DESIGN, CONTROL, AND INTERPRETATION OF TESTS FOR BITUMINOUS HOT MIX BLACK BASE MIXTURES

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TEXAS HIGHWAY DEPARTMENT

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by

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conducted by

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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.

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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 unaffected 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.

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OBJECTIVES

The need for the treatment of such a wide variety of mineral aggregates in Texas has a stong 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. A method 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 pre sented, 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.

9. That a study toward preparation of specifications for implementation of these findings be made.*

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.

*Subsequent to the early preparation of this report, specifications of this type have been written and are available upon request.

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 1 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 2 illustrates repeatability of "absolute" specific gravities obtained by use of pressure pycnometer.

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 THD 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 3 illustrates that uniform density was obtained in all sections of specimens.

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.

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 represent 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 4 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^{o} 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 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. Field data taken subsequently to preparation of Figure 3 indicates that the most practical percent density appears to be $96.5 - \frac{\text{Gyratory Field Voids}}{4}$ (see dotted line on Figure 3.)

PROPOSED USE OF AVR CURVES

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

1. By use of Procedures Parts I and II 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. Select optimum asphalt content (just slightly richer than the end of the lean side of the straight line section of the AVR curve) of 5.3 percent in this case.

3. Let us assume that a contractor believes his material will be some cleaner than the sample tested to obtain original AVR curve and it is agreed that he should start using 4.6 percent asphalt. It is most likely that revision of the AVR curve to fit the plant mix is necessary in order to verify the percent asphalt selected and minimum percent density required.

4. Take a sample from the plant mix, keep it hot, and mold in the gyratory press using procedure shown in Part II of the Appendix. Add additional asphalt to at least two other portions of the field plant mix and mold in the same manner.

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 weighing an adequate size sample, then determining its absolute volume in the pressure pycnometer.

6. Construct another AVR curve, the left leg of which is parallel to the preliminary design AVR curve's left leg and passing through the points obtained in step 5. See Figure 4.

7. Select the proper percent asphalt for use. In this case, Figure 4 indicates the use of 4.7 percent.

8. Select the minimum percent density required which is $96.5 - \frac{2.5}{4} = 95.9$.

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. Part IV in the Appendix should be used for this volume determination. Additional details for this procedure are included in Texas Test Method Tex-109-E which can be obtained upon request. 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.

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

Where: G_1 = Specific gravity of soil

G_2 = Specific gravity of asphalt

CG = Specific gravity of combined materials

A computer program for realistic values for this formula has been set up and is available upon request.

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 5.

From Table 5 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 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; the rich, or hook end of the curve may go above or below the corresponding end of the original curve.
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 interchangeable.

Control checks of voids in the compacted roadway probably should be made daily or as often as the properties of the mix are changed. Due to slowness, it may be that cutting of cores will not be the only means of control needed. Perhaps the use of nuclear and/or dielectric methods offer interesting possibilities of measuring changes in densities.

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 about 45 psi; however, there are some harsh aggregate mixes containing high percentages of asphalt that will not drop to low strength but they will show evidence of flushing and/or slumping under their own weight at 140 F.

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 equipment used for pressure wetting of specimens is shown in photograph 9. 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 five to six percent total voids are little affected by absorbed water, and that some of the lean mixtures have less than 45 psi compressive strength when wetted. The converse of this statement is not necessarily true because some mixtures having high internal voidage may be well waterproofed.

All points for mixtures appearing to the left of the heavy dashed line in Figure 5 (containing less than 4.9 to 6.3 percent voids) were not affected 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 percent 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 F are obtained. Since road bases seldom, if ever, reach 140 F, the extra five percent voids tolerance proposed earlier in this report is reasonable; however, this should be verified for 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 inches 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 10. The machine has a capacity of 60,000 pounds when performing slowly, but of lesser capacity when testing at faster rate of loadings up to 36 inches per minute.

The data obtained from specimens of many identical mixtures tested at various rates of loading at 140 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-lb. 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 lb per cu ft higher than those obtained by use of the 10-lb. rammer dropped 18 inches. 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 the gyratory procedure shown in this report for molding specimens of untreated soil materials should not be used for compression tests of untreated soil materials 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 the case when tested at slow rates of loading. Except for a few lean mixtures, the maximum strengths continued to gain as rate of loading increased but appeared to diminish in rate of gain when the rate of loading exceeded 8 to 10 inches per minute. These data strongly indicate that the strength characteristics of bituminous mixtures are superior to untreated materials if tested at faster speeds than normally used and the data implies that very high strengths of bituminous mixes can be expected under rapid traffic. It should be kept in mind that once adequate minimum strength necessary to withstand loads is obtained, there is probably little, if any, advantage in trying to make the mixture stronger.*

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

*Note: For physical characteristics of sample 68-445-R, see note following reference (1).

of base necessary to resist loading of traffic. The senior author published an article (1) 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 triaxial 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.)

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 inches per minute) 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 inches per minute. 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.

Figure 10 was used as a basis for preparation of the data shown in Table 6, which we believe to be a good means of interpreting the quality mix designations shown in Figure 11 in terms of highway usage. In order to simplify matters for specification writing, the quality designation groups have been changed to grades 1, 2, and 3 as shown in Part II of the Appendix. Roughly speaking, grade 1 takes the place of A and strong B designations; grade 2 takes the place of the low strength B designation, and grade 3 takes the place of the D designation group.

RECOMMENDATIONS

In order to implement 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.*

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 inches per minute and 10.0 inches per minute can be performed on pressure wetted specimens at 140 F.

4. By the use of Figure 11, Table 6 and the Appendix, select a mixture which meets the grade or quality category necessary for anticipated traffic.

5. Set up adjusted AVR curves as suggested in Figure 4 of the main body of the report so that percent density and asphalt content can be controlled.

*Subsequent to the early preparation of this report, 31 gyratory compactors are either under construction or have been completed. Twenty-one are now in use.

6. Check roadway density and asphalt content against those established under 5, above. If extraction tests for samples containing large size aggregates are necessary, much larger samples than customarily used are indicated.

7. When possible, the percent asphalt in the black base road mix 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.

8. For high absorption aggregates, which do not dry out completely in the dryer, the "optimum" asphalt content should be reduced an amount equal to the moisture content retained but this should be utilized as a last resort.

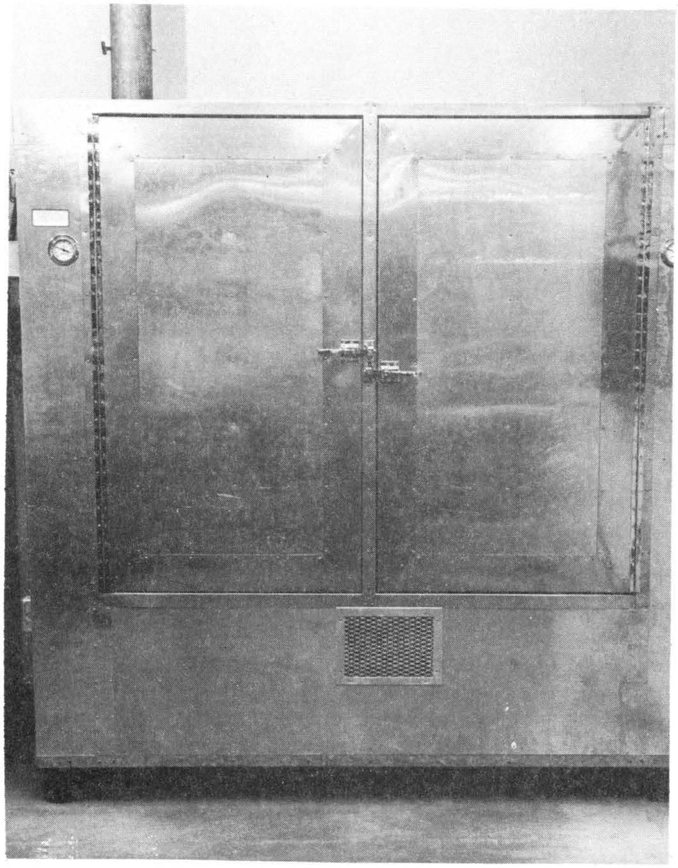
ACKNOWLEDGMENTS

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.

REFERENCE

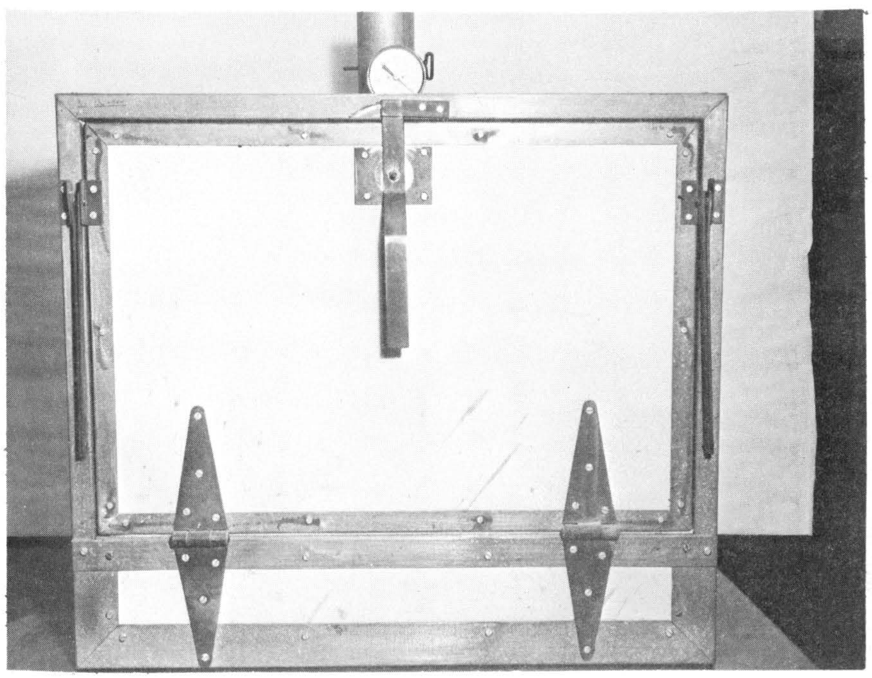
(1) "Comparison of AASHO Guide and THD Design of Pavement Thicknesses". Published in THD Foundations for Pavements and Lightweight Structures, Part I, Article 14.

