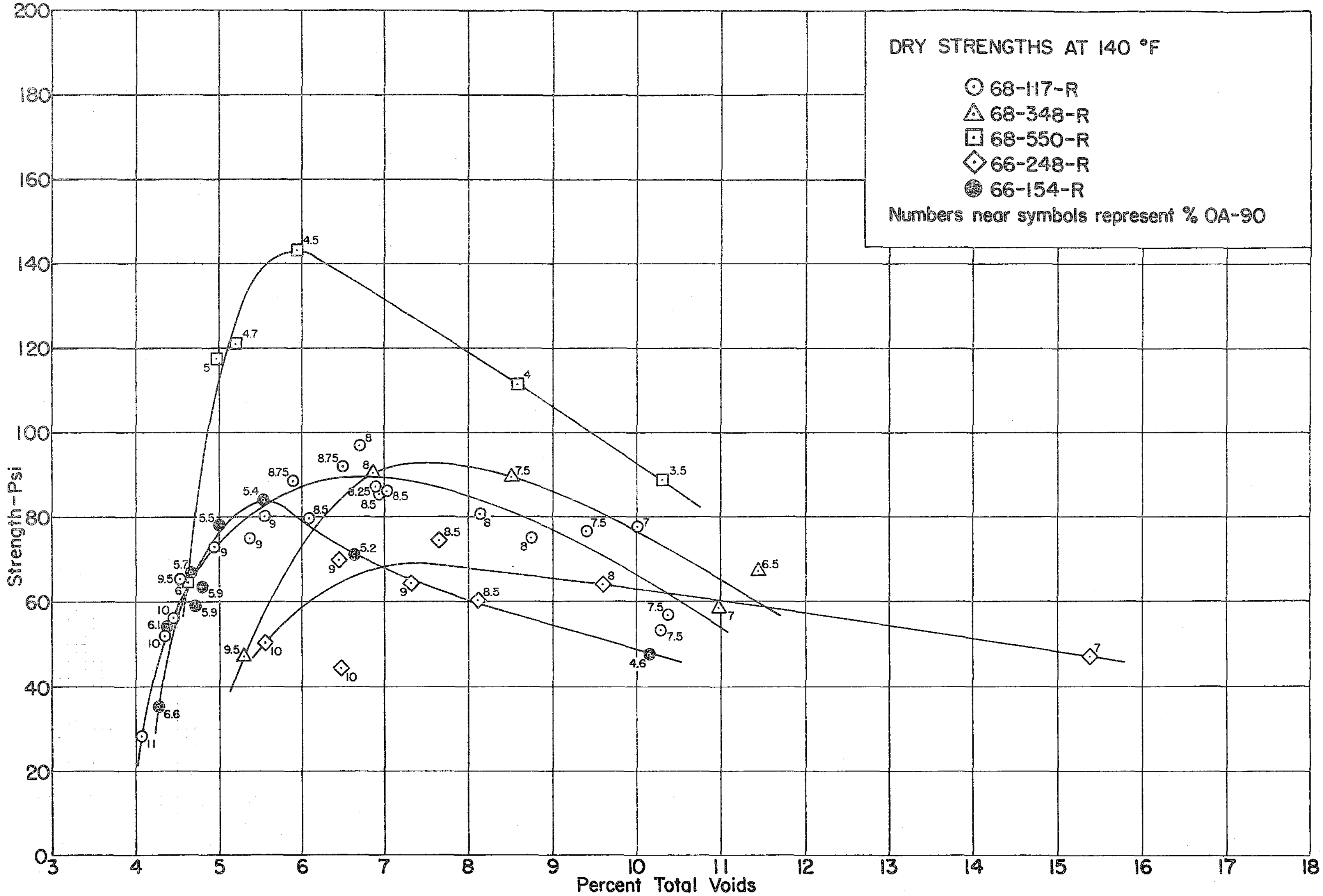
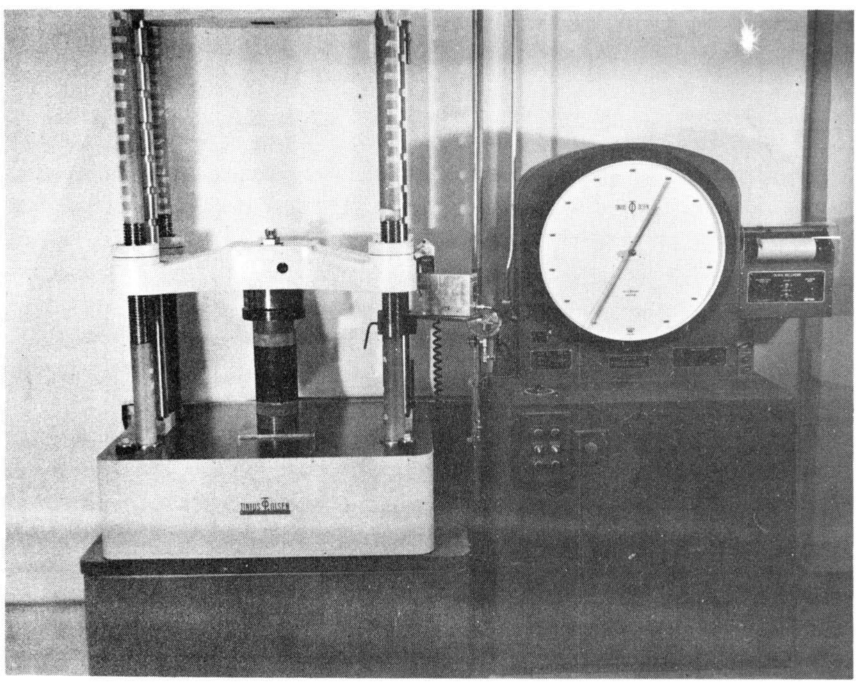


Figure 6, Relation of Percent Voids to Unwetted Strength each material proposed for use.

Up until now all statements in this report relative to unconfined compression tests have reference to a conventional type of compression test where the rate of travel of the cross head is about 0.15 in. per minute. It has been observed many times that this type of test for some materials fails to register any improvement for mixes containing asphalt over those containing no asphalt. It was believed that conventional or slow rate of loading tests failed to recognize the advantage of the cohesive attraction of a viscous liquid like asphalt to aggregates. It was for this reason that we decided to purchase a high speed testing machine shown in photograph 9. The machine has a capacity of 60,000 lbs. when performing slowly, but of lesser capacity when testing at faster rate of loadings up to 36 in. per minute.



Photograph 9

Showing high speed testing machine

The data obtained from specimens of many identical mixtures tested at various rates of loading at 140^{o} F. are shown in Figures 7, 8, and 9. Figure 7 shows results obtained for a stabilized gravel and Figures 8 and 9 show results obtained when tests were run on good crushed stone base materials. From the results shown, it must be concluded that the conventional compression tests (shown at left edge of charts) not only fail to show the benefits of asphalt treatment over water bound mixes, but sometimes shows a loss of strength when comparing the treated with the untreated. Figures 7, 8 and 9 show results of water bound or untreated granular materials when molded at 13.26 ft. lbs. per cu. in. compactive effort and moist-cured by capillary wetting before testing. (See AASHO Method 212-T.) There is also another line on Figure 7 which depicts the strength characteristics of untreated gyrated samples. Although the gyrated specimens were considerably weaker, their densities were several lbs./cu. ft. higher than those obtained by use of the 10 lb. rammer dropped 18 in. The reason for this inconsistency is believed to be due to the establishment of shear planes during gyratory molding. We do not believe these planes develop during gyratory molding of bituminous mixes. The finding suggests that gyratory molded samples of untreated soil materials should not be used in compression tests and that "over rolling" may be injurious to some untreated flexible base materials. It may also be noted that when testing is done at fast rates of loading that a definite improvement in compressive strength of asphalt treated materials over untreated materials was obtained. It was interesting to note that mixtures containing optimum asphalt contents (based upon shape of AVR curves) developed the maximum or greatest strength although this was not