Note: Sample 68-445-R referred to in Figure 8 was a hard limestone and has a PI of 5 and the following amounts of 0, 29, 64, and 88, respectively, retained on the 1-3/4, 7/8, No. 4 and No. 40 sieves. This information was inadvertently left out of Table 4.



Photograph 1

Large Electric Drying Oven

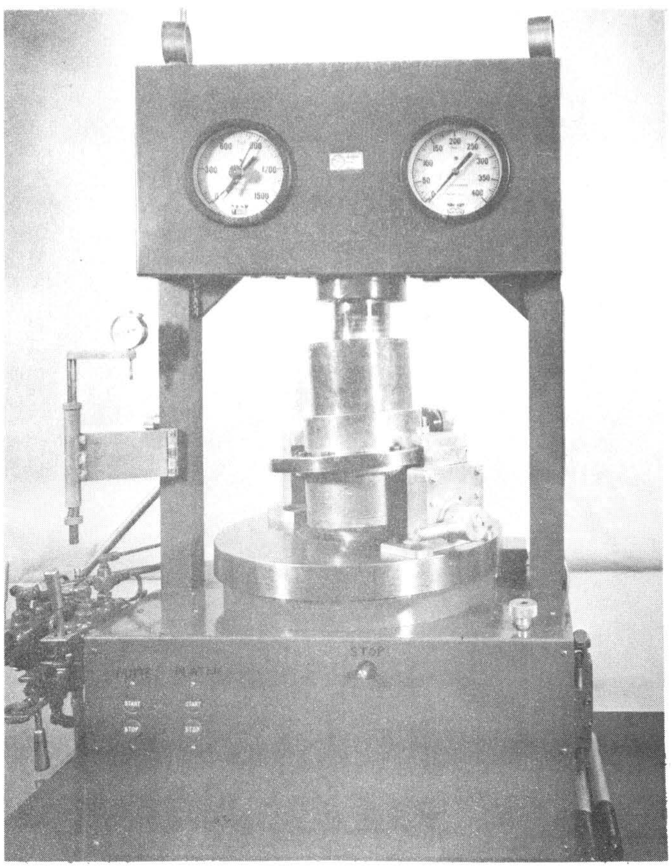


Photograph 2

Small Electric
Drying Oven

Photograph 3

Large Size Hotplate



Photograph 4

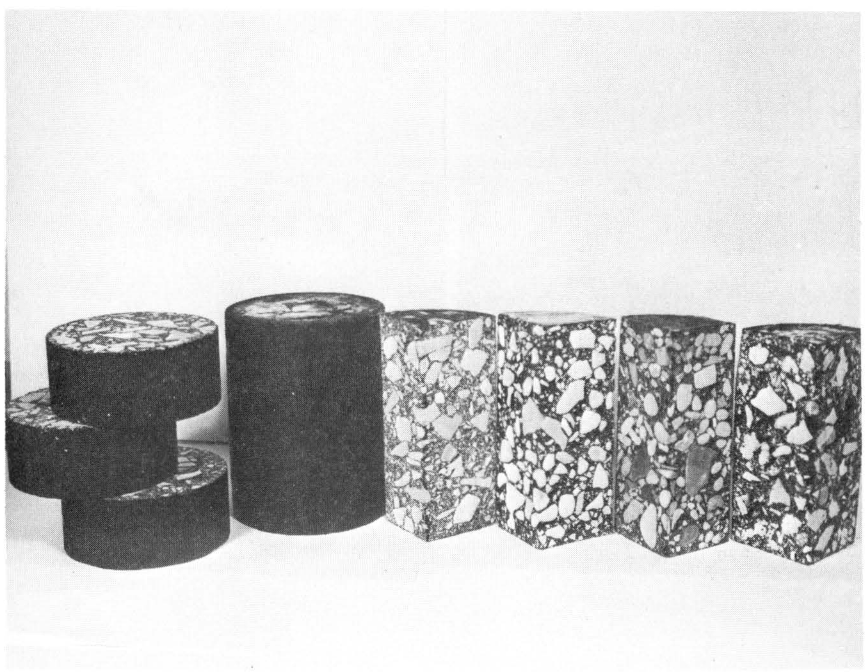
Motorized Gyratory Press and 6 x 12 Mold

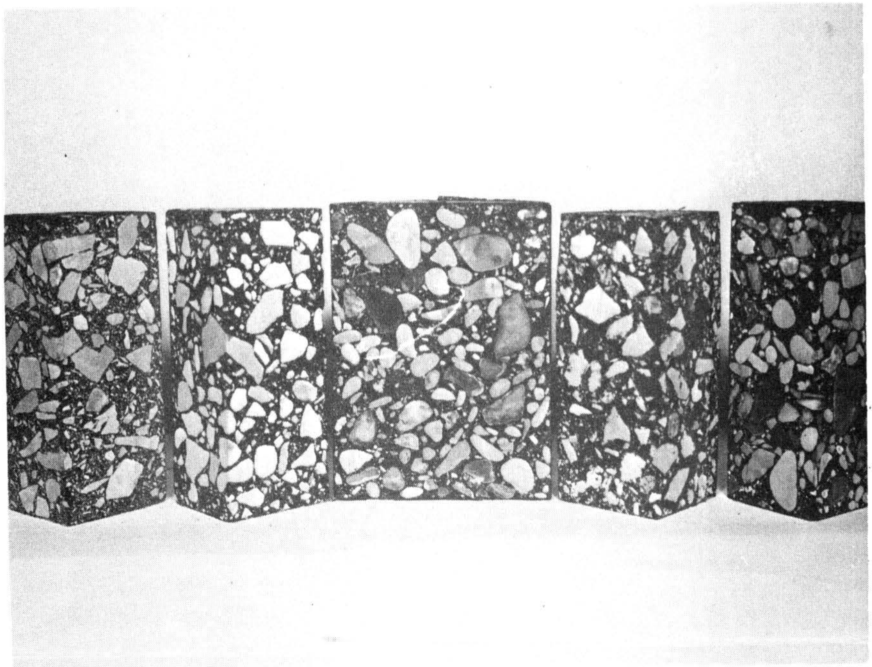
Photograph 5

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

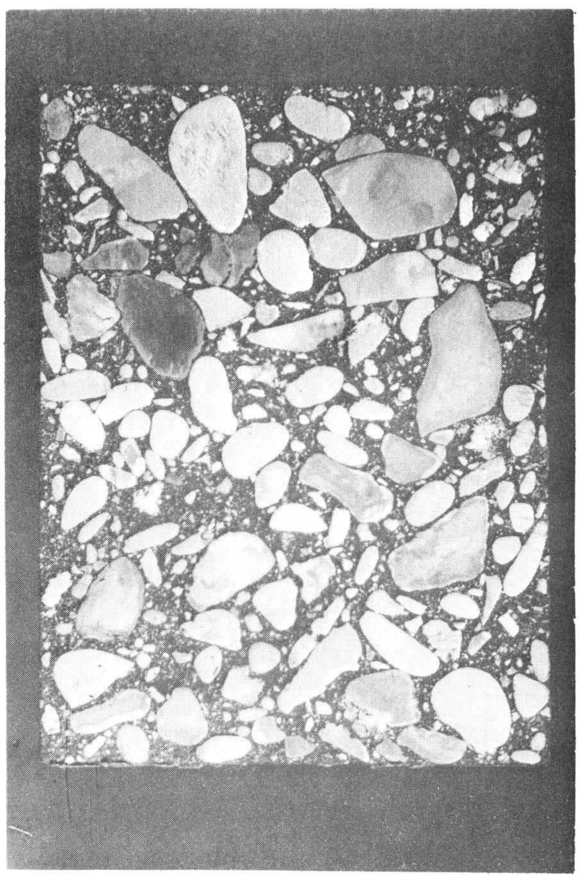
Photograph 6

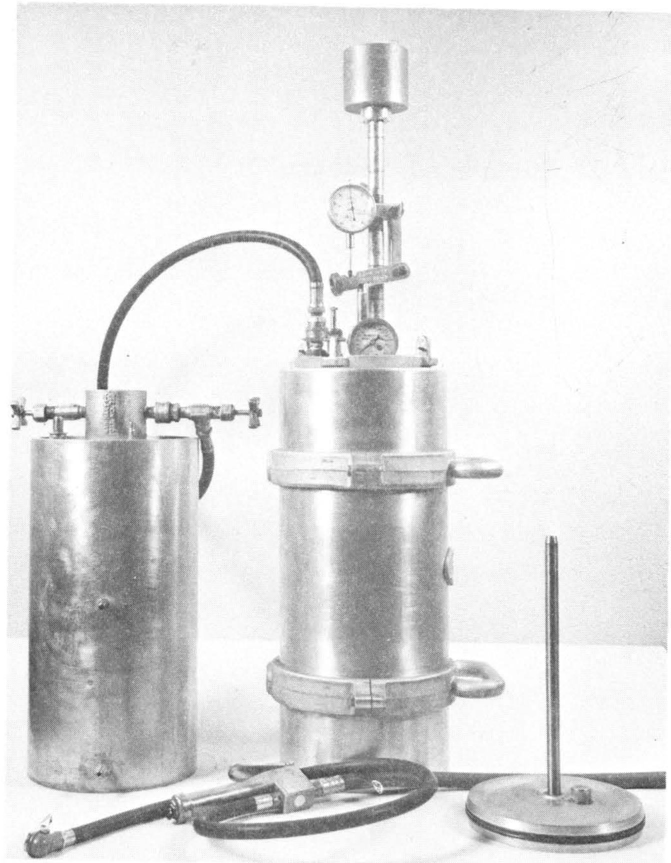
Showing one whole specimen and several sawed sections of specimens.





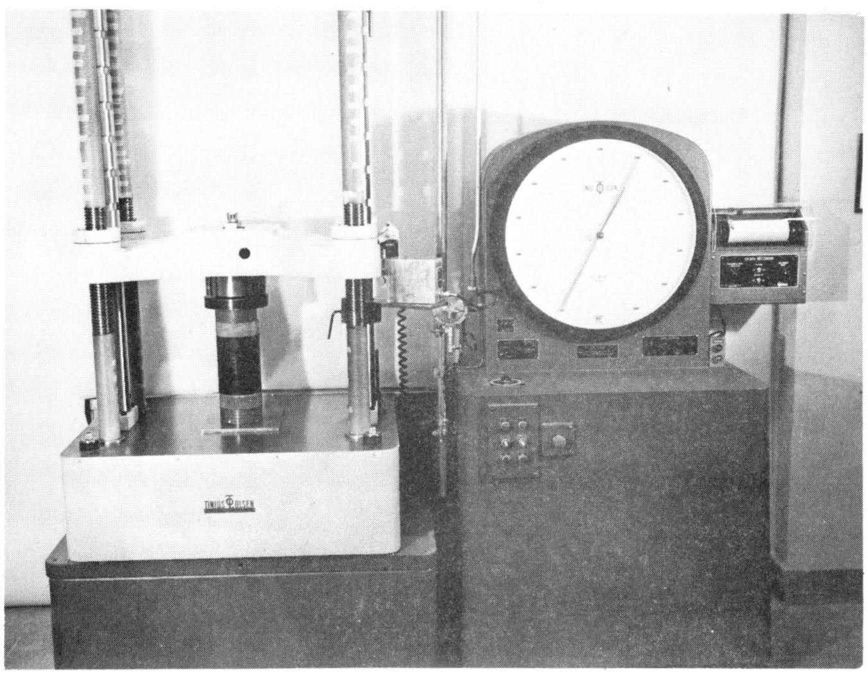
Photographs 7 and 8 Showing close ups of sawed faces.





Photograph 9

High Pressure
Pump and
Pycnometer



Photograph 10

Showing
high speed
testing
machine

TABLE 1

Inaccuracy of Saturated Surface Dry Specific Gravities

Lab. No.	Saturated Surface Dry Specific Gravities: 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

TABLE 2

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	

TABLE 3

Uniformity of Gyrated Specimens

Lab. No.	Spec.	No.	Percent 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

*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 pounds per cubic foot uncoated. Side voids, filled with paraffin, should be trimmed smooth, leaving a minimum of paraffin.

**AASHO T-166.

TABLE 4

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								Sieve Numbers							Grain Diam. In Millimeters			Spec. Grav.	Material
	3	2½	2	1¾	1¼	7/8	5/8	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.

TABLE 5

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

Lab. No.	Field Mix. No.	Sta. No.	Spec. No.	Increment 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.

TABLE 6

Use - Interpretation of Quality Mix Designations

Quality Mix Designation	Type of Traffic: Light Less than 200,000*	Type of Traffic: Medium 200,000 to 1,700,000*	Type of Traffic: 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.

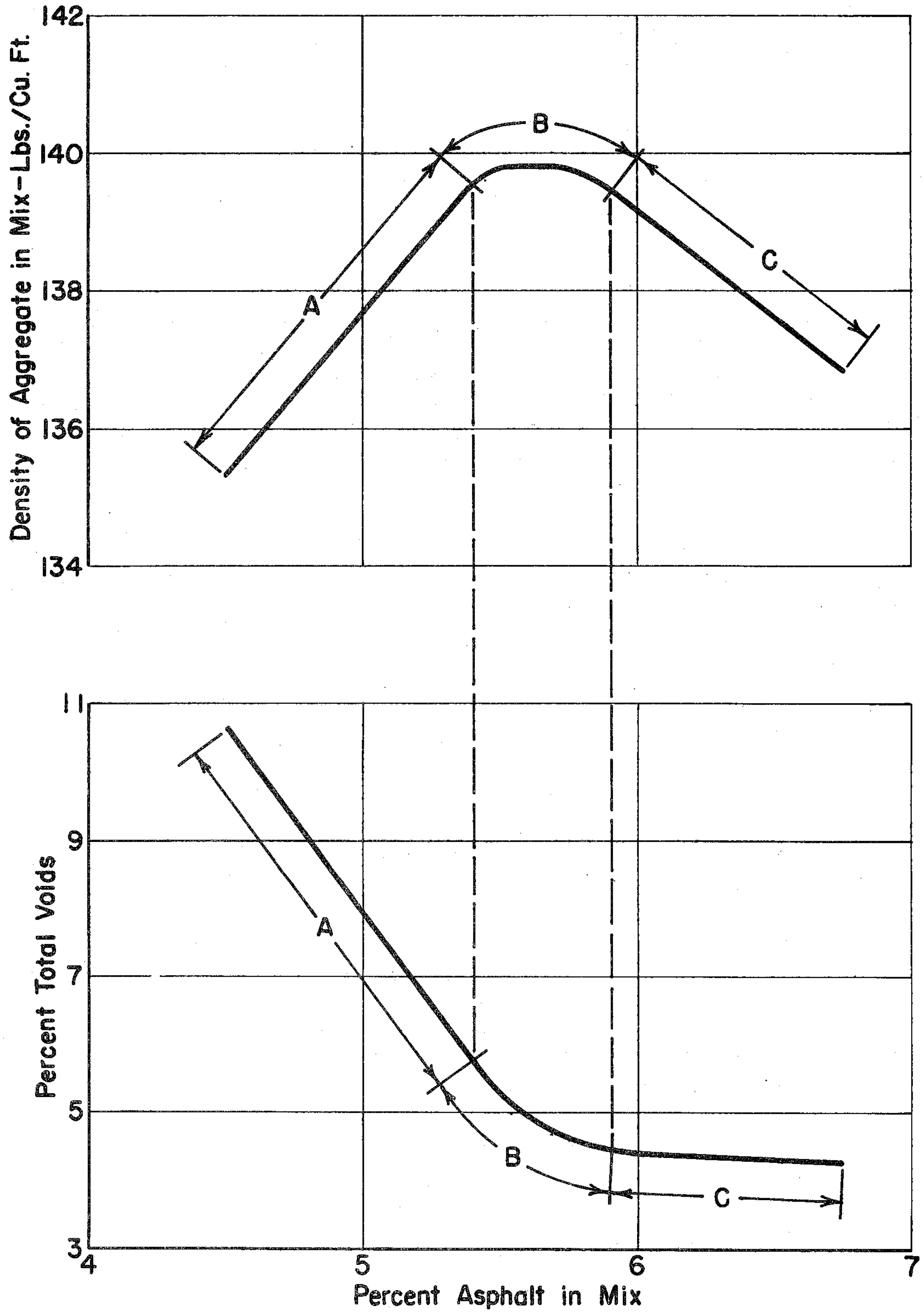


Figure 1, Compaction Characteristics of Hot Mix Black Base Mixtures

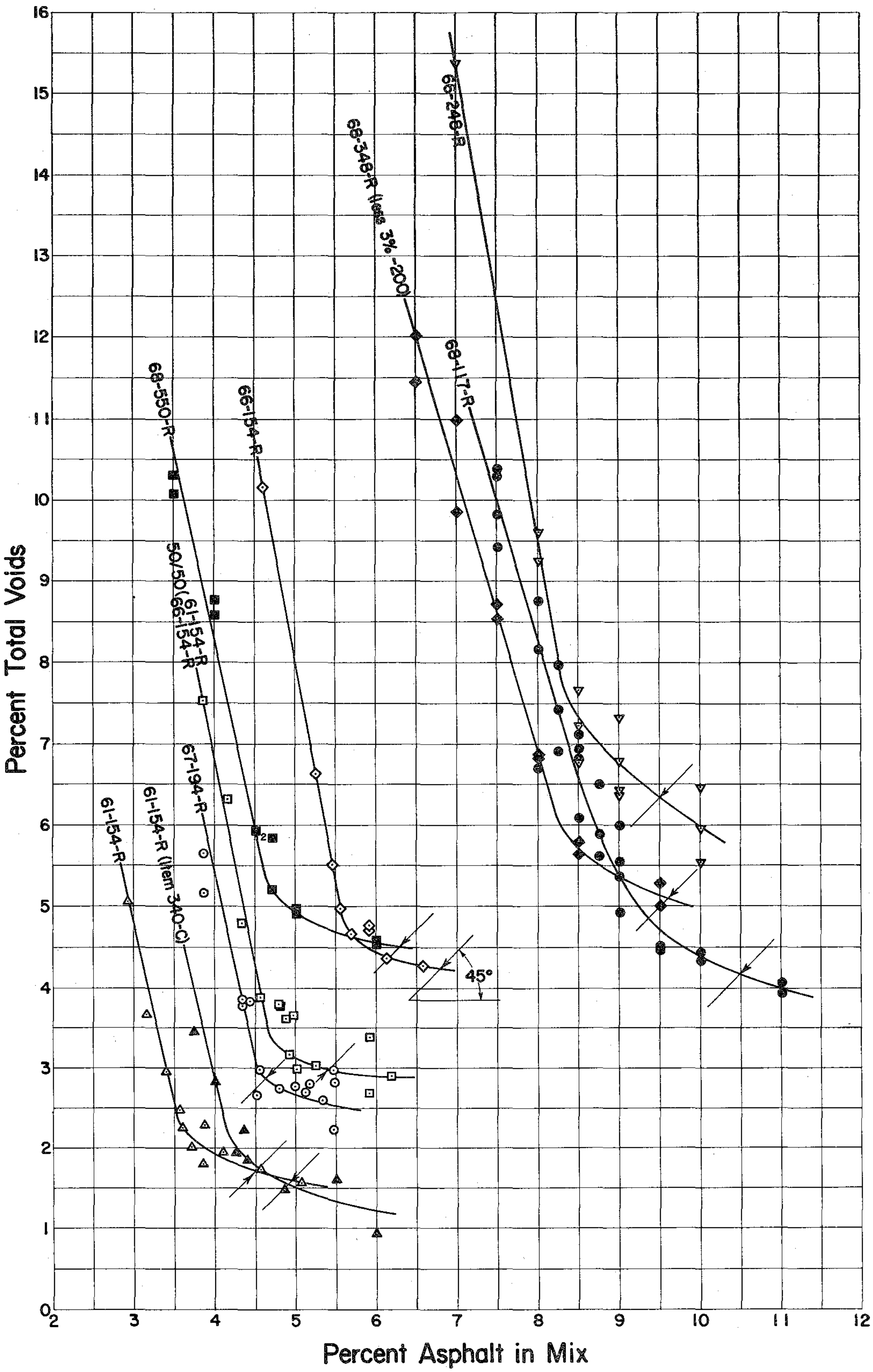


Figure 2
Typical Asphalt-Voids Ratio Curves for Several Types of Soil-Aggregate Materials