67-194-R

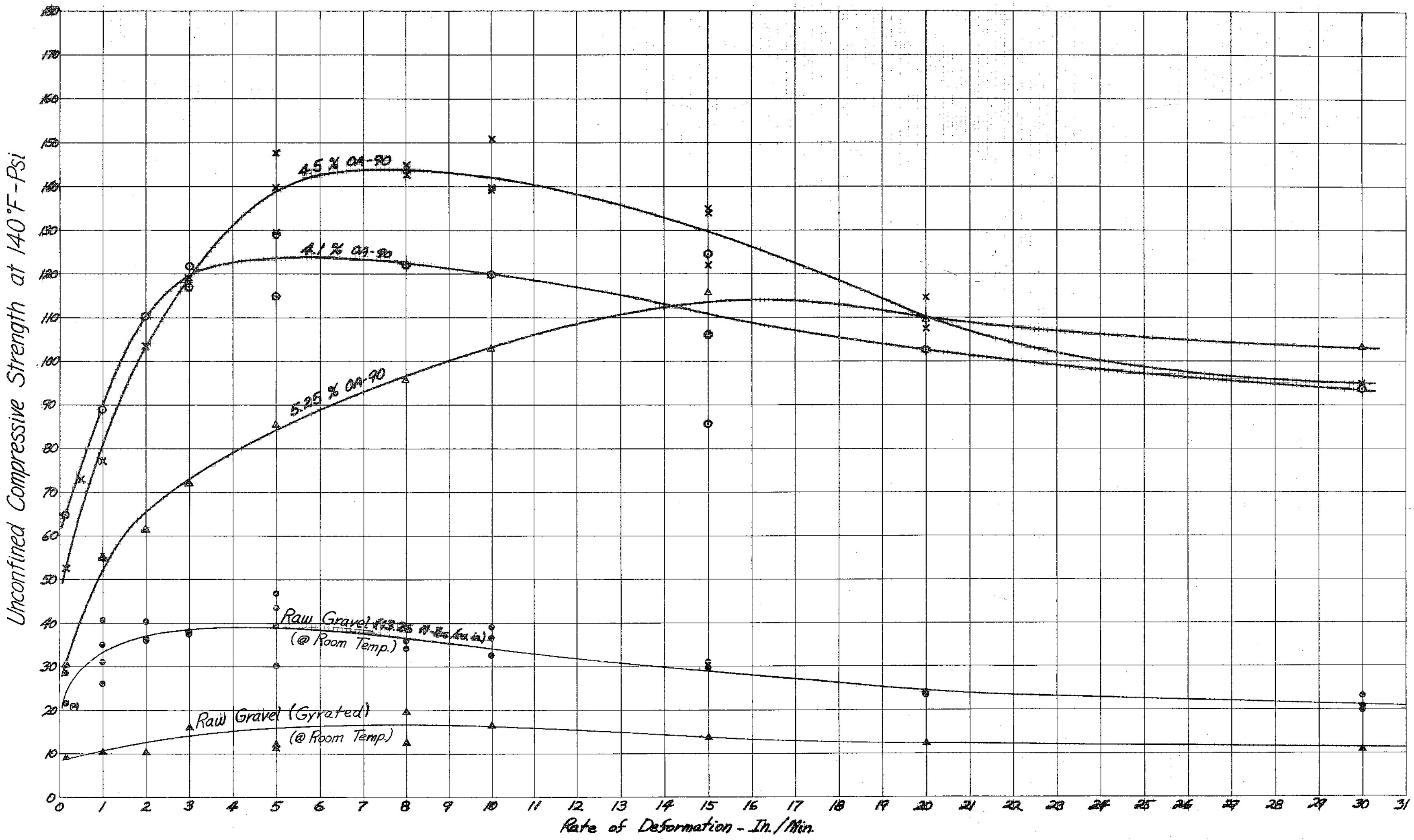


Figure 7, Effect of Rate of Loading Upon Strength of Gravel Mixtures

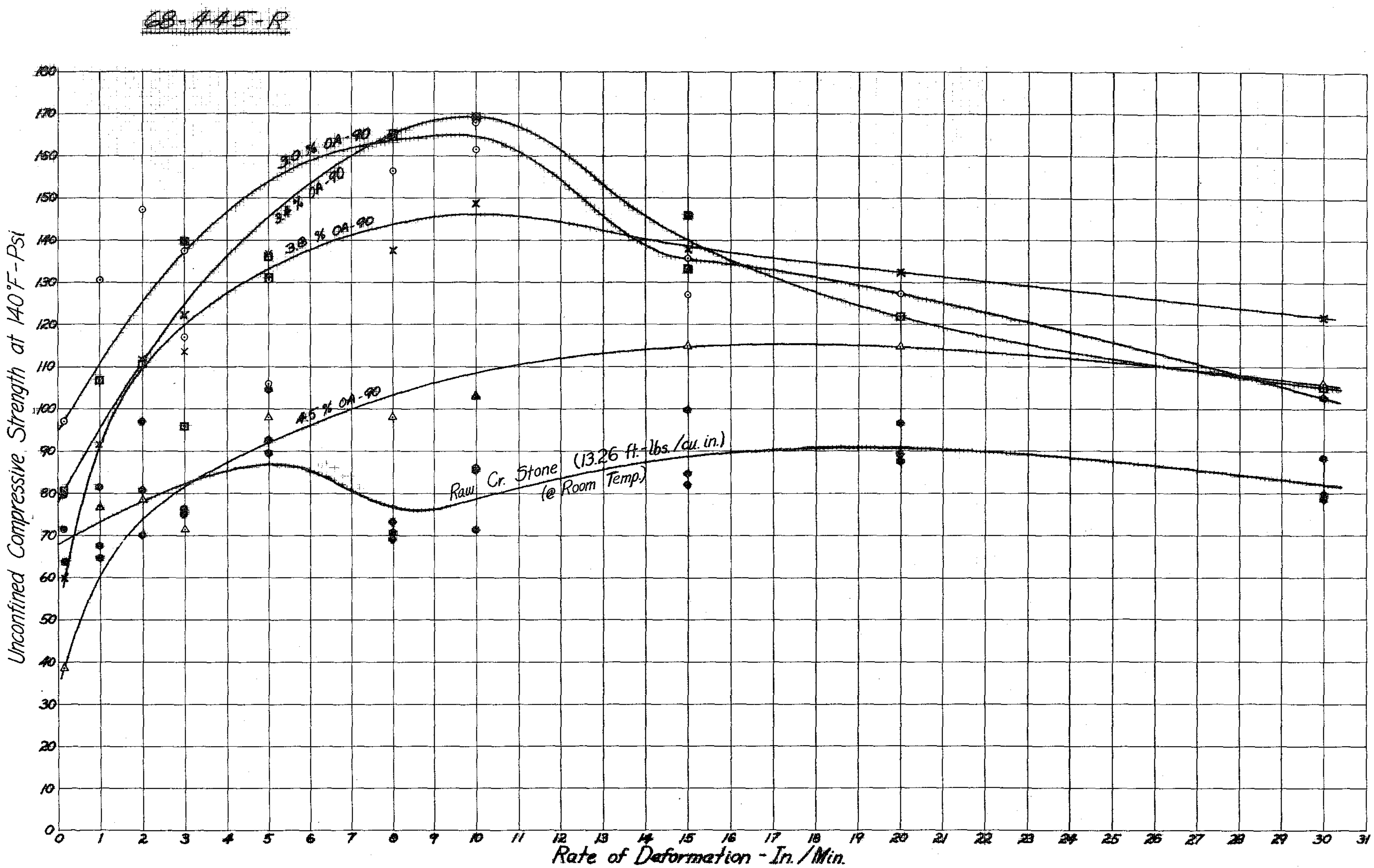


Figure 8, Effect of Rate of Loading on Strength of Crushed Stone Mixtures

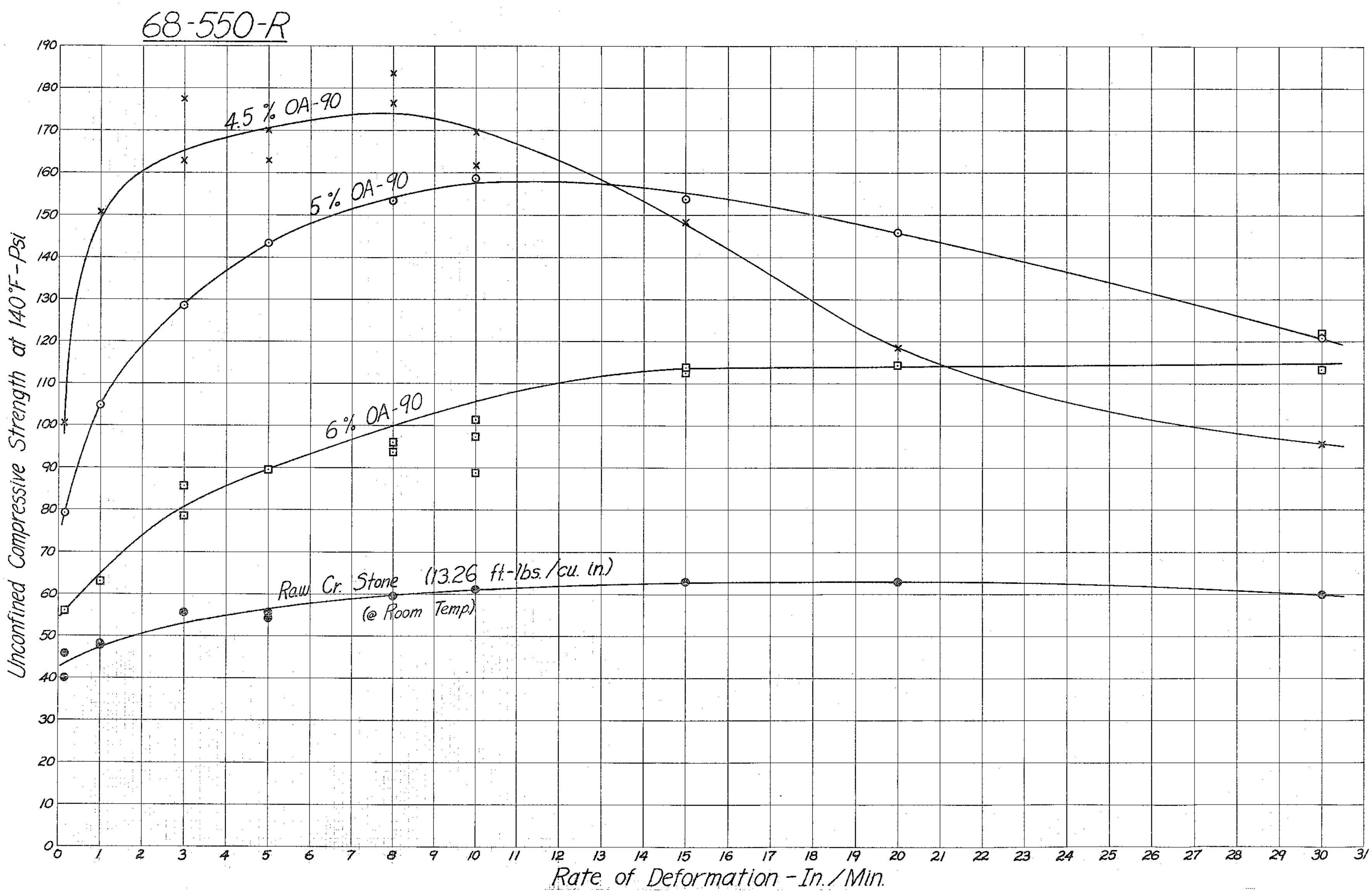


Figure 9, Effect of Rate of Loading on Strength of Crushed Stone Mixtures the case when tested at slow rates of loading. These maximum strengths usually occurred at rates of loading between 6 and 15 inches per minute; however, 8 to 10 inches per minute appeared to be most critical. It was at these rates of loading the maximum differentiation in strength characteristics became apparent. It may also be observed that the richer mixes maintained strength advantages over a wide range of faster loadings. For the first time these data began to shed some light on the strength characteristics of bituminous mixtures.