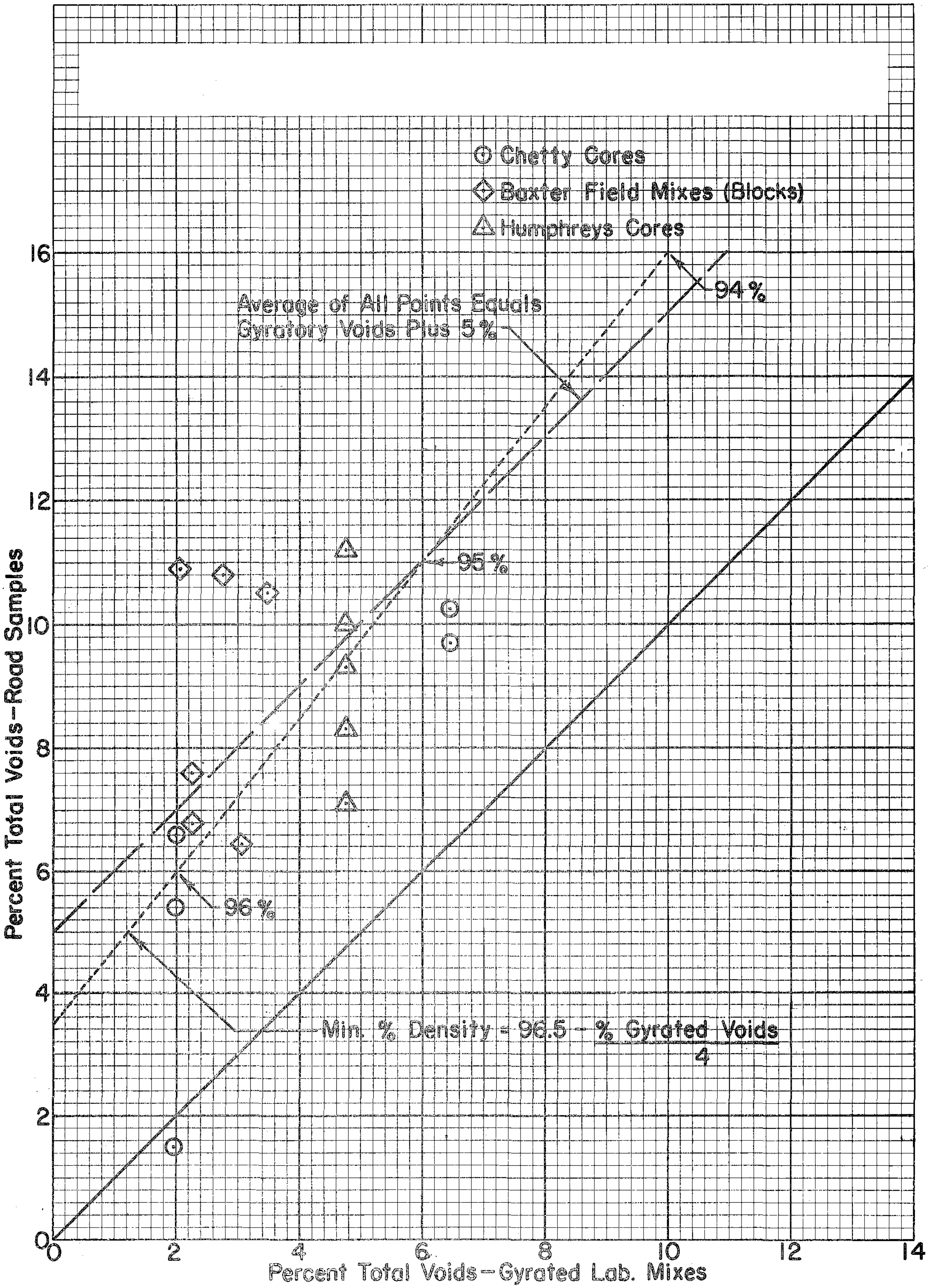


Figure 3, Comparison of Total Voids of Gyrated Mixtures with Road Sample Voids

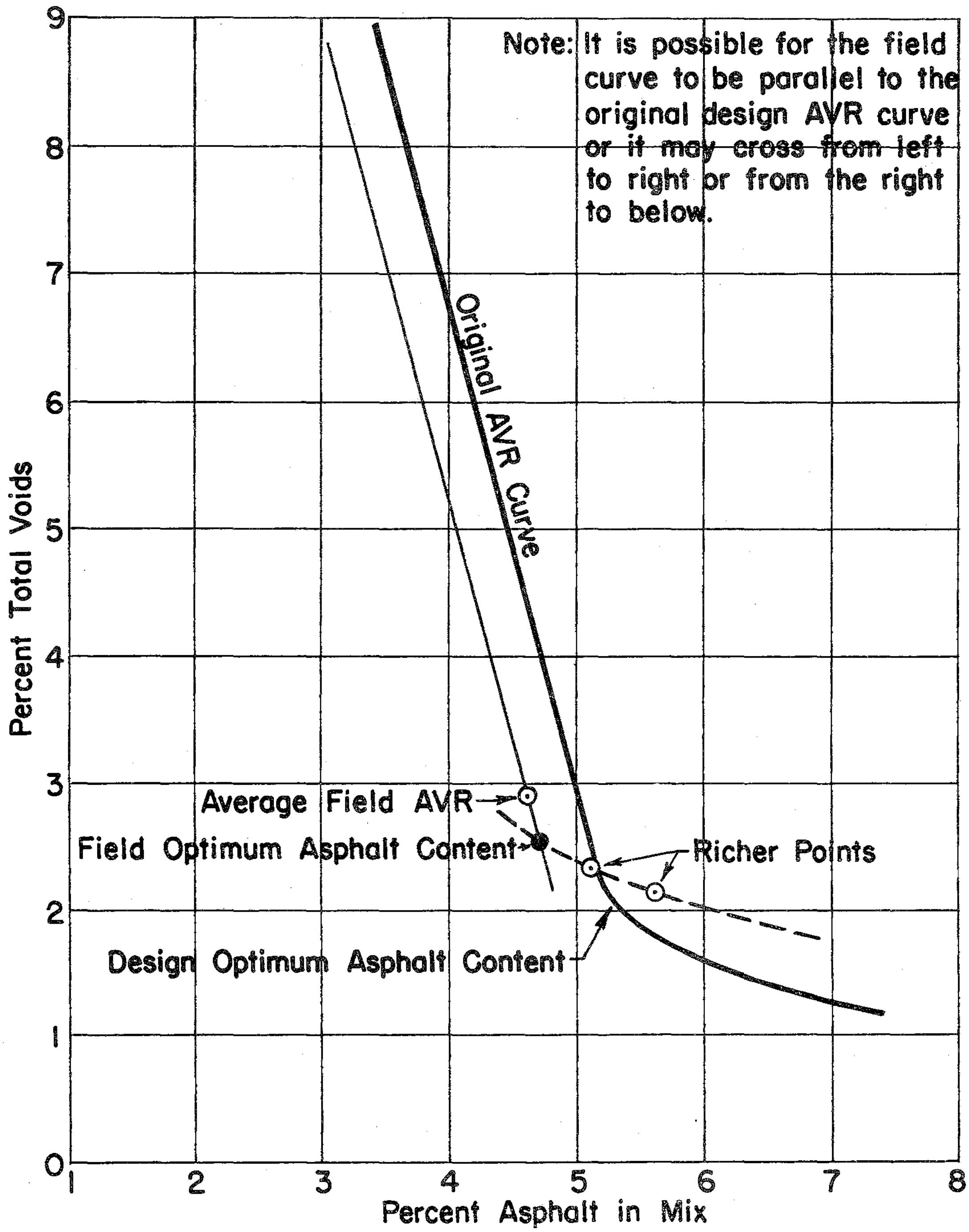


Figure 4, Asphalt-Voids Ratio Curve for Mixture and Voids Control

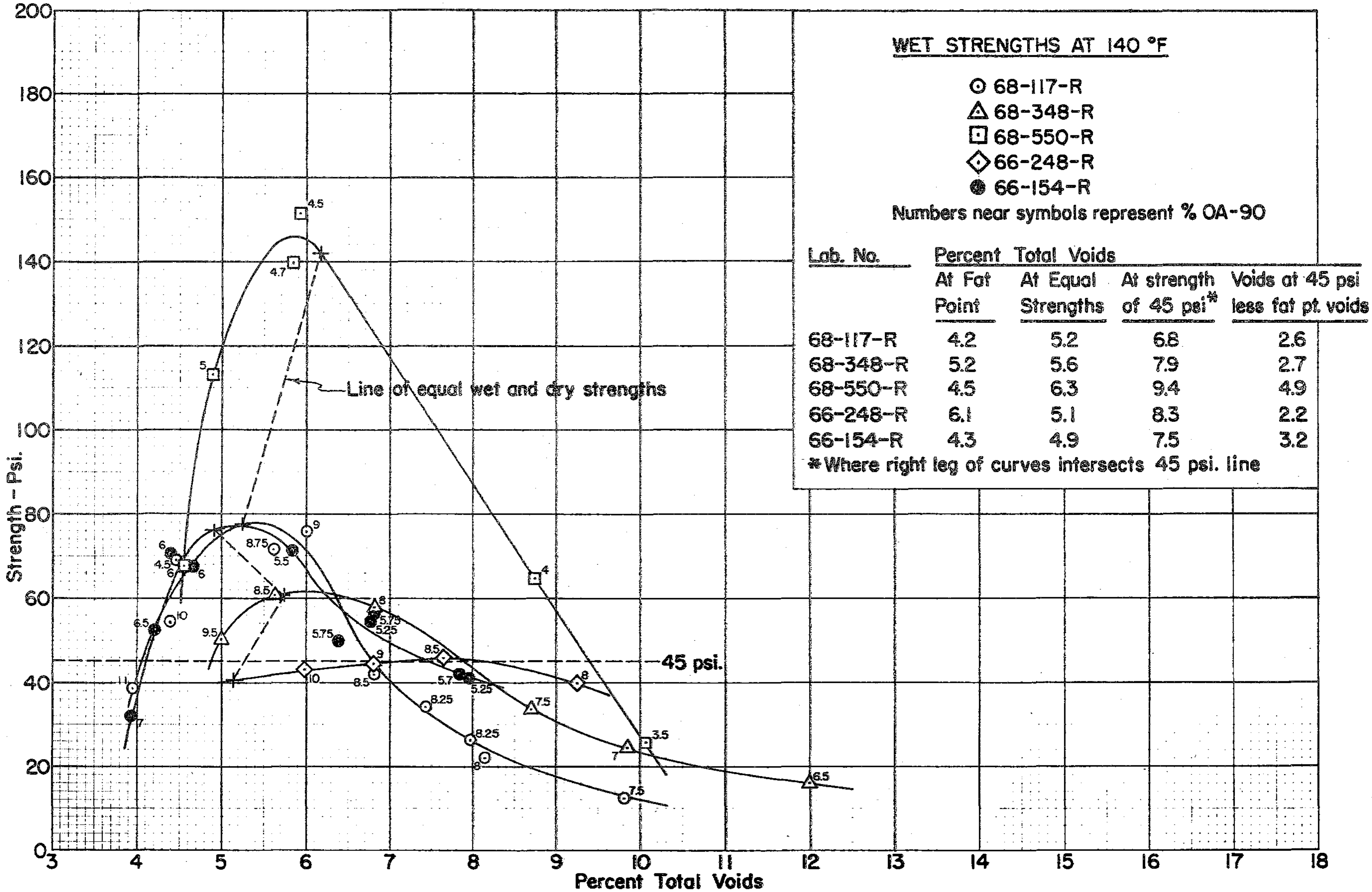


Figure 5, Relation on Percent Voids to Effect the Absorption on Strength

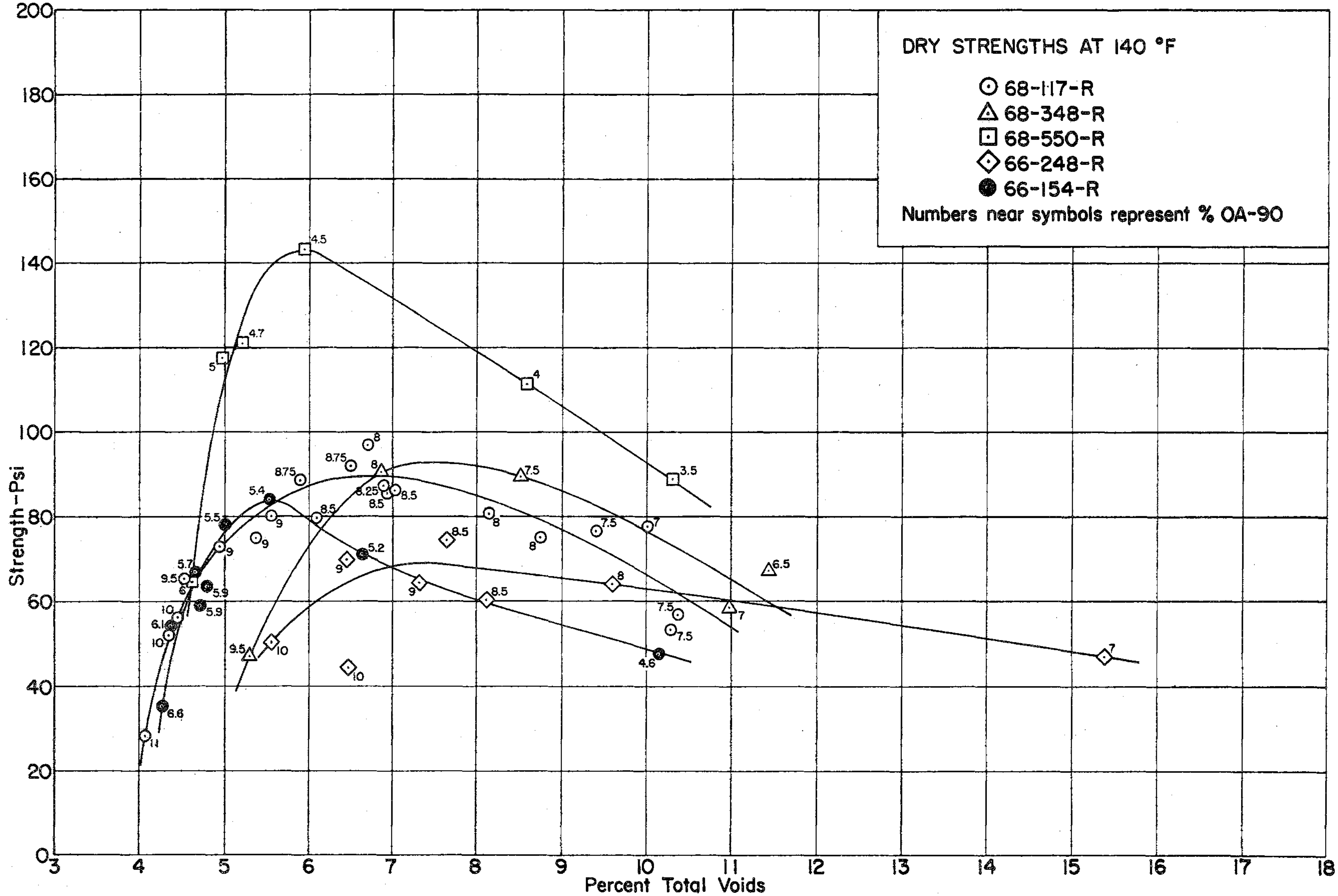


Figure 6, Relation of Percent Voids to Unwetted Strength

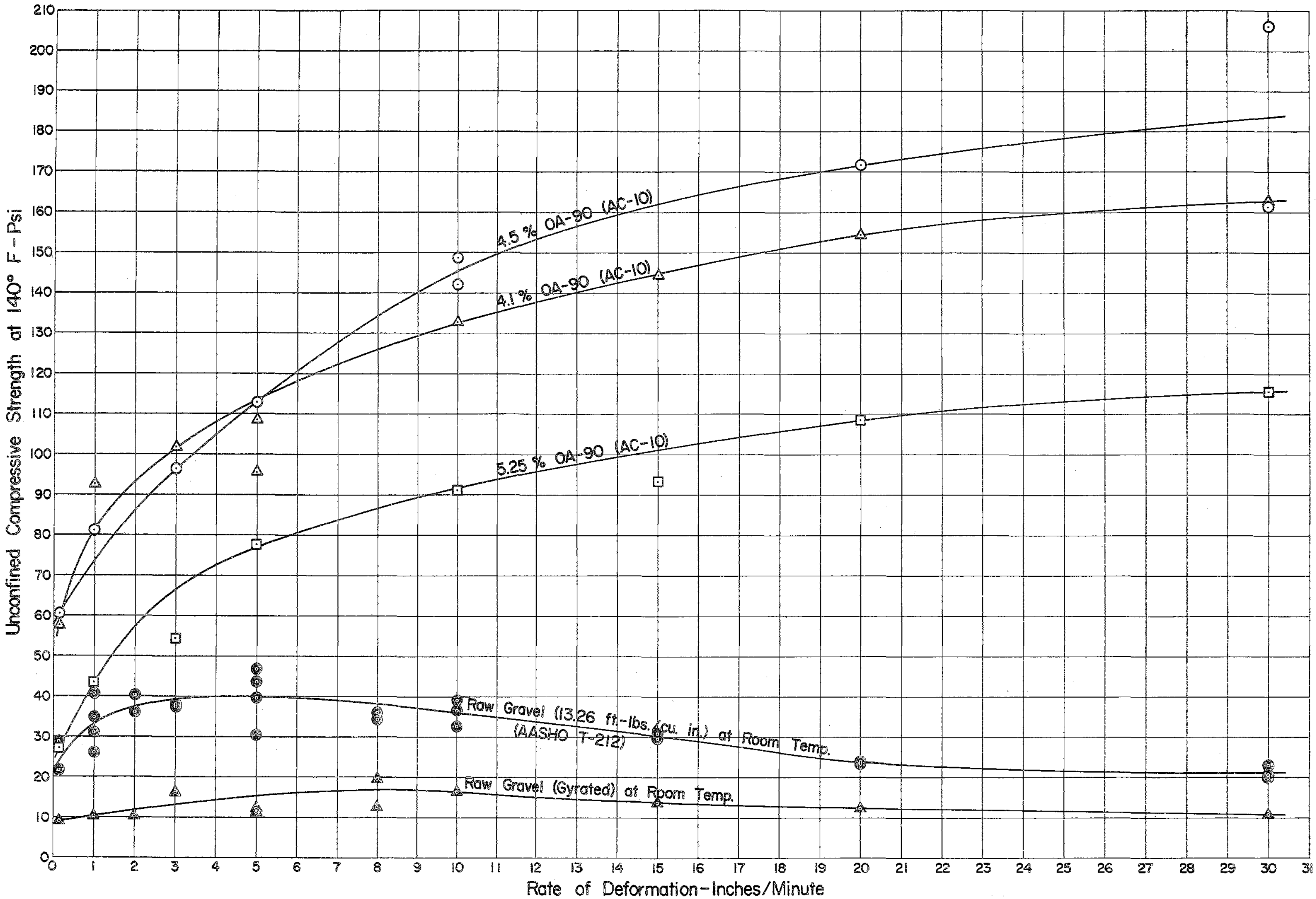


Figure 7, Effect of Rate of Loading Upon Strength of Gravel Mixtures

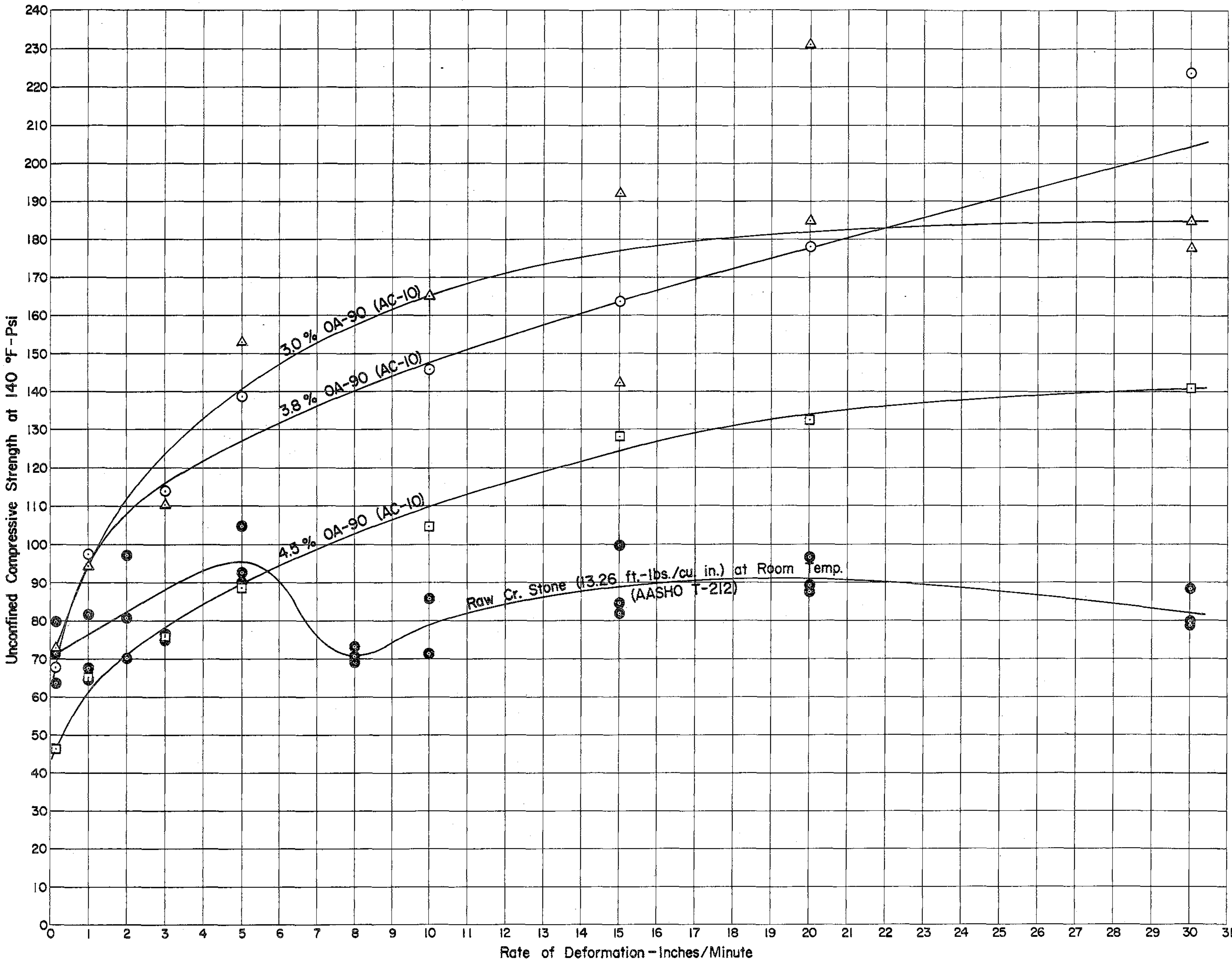


Figure 8, Effect of Rate of Loading on Strength of Crushed Stone Mixtures

66-154-R

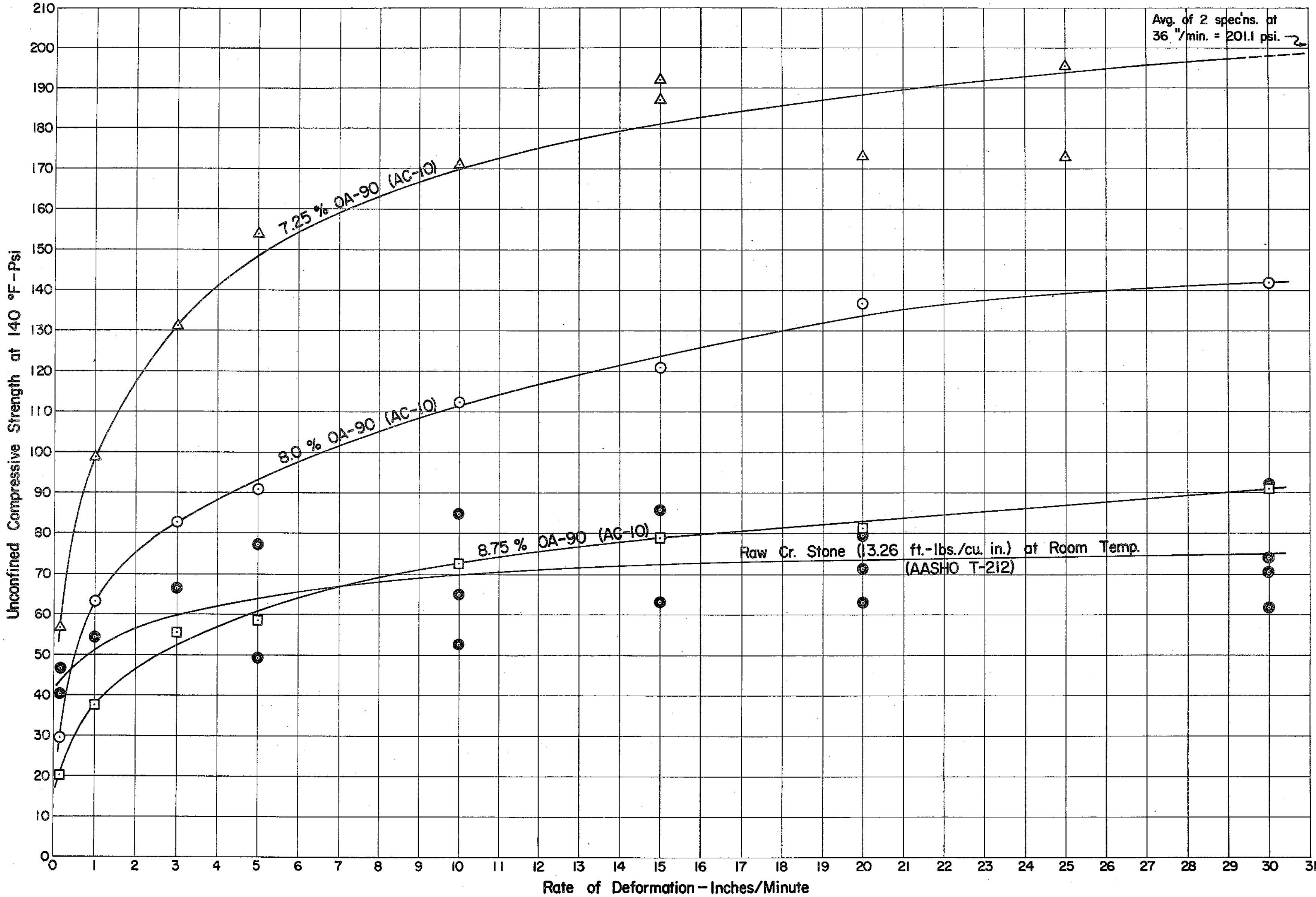


Figure 9, Effect of Rate of Loading on Strength of Crushed Stone Mixtures

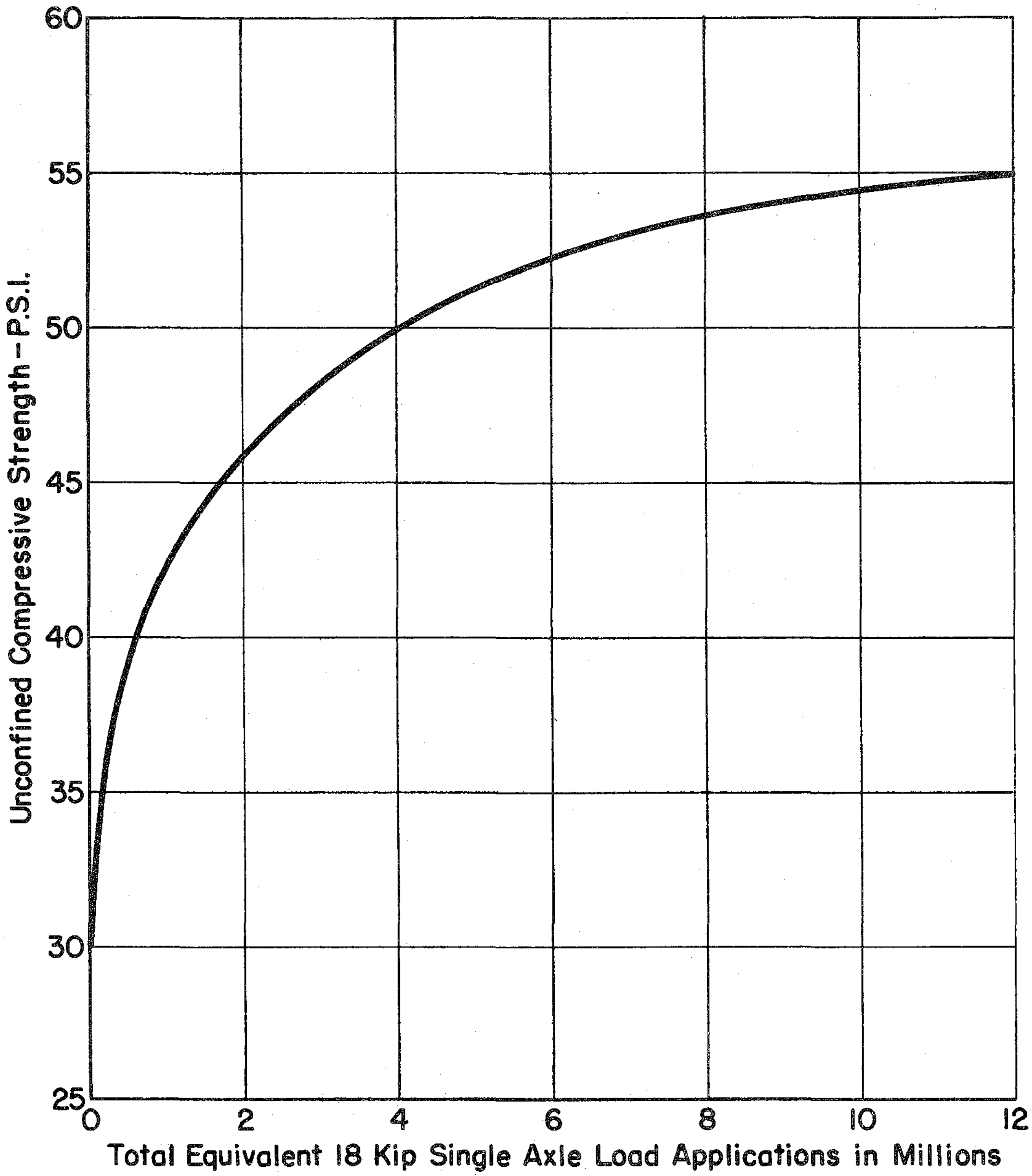


Figure 10
Relation of Unconfined Compressive Strength to Total 18 Kip Single Axle Load Applications

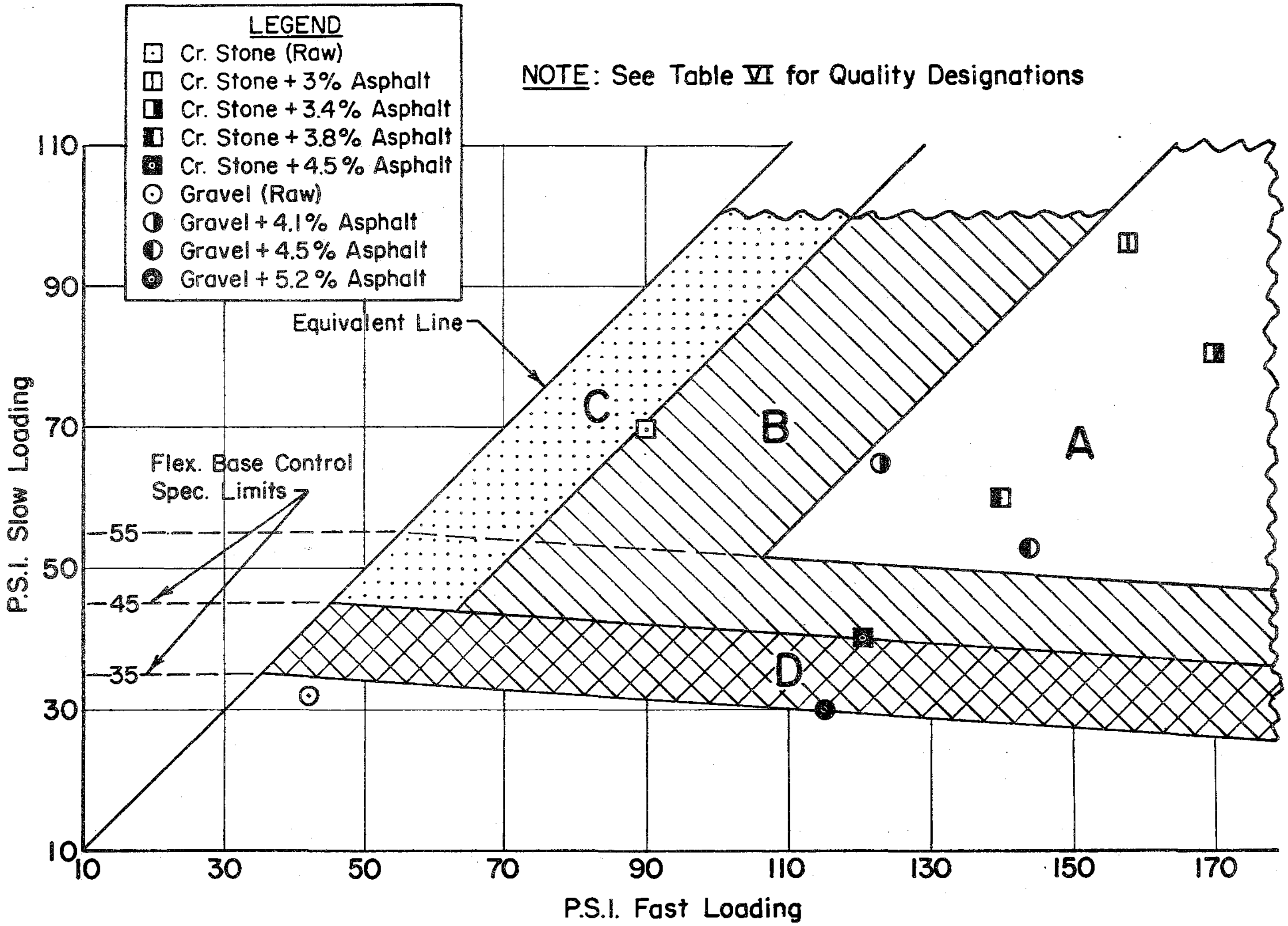


Figure 11, Quality Designation of Mixes

APPENDIX TO

DESIGN, CONTROL AND INTERPRETATION OF TESTS FOR BITUMINOUS HOT MIX BLACK BASE MIXTURES

Scope

This test method is intended for presenting the means for molding a hot mixed asphalt stabilized (black base) material, and for determining the relationship between the percent total voids and percent asphalt in the mixture. The method also describes the means for preparation of specimens for testing by pressure wetting using the long barrelled pycnometer; and then, it describes both a slow and a fast rate of deformation unconfined compressive test by which the material is graded or evaluated.

Briefly, the 6- by 8-in. size specimens are molded from prepared materials passing the 1-3/4 inch sieve using the large gyratory soils compactor to compact the hot soil and asphalt mixture. Later, the 140 F temperature specimens are pressure wetted by high pressure means and then duplicate specimens are tested unconfined using the slow test on one and the faster rate of deformation on the other.

From the testing process, strength parameters have been set up for three grades of black base, where Grade 1 would require a minimum thin surfacing (up to 3 inches*), Grade 2 something thicker (up to 4-1/2 inches*), and Grade 3 the thickest (up to 6 inches*) surface for comparable traffic. Grades 1, 2, and 3 should have the capability for use as subbase for other base layers or for concrete pavement.

For convenience to the user, this test method has been divided into seven sections as follows:

A. Procedure for Preparation of Materials

B. Procedure for Weight Batching of Materials to be Mixed

C. Procedure for Determining Specific Gravity

D. Procedure for Mixing and Molding Black Base Specimens and Determination of Percent Total Air Voids

E. Procedure for Pressure Wetting of Black Base Specimens

F. Procedure for Testing Black Base Specimens in Unconfined Compression

G. Determination of Field Density, Percent Total Voids, Percent Asphalt, Minimum Allowable and Actual Percent Density for Field Control

*Minimum thicknesses for very heavy traffic.

Procedures B, D, F, and G are presented in detail in this test method under Parts I, II, III, and IV, respectively.

Definitions

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

2. Minimum Allowable Percent Density: The minimum percent density allowed on a given black base material based on a sample of freshly gyrated road mix. It is further defined as $96.5 - \frac{\text{Percent Gyrated Voids}}{4}$ when the material gyrated in the fresh road mix is at or near the optimum asphalt content.

3. Actual Percent Density: The quotient obtained from the density of a roadway core divided by the density of the same roadway mix gyrated in the motorized gyratory press times 100.

4. 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.

5. 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.

6. Optimum Asphalt Content: The percent asphalt recommended for use from these procedures. The recommended percent asphalt is taken as the percentage slightly higher than the "break" in the AVR curve, unless field drying leaves some moisture in the aggregates. In such cases the amount at the break in the curve shall be reduced by the amount of moisture found in the field mixture.

Apparatus

1. All apparatus listed in items 2 through 6 in Test Method Tex-101-E.

2. All equipment listed in Part I, Test Method Tex-109-E, except item 2. The pycnometer shall have a barrel length of 18 inches.

3. Motorized Gyratory Press: A motorized compaction device (Figure 5) 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^{o} and shall have a hydraulic ram capable of maintaining a load of 500 psi on the gyrated specimen.

4. Compaction Mold: A 6-inch ± .030 inch I.D. and 12-inch ± 1/16 inch height forming mold with gyratory flange collar and mold base plate. (Figure 3) It is preferable, but not necessary, that the mold be chromium plated.