No matter how much is known about void contents and strength characteristics, it is still necessary that the practicing Engineer recognize the application limits for a wide variety of mixtures. All mixes are not adequate for the same uses. An attempt was made to formulate more information on strength of base necessary to resist loading of traffic. The senior author published an article[2] which showed the relationship between thickness of surfacing, triaxial classes (AASHO 212-T), and total equivalent 18 kip single axle load applications. For use in this report, we have selected points reflecting the boundary line between class 1 and 2 base materials. It is believed that this division represents a significant relationship in that we might observe how strength of base varies with traffic. (See Figure 10.)

[2] "Comparison of AASHO Guide and THD Design of Pavement Thicknesses". Published in THD Foundations for Pavements and Light Weight Structures, Part I, Article 14.

Although we have developed considerable information on mix design, strengths and stresses, the need for a system of quality grouping of mixes for interpretative purposes appeared to be necessary. The relationship between slow testing and maximums obtained for fast testing (8 to 10 in. per min.) was plotted in Figure 11 for grouping purposes. The ordinate of Figure 11 shows values of unconfined compressive strength obtained while testing at a rate of 0.15 in. per min. It may also be noted that values of 35, 45, and 55 psi are shown on the ordinate as an aid in establishing a chart for mix quality identification. The value of 55 psi was taken from Figure 10 for extremely heavy traffic. The two lowest values have been used in quality control of flexible base materials. It can be seen that the values for untreated base materials occur slightly to the right of a 45 degree equivalent line and that the preferred mixes (based on AVR curves) appear considerably to the right and in the A quality area. Less desirable quality areas are shown as B, C, and D. Results of tests not included in this report on mixes consisting of sand-clay and RC-2 cutback asphalt will usually plot in D or in the lower portions of B and C quality areas.

By referring to Figure 10, it appears that the data shown in Table VI represents a good means of interpreting the quality mix designations shown in Figure 11 in terms of highway usage.

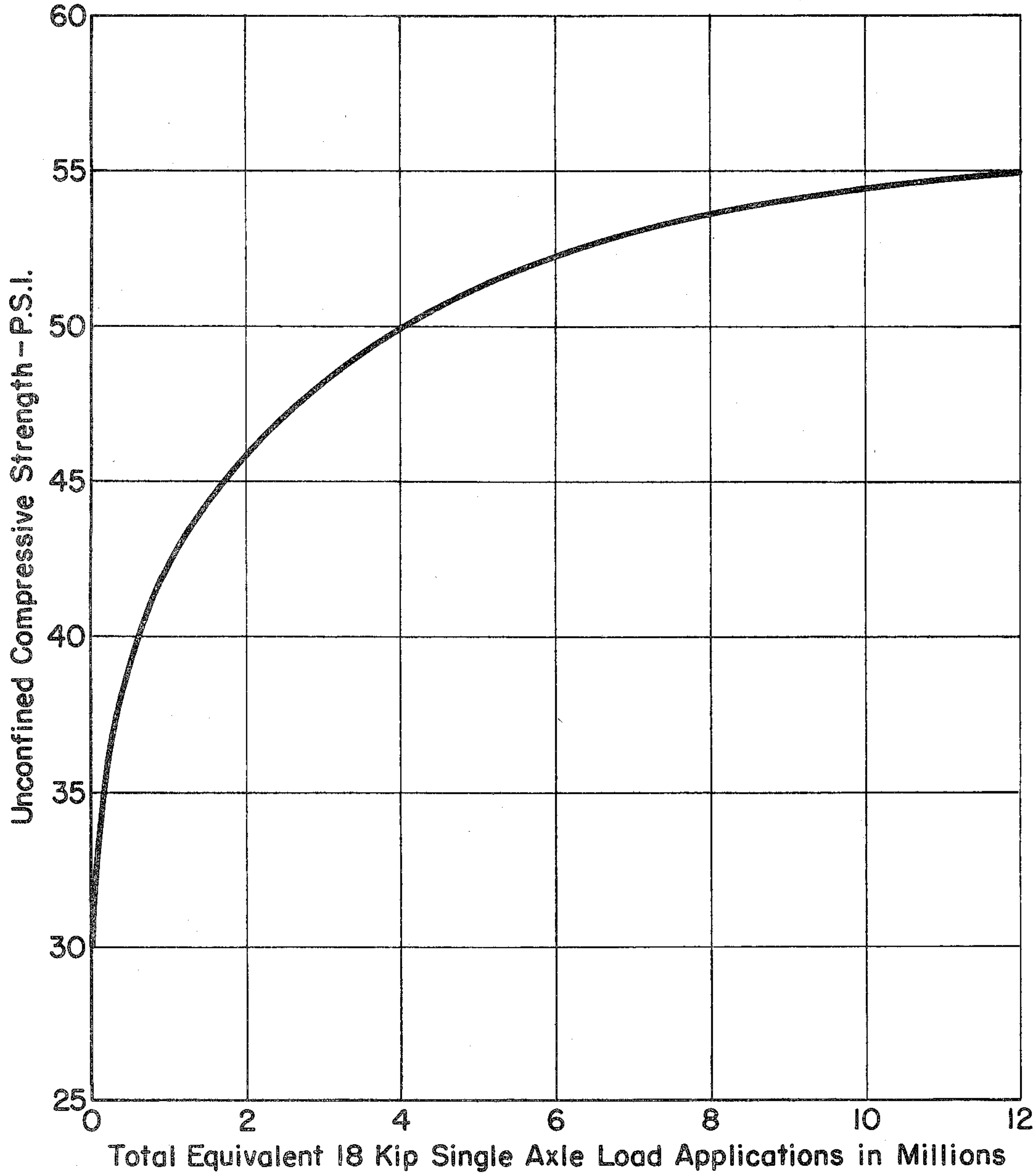


Figure 10
Relation of Unconfined Compressive Strength to Total 18 Kip Single Axle Load Applications

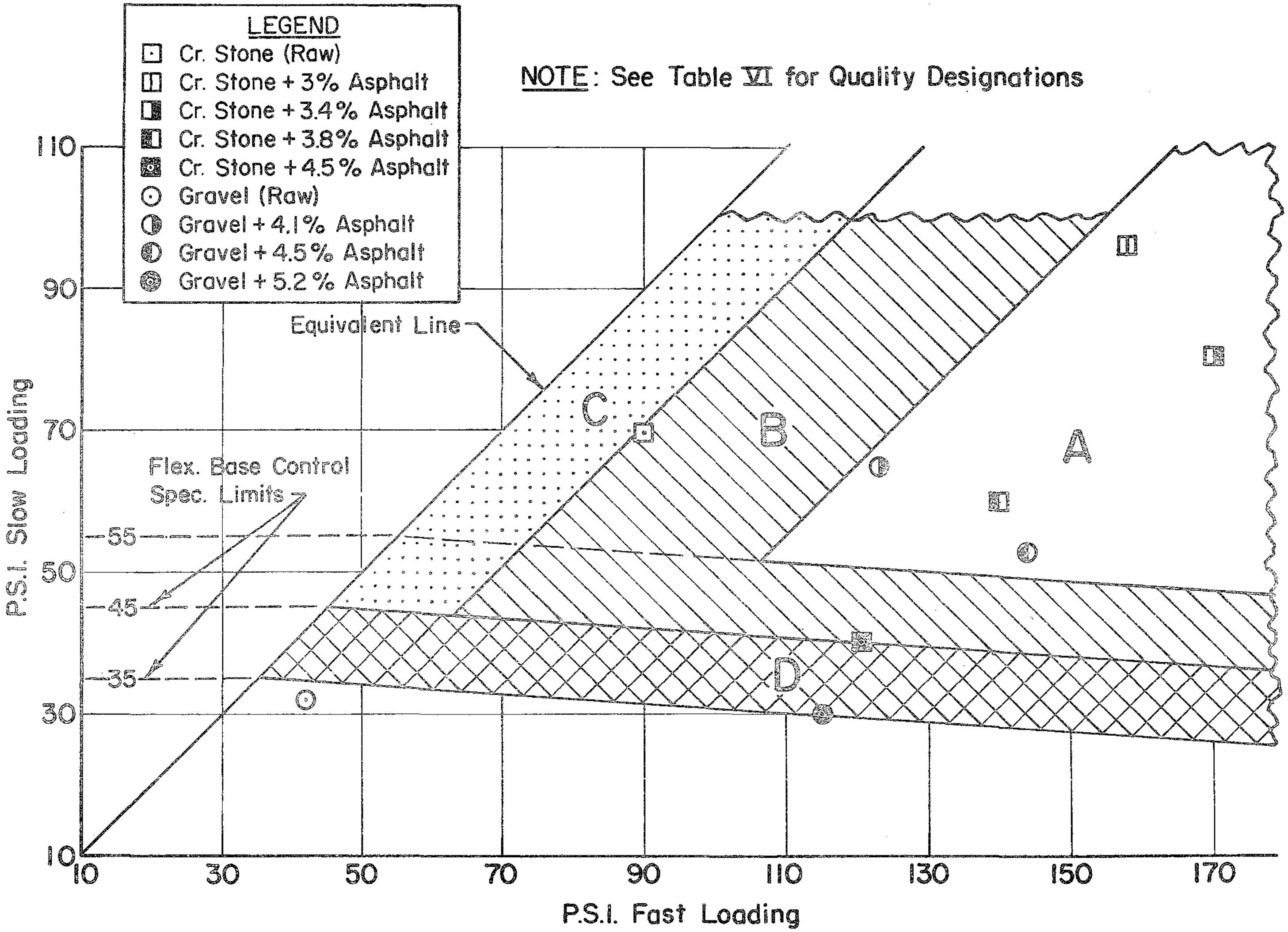


Figure 11, Quality Designation of Mixes

TABLE VI

Use - Interpretation of Quality Mix Designations

Quality Mix Designation	Type of Traffic: Light Less than 200,000*	Medium 200,000 to 1,700,000*	Heavy 1,700,000 to 12,000,000*
A	Special Subbase or Base	Special Subbase or Base	Special Subbase or Base
B	"	"	Special Subbase Only
C	"	"	"
D	"	Special Subbase Only	"

*Total number of "Equivalent 18 Kip Single Axle Load Applications" expected during life of the facility.

RECOMMENDATIONS

On the basis of the findings covered in this report, it is recommended that the following be accomplished:

1. Most Central, District and major field laboratories be equipped with large size motorized gyratory presses, etc., as soon as possible. This is a time consuming step because this equipment is not in stock and must be shop made. This recommendation is also based upon potential use of this equipment for density control of soil and base materials. This subject is to be presented in a subsequent report by the Authors.

2. The recommended procedures be followed so as to obtain asphalt-voids ratio (AVR) curves using gyratory presses and pressure pycnometers as essential tools.

3. Mold enough specimens consisting of mixtures of interest (determined in No. 2) so that unconfined compression strengths at 0.15 in./min. and 10.0 in./min. can be performed at 140° F.

4. For specimens of mixtures containing more than 5.5 percent voids pressure wet before testing for compressive strength.

5. By the use of Figure 11, select a mixture which meets the quality category necessary for anticipated traffic. (See Table VI.)

6. Set up job control limits for percent voids and asphalt contents by use of adjusted AVR curves as suggested in the main body of the report.

7. Check roadway void contents against those established under 6, above. If extraction tests for samples containing large size aggregates are necessary, much larger samples than customarily used are indicated.

8. When possible, the percent asphalt in the black base should be checked by use of the pressure pycnometer as set forth in the section; Proposed Use of AVR Curves, as well as by extraction.

9. For high absorption aggregates, which do not dry out completely in the dryer, it may be necessary to use less than "optimum" asphalt content. In this case, the rectangle limits of voids and asphalt contents should be selected around the asphalt content chosen for use. Any mixture selected for use, when compacted to the total voids content of gyratory molding plus 5 percent, should have a strength at 140°F. after pressure wetting of at least 45 psi.

ACKNOWLEDGMENTS

Acknowledgment is made to members of the Texas Highway Department, Materials and Tests Division, under the leadership of Mr. A. W. Eatman, Materials and Tests Engineer. The performance of many tests and their presentation by members of the THD Soils Section of the Materials and Tests Division is gratefully acknowledged. The assistance in sampling and the gathering of construction data by personnel in the San Antonio, El Paso, and Lubbock Districts of the Texas Highway Department was also an outstanding contribution to this project.

APPENDIX

Texas Highway Department
Materials and Tests Division

MOLDING BITUMINOUS BLACK BASE MATERIALS USING LARGE GYRATORY COMPACTOR AND DETERMINATION OF VOID CONTENTS

Scope

This test method is intended for determining the relationship between the percent asphalt and percent total voids in a soil-asphalt material (black base) when compacted in the laboratory as specified herein. The test is performed on prepared materials passing the 1-3/4 inch sieve by mixing with hot asphalt and determining the dry weight and volume of gyratory compacted specimens. Primarily, the intent of this test method is the use of penetration grade asphalts.

In order for this test method to be self contained and for easier reference for the user, it has been divided into four parts as follows:

Part I Procedure for Preparation of Sample

Part II Procedure for Weight Batching of Materials to be Mixed

Part III Procedure for Determining Specific Gravity and Percent Air Voids

Part IV Procedure for Mixing and Molding Black Base Specimens

Definitions

1. Maximum Density: The highest value for density calculated on the basis of dry weight of material per cubic foot.

2. Combined Specific Gravity: The theoretical calculated gravity of the mixture of soil and asphalt based on their actual absolute specific gravities and their respective percentages in the mix.

3. Percent Total Voids: The calculated percent voids in a specimen of a given density when compared with the zero air voids density for that particular mix.

4. D_G: The highest density obtainable in gyrating a raw soil in the 7 in. by 3 in. gyratory mold using water as a lubricant and gyratory procedure similar to that used herein.

5. Optimum Asphalt Content: The percent asphalt recommended for use from these procedures. This percentage is bounded by the break in the straight line section of the Percent Total Voids vs. Percent Asphalt in Mix Curve and the percent asphalt where the pycnometer pressurized wet strength is 45 psi. Usually the recommended percent asphalt is taken as the percentage slightly higher than the "break" in the curve.

6. "Fat Point" Asphalt: The highest percentage of asphalt on the Percent Total Voids vs. Percent Asphalt in Mix Curve where the pressure wetted specimen strength is 45 psi. Where the wet strength is still above 45 psi and the specimens show evidence of slumping or flushing a lower percentage of asphalt should be chosen as the fat point.

Apparatus

1. Gyratory Compactor: A motorized compaction device (Photograph 1) capable of gyrating 6-inch I. D. by 12-inch height forming molds used in gyrating and compacting the material. The compactor shall be capable of gyrating at an angle of approximately 5° and shall have a hydraulic ram capable of maintaining a load of 500 psi on the gyrated specimen.

2. Compaction Mold: A 6-inch $\pm$ .030 I. D. and 12-inch $\pm$ 1/16 height forming mold with gyratory flange collar and mold base plate. (Photograph 2) It is preferable, but not necessary, that the mold be chromium plated.

3. Compaction Mold: A 7-inch $\pm$ .030 I. D. and 7-7/16-inch $\pm$ 1/16 height forming mold with gyratory flange collar and mold base plate. (Photograph 3) It is preferable, but not necessary, that the mold be chromium plated.

4. Measuring Device: A micrometer dial assembly for determining height of specimens, with set of standardized spacer blocks.

5. Scale, rated 30 pound capacity, sensitive to 0.01 pound.

6. Press, to eject specimen from mold. (Photograph 4)

7. Drying Oven, controlled to 230° F. (110° C.) $\pm$ 9° F.

8. Drying Oven, controlled to 400° F. $\pm$ 20° F. for heating mixing pans with aggregate materials.

9. Electric hot plate for retention of heat during mixing of specimens.

10. Dolly, caster mounted, made to same height as compactor platen and extrusion press platen. (Photograph 5)

11. Metal pans, approximately 21" x 15" x 4" for drying and mixing materials.

12. Circular porous stones, slightly less than 6 inches in diameter and 2 inches high.

13. Metal disks, 6" diameter by approximately .040" thick. No.18 gauge sheet metal.

14. Filter paper, 6" diameter.

15. A supply of small tools, trowels, plastic mallet, etc.

16. Asphalt: A plentiful supply of the desired asphalt for use in molding specimens. A test report giving the specific gravity is necessary.

17. Fine soil pans: A supply of round pans approximately 8 to 8-1/2 inches in diameter for heating fine sizes of soil separate from the larger particles.

18. Asbestos gloves, rubber syringe, and a supply of plastic bags.

19. Suitable high pressure pycnometer and pump. (See photograph 6.)

20. Compressed air source or other suitable gas capable of furnishing 100 psi during test.

21. Sieves: Standard U. S. woven wire sieves with square openings (A. S. T. M. E 11 specifications) 2-inch, 1-3/4-inch, 1-1/4-inch, 7/8-inch, 5/8-inch, 1/2-inch, 3/8-inch, No. 3, No. 4, No. 10, No. 20, and No. 40. A mechanical shaker is convenient, but not absolutely necessary.

22. Heavy Duty Scale: A scale of adequate capacity and sensitive to 0.5 pound or less.

23. Electric air dryer, or oven, controlled to 140° F. (± 9° F.).

24. Sample pans: A supply of metal pans for use in sieving and storing sieved materials.

Test Record Form

Record test data on work sheet, Gyratory Work Sheet. (Figure 1.) Record specific gravity data on work sheet, Pressure Pycnometer Work Sheet. (Figure 2.)

Calibration of Equipment

Specimens approximately 6 inches in diameter and 8 inches in height are compacted in the 6 in. by 12 in. mold. Since the compacted specimen does not completely fill the mold, it is necessary to determine the volume per linear inch of height of the mold. Determine this factor as follows:

1. Measure the diameter of the mold, by means of the micrometer caliper and micrometer dial, at the ends and several intermediate points to obtain an average value for the diameter.

2. Use the average diameter to calculate a mean cross sectional area of the mold.

3. Calculate the volume in cubic feet for one inch of height of the mold as follows:

$$\text{Volume of mold cu. ft. per inch} = \frac{\text{Area in sq. in.} \times 1 \text{ inch}}{1728}$$

Using the micrometer dial assembly and an appropriate 8 inch spacer block, place the mold base plate in position on the gyratory platen. Then bring the top gyratory head down on the spacer and determine the dial setting for a specimen of 8 inch height. Set the dial face to read zero. Specimens taller than 8 inches will read greater than the "zero" reading; shorter specimens, less.

PART I

Procedure for Preparation of Sample

Prepare the material as follows:

1. Select a 300-pound representative sample. Check specifications for maximum size aggregate.

2. Spread sample on clean floor to air dry or use forced drafts of warm air.

3. Soil which form into hard lumps when dried, but contain no appreciable amount of aggregate should be crushed to pass the No. 10 sieve.

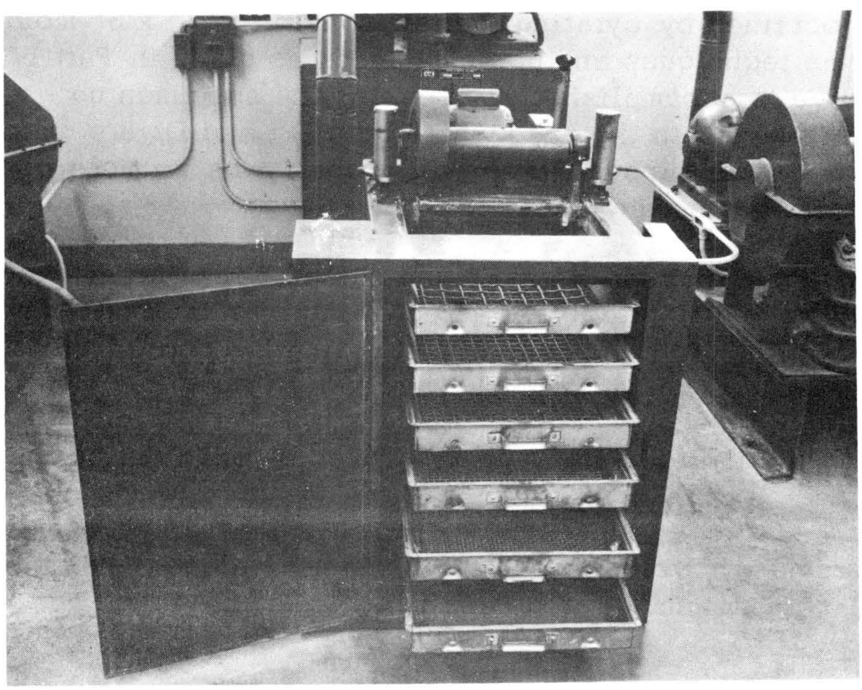
4. Soils containing aggregate should be broken up to pass a No. 4 sieve without breaking the aggregate. This may be done by means of a plastic mallet, rubber-covered tamp, or similar hand tool. The material is then separated as described in step 5.

5. Aggregate materials, caliche, crushed rock, and gravel should be separated into sizes by dry screening to convenient cuts. The following size sieves: 1-3/4", 1-1/4", 7/8", 5/8", 3/8", No. 4, and No. 10 are adequate. (Photograph 7 shows 1/2 cu. ft. batch sieve shaker.)

6. Mix each size to make moisture as uniform as possible.

7. Weigh each size of material and compute the percentages, cumulative, retained on each size. These values are not to be used as a true sieve analysis, but are to be used in recombining the sample for individual specimens.

8. On the basis of the cumulated sieve size percents obtained in step 7 above, calculate and weigh out a 10-pound representative sample for soil constants and sieve analysis.



Photograph 7

Sieve Shaker

Calculations

1. Determine the percentage retained on each sieve, i.e.,

$$\text{Percent retained} = \frac{\text{Weight Retained}}{\text{Total Weight of Sample}} \times 100$$

2. $$\text{Weight retained (any sieve)} = \frac{\text{10.0 lbs. x percent retained}}{100}$$

PART II

Procedure for Weight Batching of Materials to be Mixed

To begin the asphalt-voids curve, a specimen must be weighed out and a good estimate of the beginning percentage of asphalt should be known.

1. Find D_G, the maximum gyrated density. Use Figure 3 to obtain D_G when D_A from Test Method Tex-114-E or the maximum density from Test Method Tex-113-E is known. If neither value is available, then carefully estimate D_A as closely as possible using all the information that is available. Read D_G from the chart.

NOTE: D_G may be obtained by gyrating the raw soil in the 7" x 3" mold using basically the same techniques and pressure loads as given in Part IV, to follow. The M-D curve is accomplished by breaking the specimen up, rewetting and remolding. However, in the case where both D_G and D_A are unknown, the making of a few extra bituminous mixes will probably be no more difficult than obtaining D_G or D_A for the raw soil.

2. Using the pressure pycnometer and the procedure in Part III, to follow, find the absolute specific gravity of a representative grading of the soil material being used. About 6 to 10 pounds of material is needed for this determination with about 8 pounds being good for average material.

3. Multiply the gravity from paragraph 2, above, by 62.4 to find the zero air voids dry density.

4. Find the percent air voids in the soil material alone when the soil particles are at D_G, or maximum gyrated density as follows:

$$\text{\% Air Voids} = 100 \left(1 - \frac{(D_G \text{ Density})}{(\text{Sp. Gr. of Soil})\ (62.4)}\right)$$

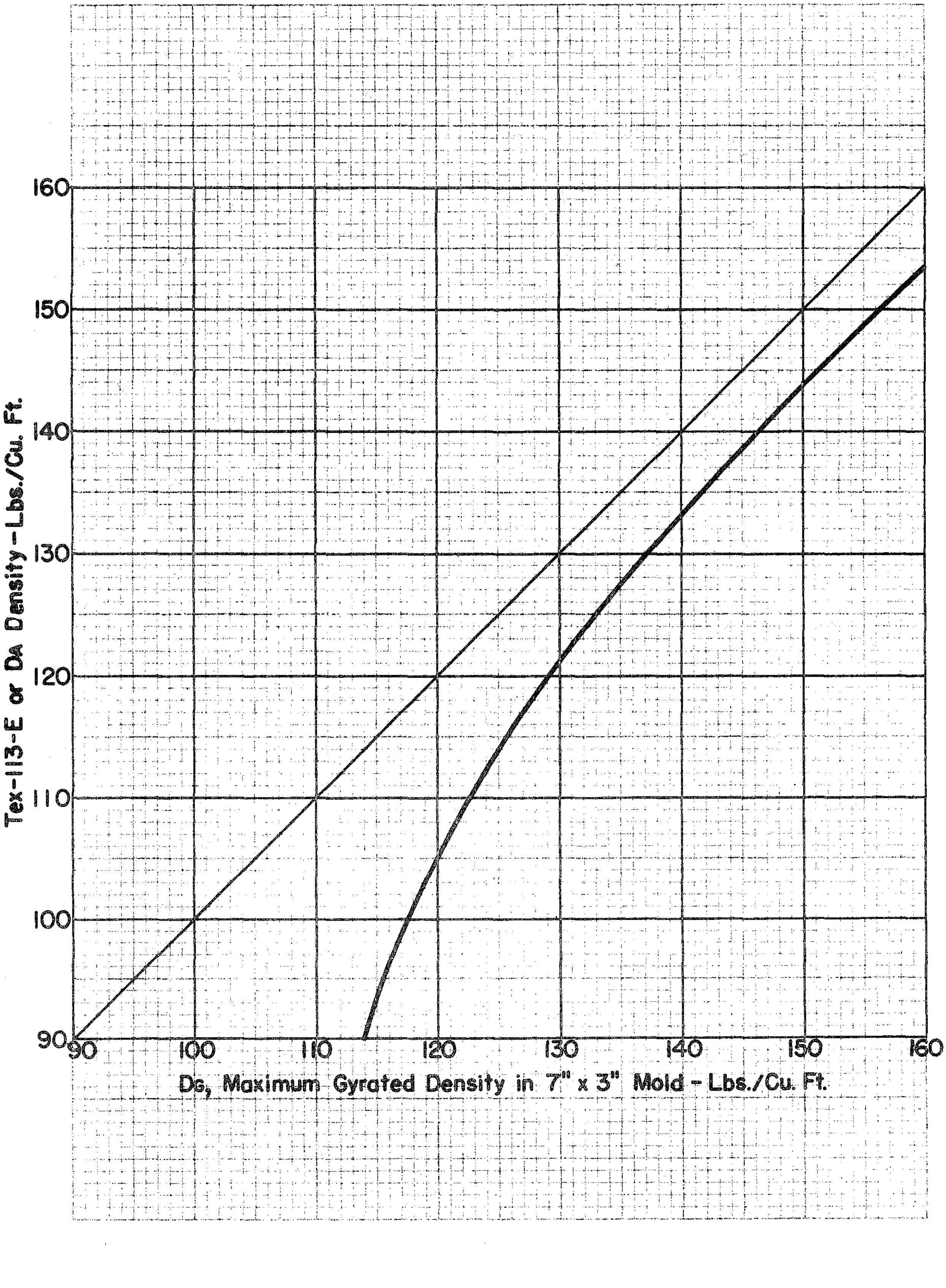
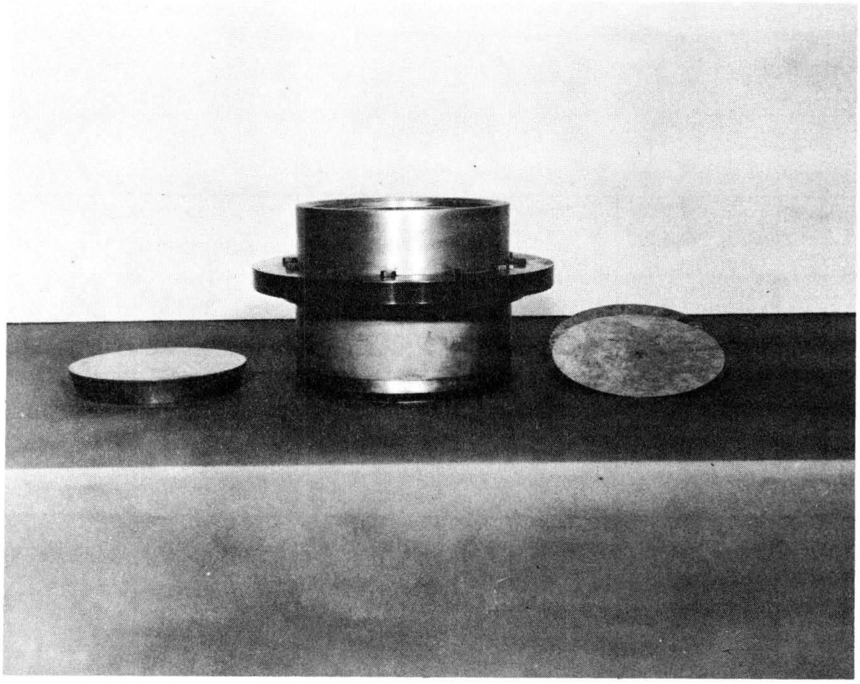


Figure 3, D_A vs. D_G Chart



Photograph 3

7" x 3"
Compaction
Mold and
Base Plate

5. Begin the first specimen using a percentage of asphalt added equal to 35% of the air voids found in paragraph 4, above.

NOTE: This 35% figure has been determined from correlation experience and it should be noted that this figure is different from the percent asphalt in the mix. The figure obtained from paragraph 5, above, is a good place to begin and in many cases will be within 1% or less of the optimum asphalt content.

6. Place a supply of asphalt to be used in the oven and heat to 375° F. for later use.

7. Since the density in the gyrated soil particles in black base should approximate D_G, then determine the weight of air dried soil to batch out for the first specimen.

Wt. of dry soil = (D_G density) (*calibration factor of mold) (8")

This weight of soil when mixed and molded is intended for use in molding one 6" x 8" specimen when the soil particles, exclusive of the asphalt, are at D_G density. In case D_A or D_G were not determined accurately, then adjust the weight of material to obtain an 8 inch specimen.

* Calibration factor of mold is in cubic feet per linear inch of height.

8. Using this weight and the percentages of the various sizes of particles obtained in preparation of the large sample, compute the cumulative weights of each size to combine to make a specimen.

9. Weigh up the specimen as calculated in step 8 keeping the plus No. 10 portion separated from the minus No. 10 portion.

10. Place the plus No. 10 fraction in a tared mixing pan and the minus No. 10 portion in one of the smaller tared pans and place both pans in the oven for heating and mixing. If all the material is minus No. 10, the large mixing pan only should be used.

PART III

Procedure for Determining Specific Gravity and Percent Air Voids

1. Select an adequate representative sample.

2. Slice any clay lumps, which might exist in the sample, to a maximum thickness of 1/4-inch. In this operation precautions should be taken to avoid the loss of any more moisture than is absolutely necessary.

3. Place sample in plastic bag, weigh and subtract weight of plastic bag and record as W. If the sample is weighed out to an exact ten pounds or any convenient percent thereof, then the calculations under step 16 can be replaced by available tables.

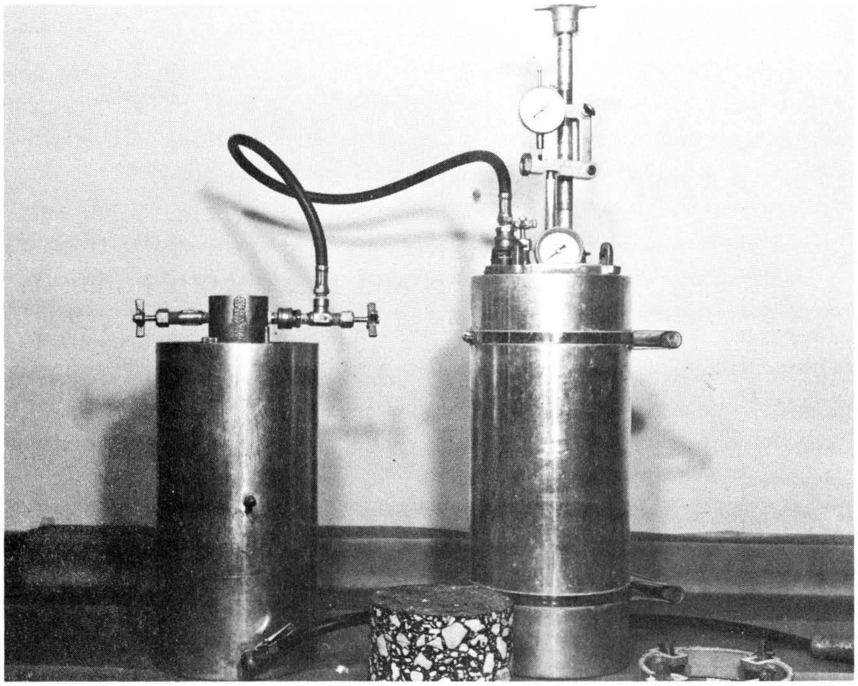
Zero determination for water only.***

4. Fill lower portion with ample amount of zeroing water to cover sample (which will be introduced in step 12) usually about 6 to 8 inches.

5. Place piston with vent plug removed in pressure pycnometer. Press gently until water is barely visible in vent plug opening.

6. When water level in opening is properly adjusted, screw in plug tightly.

*** Although almost any convenient temperature may be used for running tests, precautions should be taken to prevent any significant change in temperature during any single test.



Photograph 6

High Pressure Pump and Pycnometer

7. Fill remainder of pressure pycnometer with water to the shoulder and insert head of pycnometer with release valve open so that water overflows. Then fasten head securely.

8. Apply pressure to water reservoir with high pressure water pump** with water reservoir valve open. When pressure gauge indicates line pressure close water reservoir valve. Move air pressure line to bottom stem on pressure pump. Pump to 1200 psi.

9. Set dial indicator on piston rod at zero by selection of calibrated spacers for coarse adjustment and micrometer screw for fine adjustment and lock adjustment.** Carefully recheck pressure and readjust, if necessary, then remove dial indicator.

10. Release pressure and remove head. Drain water and wipe all parts until dry.

11. Extrude piston** and remove vent plug and set aside without losing any <u>zeroing water from bottom of piston or pycnometer</u>.

Volumetric determination of sample.***

**See manufacturer's instructions for operation.

12. Place sample, mentioned in step 3, in water in pressure pycnometer so that water overflows into the bag without washing out soil.

13. Replace piston in pressure pycnometer as indicated in steps 5 and 6. If water overflows, raise piston and by use of a pre-wetted syringe, suck up water and return through vent opening.

14. Fill remainder of pressure pycnometer with water and pump to 1200 psi as set forth in steps 7 and 8. Maintain this pressure for a minimum of 15 minutes. Care must be taken to reproduce exact pressure gauge reading that was used in setting zero dial indicator in step 9.

15. By selection of calibrated spacers, etc.** (see step 9), set dial indicator on piston rod and record volume of solids and moisture displaced in pycnometer as V_1 from which the volume of the plastic bag must be subtracted to obtain V. The volume of the bag can be determined using the bag as the sample in steps 4 to 15. The use of plastic bags of uniform volume and weight is highly desirable in order to avoid repetitious volume determinations.

16. Calculations (The use of high pressure pycnometer tables will replace most calculations as expressed in the formulas given below.)

$$DW = W - \frac{GV - W}{G - 1}$$

and

$$M = \left(\frac{GV - W}{G - 1} / DW \right) 100$$

Where:

W = Total weight of sample

DW = Oven-dry weight of sample. If sample is from density determination, divide DW in lbs. by volume of hole in cu. ft. for density in lbs./cu. ft.

V = Volume displaced by sample (solids and water)

G = Specific gravity of solids

M = Moisture content expressed as a percentage of dry weight

If specific gravity has not been previously determined, remove sample from pressure pycnometer and oven dry at 230° F. and determine DW.

Then

$$G = \frac{DW}{V - (W - DW)}$$

or if a separate representative moisture content sample is used to find M and DW,

$$G = \frac{W}{V - (W - DW) \ (1 + \frac{M}{100})}$$

and

$$DW = \frac{W}{1 + \frac{M}{100}}$$

Record specific gravity data on Pressure Pycnometer Work Sheet, Figure 2.

PART IV

Procedure for Mixing and Molding Black Base Specimens

1. When the soil and asphalt reaches approximately 375° F. it is ready for mixing. Remove the two pans of soil from the oven and weigh. Subtract the sum of the tares of the pans and obtain the dry weight of soil.

2. Place the pan containing the minus No. 10 portion back in the hot oven, and place the mixing pan and its contents on the preheated hot plate for temperature retention.

3. Calculate the weight of asphalt required in the specimen, then place the mixing pan back on the scales and accurately weigh in the hot asphalt from the oven. Return the mixing pan to the hot plate.

4. Using a trowel or other convenient mixing tool, mix and turn the hot mixture of asphalt and plus No. 10 material until it appears to be as well coated as it can be using that particular percentage of asphalt. This may require several minutes.

PRESSURE PYCNOMETER WORK SHEET

ABSOLUTE VOLUME, SPECIFIC GRAVITY, AND MOISTURE

CONTENT TEST DATA

DATE: ____________________

SAMPLE NO.						
PRES.-PYC. VOLUME (LBS.)						
VOLUME PLASTIC BAG (LBS.)						
VOLUME SAMPLE (LBS.)						
WET WT. SAMPLE (LBS.)						
* DRY WT. SAMPLE (LBS.)						
WT. WATER IN SAMPLE (LBS.)						
** % WATER IN SAMPLE						
CORR. PRES.-PYC. VOL.(LBS.)						
*** SPECIFIC GRAVITY						

* DRY WEIGHT FORMULA

$$\text{DRY WT.} = \text{WET WT.} - \frac{\text{SP. GR. X VOL.} - \text{WET WT.}}{\text{SP. GR.} - 1}$$

** MOISTURE CONTENT FORMULA

$$\text{\% MOIST.} = \left\{ \frac{\text{SP. GR. X VOL.} - \text{WET WT.}}{\text{SP. GR.} - 1} \Big/ \text{DRY WT.} \right\} 100$$

*** SPECIFIC GRAVITY FORMULA

$$\text{SP. GR.} = \frac{\text{DRY WT.}}{\text{VOL.} - (\text{WET WT.} - \text{DRY WT.})}$$

File 9.400

Figure 2, Pressure Pycnometer Work Sheet

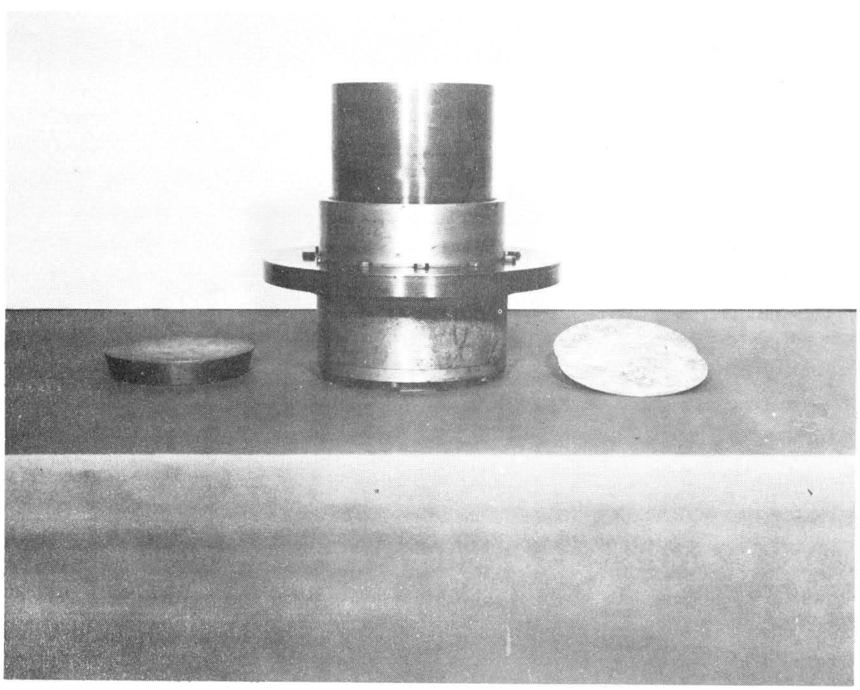
5. When the mixing of the aggregate particles is completed, add in the minus No. 10 portion from the oven and completely mix the material for molding.

6. The 6 in. by 12 in. mold and base plate should be preheated in the 230^{o} F. oven in order not to cool the mixture during loading and gyration. Remove the base plate from the oven and place it on the loading dolly. Place the hot mold on the base plate and insert one of the thin 6-inch metal disk in the mold on top of the base plate. Place one piece of the round 6-inch filter paper on the metal disk.

7. Load the hot soil and asphalt mixture into the mold as follows:

a. After mixing, but before removal of the mold from the oven, separate the larger aggregates equally, as judged by eye, in the corners of the mixing pan.

b. Bring the dolly and mold assembly to the mixing pan, placing the hot plate and mixing pan near the mold. Begin loading by placing about 1/2 inch loose thickness of the finer sizes of the mixture on top of the filter paper. With a spatula or any convenient tool, level these fines out in the mold.



Photograph 2

6" x 12" Compaction Mold and Base Plate

GYRATORY WORK SHEET

Lab. No.________

Date Molded															
Sample No.															
% Asphalt in Mix															
% Asphalt Added															
Pounds Material															
Temp. Material															
Wt. Material & Pan															
Tare Wt. Pan															
Dry Wt. Material															
Wt. + ___ m Mat'l. & Pan															
Wt. Asphalt Added															
Total Wt. in Pan															
Temp. in Mold															
Mold No.															
Time @ 20 psi															
Time @ 40 psi			REDUCED SIZE - TOO SMALL FOR RECORDING DATA												
Time @ 60 psi															
Time @ 500 psi															
Ht. Specimen & Plates															
Thickness of Plates															
Ht. Specimen															
Pushed Out Ht.															
Wt. of Specimen															
Vol. per Linear Inch															
Vol. of Specimen															
Density of Specimen															
Density of Soil															
Sp. Gr. Soil															
Sp. Gr. Asphalt															
Comb. Sp. Gr.															
ZAVD															
% Voids in Specimen															
Wt. before Wetting															
Wt. after Wetting															
Wt. at Test															
% Moisture at Test															

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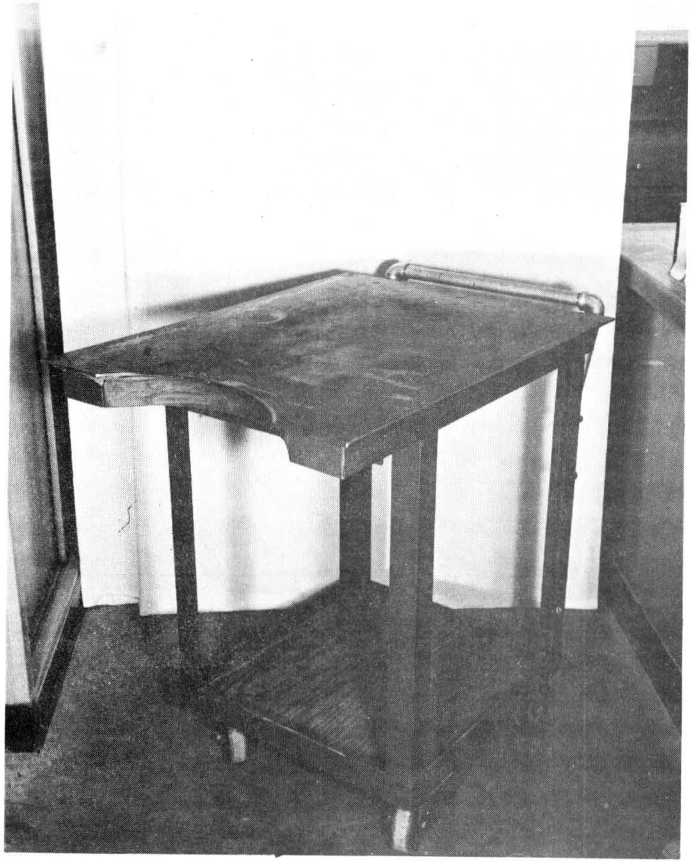
Figure 1, Gyratory Work Sheet



Photograph 5

Caster
Mounted
Dolly

c. Then place one quadrant of the larger aggregates from one of the corners in the mold and level as above. Place the remaining intermediate sizes and fines, from that quadrant of the pan, on top of the larger aggregates and spade well around the sides of the mold and in the layer as well. Do not allow the larger aggregates to come to the top of the loose layer.

d. Then load in the second, third, and fourth quadrants of the mixture in the same manner except that about 1/4 inch of loose fines at the beginning is sufficient. Spade well around the sides after the addition of each quadrant of the mixture.

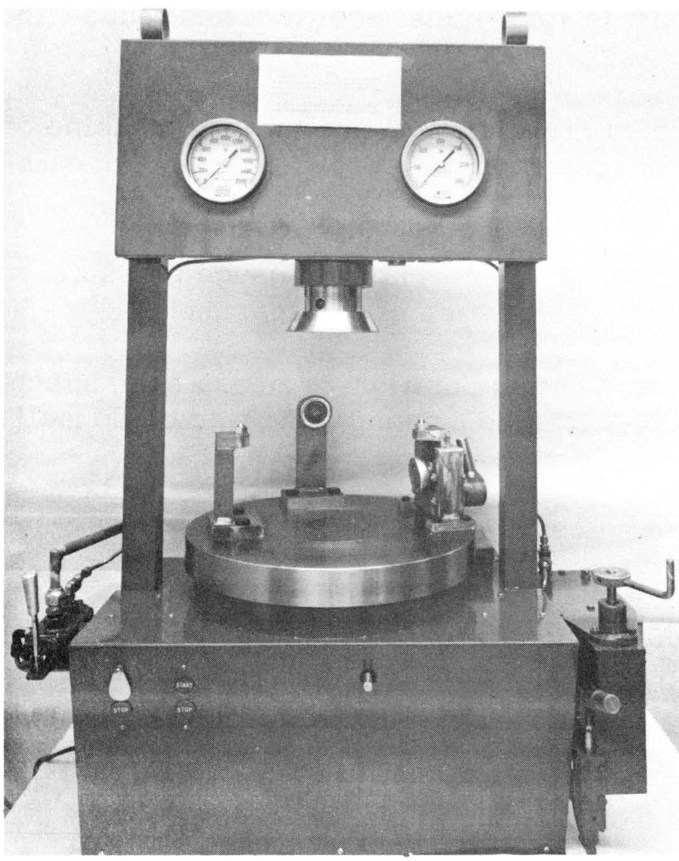
e. In finishing up the loading of the fourth quadrant, top off the layer with about 1/4 inch of fines, and using a wide blade putty knife or similar tool, scrape out the remaining contents of the pan and place in the mold.

f. The intent of this technique is to load the mold each time for maximum density, placing the intermediates and fines with the larger aggregates so that minimum travel by gyration will move it into its final position.

This reduces time of gyration and produces more uniform, repeatable specimens. Note that all the contents of the pan are placed in the mold for gyration for one 6" x 8" specimen.

g. In loading hot sand and asphalt mixes, or any fine sized, fluffy material, the amount of mixture that will gyrate into a 6" x 8" specimen may more than fill the 6" x 12" mold. In this case, after the addition of each quadrant, push the material down using any convenient tool. It may be convenient to use a finishing tool that covers the cross section of the mold and tamp the loose mixture, using a plastic or rawhide hammer. Excessive hammering or tamping should not be done, using only that to allow the ram to enter the mold for gyration. (Note: This is not detrimental, since in step 11, to follow the mixture is further shortened by loading before gyration begins.)

8. When the mold has been loaded, then level the fines on top with any convenient hand tool and insert a thermometer in the mix. Record the temperature on the data sheet. The temperature should be 260° F. ± 20° F. Mixes usually lose about 100° F. during mixing and loading, and it is desirable that the electric hot plate have some means of temperature control.



Photograph 1

Motorized Gyratory Press

9. Remove the thermometer, place another 6-inch filter paper on top of the mix, then a thin 6" metal disk and remove the dolly with mold to the compactor.

10. Slide the mold, with base plate, onto the platen of the compactor. The platen must have a generous coat of good lubricant or the platen and base plate can be damaged. Center the mold, lower the compactor head on the material, and turn the lift cam down to give the mold its 3/4 inch lift angle.

11. Using the machine controls, place a load of 20 psi with the loading ram on the specimen, and turn on the machine. Gyrate the specimen for two minutes at 45 psi gauge loading. 45 psi gauge is 20 psi on the specimen.

12. At the end of 2 minutes, increase the load to 90 psi gauge and continue gyrating 2 minutes at 40 psi on the specimen.

13. Then increase the load on the ram to 135 psi gauge, and continue gyration until the gauge needle will stand steady on 60 psi on the specimen for 5 revolutions of the platen. This means that there has been no appreciable shortening or densification in the five revolutions. Turn the compactor off.

14. Release the pressure from the top of the specimen slightly, and using the handle provided, return the cam lift to its original position, and reduce the angle of lift to zero.

15. Place 45 psi gauge pressure on the specimen, and turn the machine on for a few revolutions. This tends to square-up the specimen. Turn the machine off.

16. Wipe off any oil on the platen, and place 1125 psi gauge pressure on the specimen. This is 500 psi on the cross-section of the specimen.

17. Place the pre-set measuring stand in position to measure the specimen (Photograph 8). Hold the load on the specimen until the rate of consolidation is 0.002 inches or less in 5 minutes.

18. Observe the dial reading, and record the net height of specimen only, making allowance for the thickness of the metal disks.

19. Remove the measuring device, and then the load on the specimen. Raise the ram out of the mold, and remove the mold from the machine platen to the dolly.

20. Slide the mold with base plate on the platen of the ejection press and eject the specimen up and out of the mold.

Photograph 8

Measuring Height of Specimen

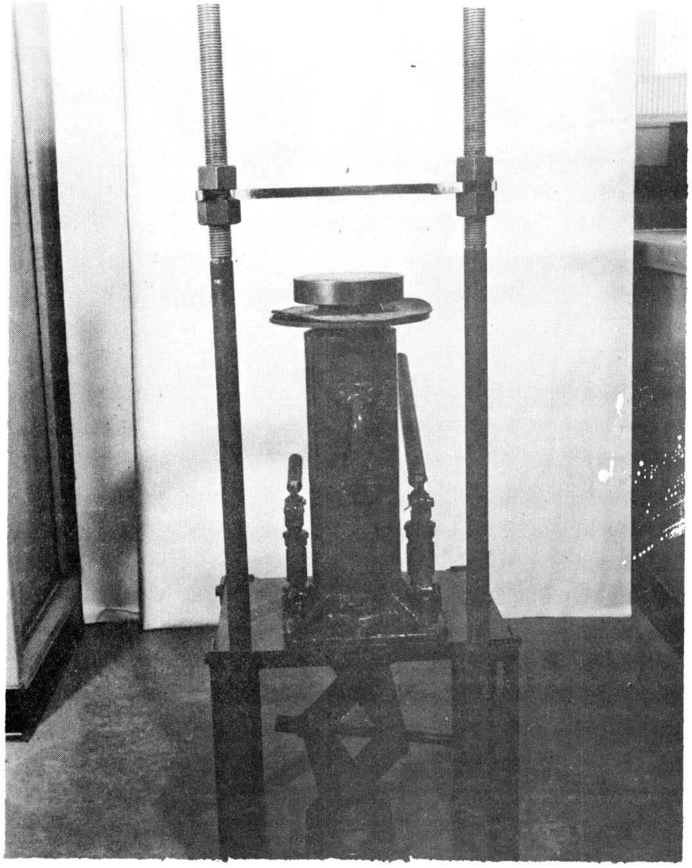
21. Remove the top and bottom metal disks and weigh the specimen to the nearest estimated 0.001 pound. Clean any material adhering to the disks that was included in the measured height and weigh this with the specimen.

22. Place the specimen with 6-inch porous stones on top and bottom and place in the 140^{o} F. oven for storage if further testing for strengths is desired.

23. Calculate the volume and the density of specimen.

24. Using the specific gravities of the asphalt and raw graded soil, calculate the combined specific gravity of the specimen. Then determine the zero air voids density of the specimen.

25. Calculate the percent total voids in the specimen and begin the Percent Asphalt in Mix—Percent Total Voids Graph (Figure 4).



Photograph 4

Extrusion Press

26. Vary the percent asphalt in the mix and repeat the molding procedures above until a good asphalt-voids curve is produced, clearly defining the straight line section and "break" in the curve. This requires usually a minimum of 5 to 6 specimens and often a few more.

Calculations

1. Calculate the percent asphalt as follows:

$$\text{\% Asphalt added} = \frac{\text{\% Asphalt in mix}}{\text{100-\% Asphalt in mix}} = 100 \left(\frac{\text{Weight of asphalt in mix}}{\text{Wt. of mix-Wt. of asphalt}}\right)$$

2. Volume of specimen = volume per linear inch of mold x height of specimen loaded under 500 psi.

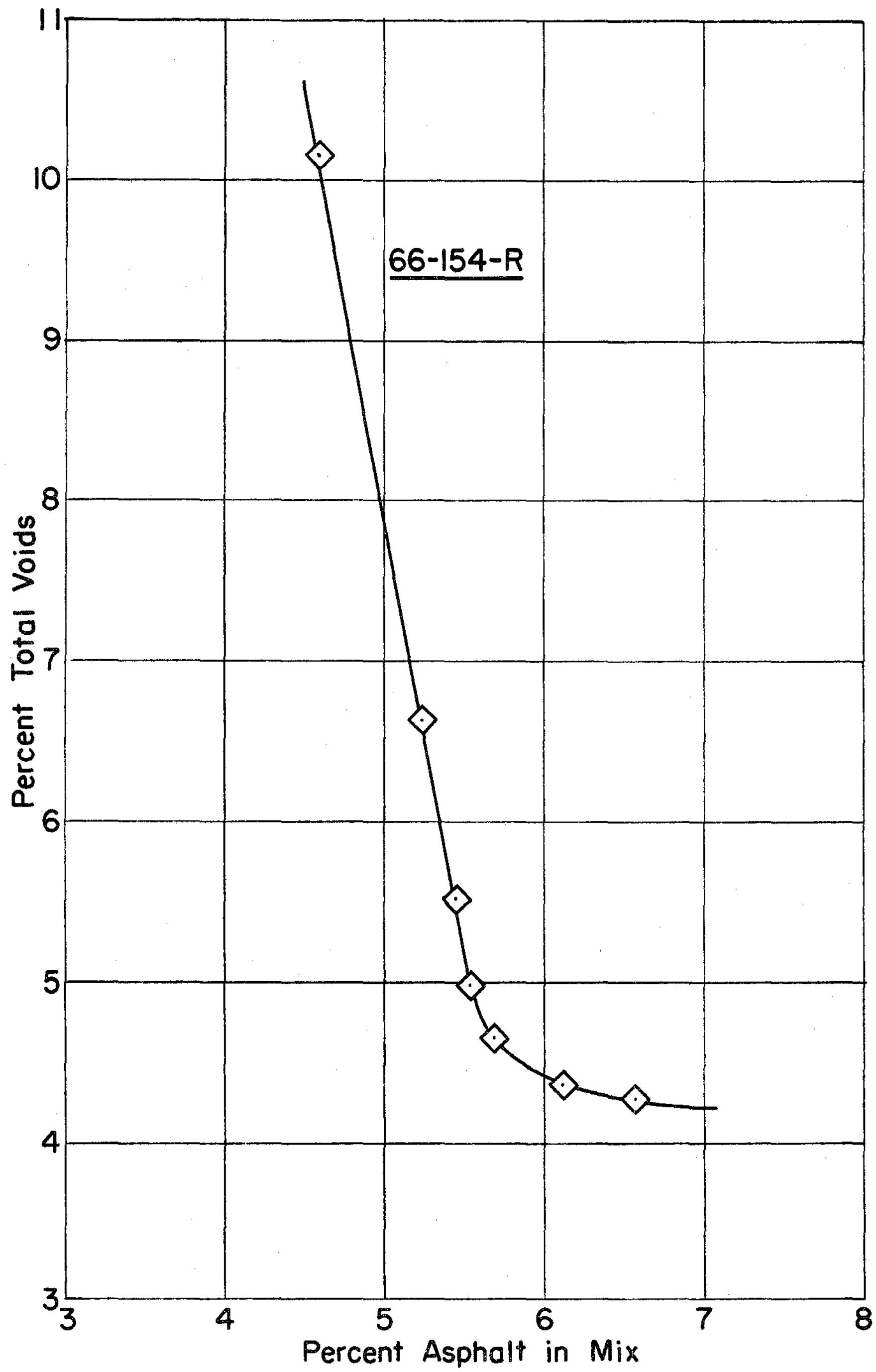


Figure 4., Asphalt-Voids Ratio Curve for Bituminous Mixtures

3. Density of specimen = weight of specimen divided by volume of specimen.

4. Density of soil = density of specimen divided by (100 + percent asphalt added).

5. Combined specific gravity = $\dfrac{100}{\dfrac{\%\ \text{Soil}}{G_1} + \dfrac{\%\ \text{Asphalt in mix}}{G_2}}$

Where:

G_1 = absolute specific gravity of a representative gradation of the gyrated soil. Obtain by use of pressure pycnometer.

G_2 = absolute specific gravity of asphalt used. Obtain from test report.

6. ZAVD = zero air voids density = combined specific gravity multiplied by 62.4.

7. % total voids = $\left(1 - \dfrac{\text{Density of Specimen}}{\text{ZAVD}}\right) 100$

Graphs

Plot the Percent Total Voids—Percent Asphalt in Mix Curve as shown in Figure 4. Usually the asphalt is plotted on the abscissa.

Notes

Usually it is preferable to have two or more molds in order to minimize time lost for heating the molds, using one and then the other. However, the use of only one base plate is preferable unless they are identical in height.