5. Set of standardized spacer blocks.

6. Press, to eject specimen from mold. (Figure 7)

7. Drying Oven, controlled to 230 F (110 C) ± 9 F.

8. Drying Oven, controlled to 400 F ± 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. (Figure 4)

11. Metal pans, approximately 21 inches by 15 inches by 4 inches for drying and mixing materials.

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

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

14. Filter paper, 6-inch 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.

19. Sieves: Standard U.S. woven wire sieves with square openings (ASTM 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. 4, No. 10, No. 20, and No. 40. A mechanical shaker is convenient, but not absolutely necessary.

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

21. Screw jack press from Test Method Tex-117-E, unless gyratory compactor is equipped for compression testing.

22. A supply of axial cells as described under Paragraph 2, Apparatus in Test Method Tex-117-E.

Test Record Forms

1. Record gyratory molding data on Gyratory Work Sheet. (Figure 8)

2. Record specific gravity data or other pycnometer data on Pressure Pycnometer Work Sheet. (Figure 12)

3. Record black base specimen testing information on Black Base Testing Data Work Sheet. (Figure 10)

4. Tabulate molding, strength, and moisture data for report purposes on Table No. __. (Figure 14)

Calibration of Equipment

Specimens approximately 6 inches in diameter and 8 inches in height are compacted in the 6- 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 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:

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

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.

Procedure for Preparation of Sample (Section A in Scope)

Prepare the material as follows:

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

2. The material should be prepared according to Part II, Test Method Tex-101-E.

PART I

Procedure for Weight Batching of Materials to be Mixed (Section B in Scope)

Note: To begin the asphalt-voids curve, a specimen must be weighed out and a beginning percentage of asphalt should be estimated. Proceed as follows:

1. Place a supply of asphalt to be used in the oven and heat for later use. Do not exceed 350 F.

2. Estimate the pounds of material, that when heated, mixed with the intended asphalt and gyratory molded, will fill the 6- by 12-in. gyratory mold to a specimen height of 8 inches.

3. 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.

4. Weigh up the specimen as calculated in step 3, keeping the plus No. 10 portion separated from the minus No. 10 portion.

5. 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. Heat to 350 F ± 20 F.

Note: It is intended that specimens be 8 inches ± 1/4 inch high when molded. In case the estimated weight for the first specimen is not in keeping with this tolerance, after molding, then adjust the weight to meet the height tolerance before weighing out other specimens.

Procedure for Determining Specific Gravity (Section C in Scope)

Determine the specific gravity of the raw woil, using a representative sample of the gradation to be used in the black base, according to Part I of Test Method Tex-109-E. The specific gravity of the asphalt to be used should be determined by using Test Method Tex-508-C, if an asphalt test report giving this value is unavailable.

Record the specific gravity data for the soil on Pressure Pycnometer Work Sheet, Figure 12.

PART II

Procedure for Mixing and Molding Black Base Specimens and Determination of Percent Total Air Voids (Section D in Scope)

Note: The 6- by 12-in. mold and base plate should be preheated in the 230 F oven in order to help retain the heat of the mixture during loading and gyration. Proceed to mix and mold the first specimen on the Asphalt-Voids Ratio Curve (AVR) as follows:

1. When the soil reaches approximately 350 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.

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. 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 disks 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.

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- by 8-in. 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- by 8-in. specimen may more than fill the 6- by 12-in. 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 $\pm$ 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.

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

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 5^{o} lift angle.

11. Using the machine controls, place a load of 35 psi gauge (20 psi specimen) with the loading ram on the specimen, and turn on the machine. Gyrate the specimen for two minutes at 35* psi gauge loading.

12. At the end of 2 minutes, increase the load to 69* psi gauge (40 psi specimen) and continue gyrating 2 minutes.

13. Then increase the load on the ram to 104* psi gauge (60 psi specimen), and continue gyration until the gauge needle will stand ready for five revolutions of the platen. This means that there has been no appreciable shortening or densification in the five revolutions. Turn the gyratory press 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 35 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 865 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 height of specimen (Figure 6). Hold the load on the specimen until the rate of consolidation is 0.005 inches or less in five minutes.

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

*To nearest pound on gauge.

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 a 6-inch porous stone on the bottom and place in the 140 F oven for storage if further testing for strengths is desired.

23. Calculate the volume and the density of specimen as follows:

a. Specimen Volume in cu ft = Height of Specimen in inches (step 18) x Calibration Factor of Mold (See Paragraph 3, Calibration of Equipment).

b. Density of Specimen in lb per cu ft =

$$\frac{\text{Weight of Specimen from Step 21}}{\text{Volume of Specimen}}$$

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 and the percent total voids of the specimen.

a. Combined specific gravity =

$$\frac{100}{\frac{\text{Percent Soil}}{G_1} + \frac{\text{Percent Asphalt in mix}}{G_2}}$$

Where: Percent Soil + Percent Asphalt = 100 percent, and

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.

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

c. Percent total voids =

$$\left(1 - \frac{\text{Density of Specimen}}{\text{ZAVD}}\right) 100$$

25. Record data on Gyratory Work Sheet (Figure 8).

26. Begin to make the AVR Curve for the material by plotting the first point for this specimen on the Percent Asphalt in Mix vs. Percent Total Voids Graph. (Figure 9)

27. Vary the percent asphalt in the mix, and mix, mold, and plot the results from enough specimens to clearly define the AVR Curve, more especially in the "hook" or break in the curve.

28. Mold duplicate specimens for each point. Where points have been made with extremely low asphalt contents and very high percent total voids and several other percentages of asphalt have been molded prior to the break in the curve, then it may be possible to omit that duplication. It may be molded later, if desired.

29. Store the fresh, hot molded specimen in the 140 F oven to await further testing or cooling in the case of just molded specimens. A supply of top porous stones should be kept in the oven, but should not be placed on the specimens because of a tendency to cause slumping. Very rich specimens should be spaced about 2 inches away from other specimens to prevent damage in the case of slumping.

Note: 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.

Procedure for Pressure Wetting of Black Base Specimens (Section E in Scope)

Pressure wet the black base specimens, except as noted below, according to Part IV of Test Method Tex-109-E. When water just slightly over 140 F is used, then the specimens may be tested for strength immediately. When specimens are less than about 5 F below the testing temperature (140 F), they should be stored with porous stones, plastic disks, and triaxial cells in place to heat in the 140 F oven.

Note: Begin pressure wetting of specimens where possible on the lean side of the asphalt on the AVR Curve. When the percent moisture induced by wetting is 0.25 percent by weight or less, then specimens of higher asphalt and lower void contents may be tested dry, or without pressure wetting.

PART III

Procedure for Testing Black Base Specimens in Unconfined Compression (Section F in Scope)

Foreword

The specimens made in duplicate should be tested in unconfined compression at 140 F after pressure wetting in hot water. One specimen should be tested slow at 0.15 inches per minute deformation, and the other at the fast rate of deformation at 10.0 inches per minute.

The triaxial testing press may be used, if desired, to perform the slow test and the gyratory compactor has the capacity to perform both the slow and fast tests. However, any testing press meeting ASTM Designation D 1633-59T requirements and having the deformation rate capabilities may be used.

Proceed to test as follows:

1. When the triaxial press is used to determine the strength at the slow rate of deformation (0.15 in per min), use the procedure as described in Section F, Testing Specimens, in Test Method Tex-117-E for the unconfined test.

a. Remove the specimen from the 140 F oven, remove the cell, obtain the weight, height, and circumference. Record these data on the data sheet, Black Base Testing Data Work Sheet, Figure 10.

b. Set up the unconfined specimen for testing as described in Test Method Tex-117-E and test. It will not be necessary to take any readings on the proving ring except the maximum readings. No area corrections are made.

c. When the test is completed, remove the specimen from the press and calculate the strength of the material.

$$\text{Unconfined strength, psi} = \frac{\text{Total Load in Pounds}}{\text{Original Area in Sq In}}$$

d. Record this strength on the data sheet in Paragraph a, above, under slow strength.

2. Most large gyratory soils compactors have the capability of performing both the slow and fast tests (0.15 in per min and 10.0 in per min). When this machine is used for testing, proceed as follows:

a. Prepare the specimens for testing as described in Paragraph 1a, above.

b. Place one of the thin, 18 gauge, metal disks on the platen to protect the surface from abrasion. Center the specimen, with top and bottom porous stones in place, on the disk in the machine. Place a thin metal disk on the top of the top stone. See Figure 11.

c. Using the controls on the machine, bring the top head down to just make contact with the specimen. Turn the machine off.

d. Set the controls on the machine for the speed desired, either o.15 in per min or 10.0 in per min.

e. Check the drag hands on the pressure gauges to see that they are at zero.

f. Start the machine and read the maximum reading on the gauge at failure. Watch this reading to insure against overthrow of the follower by the gauge needle. Record this value on Figure 10.

g. Since the ratio of the area of the specimen to the ram of the pump is 1.73 to 1 for a 6-inch diameter specimen, calculate the strength of the specimen as follows:

$$\text{Strength, psi} = \frac{\text{Gauge Reading, psi}}{1.73}$$

h. The specimens, having been molded in duplicate and pressure wetted, are tested at 140 F. One specimen is tested slow at 0.15 in per min, and the other the fast test at 10.0 in per min. Record all data on the data sheet.

i. Three grades have been established for black base on the basis of the fast and slow tests. They are Grades 1, 2, and 3 with minimum strengths as follows:

Grade No.	PSI Strength Slow (0.15 in per min)	PSI Strength Fast (10.0 in per min)
1	50	100
2	40	100
3	30	100

PART IV

Determination of Field Density, Percent Total Voids, Percent Asphalt, Minimum Allowable and Actual Percent Density for Field Control (Section G in Scope)

Foreword

Densities in the field should be determined from core samples, preferably using a 6-inch diameter size. Proceed to determine the density of a field core as follows:

1. Obtain the weight of specimen to the nearest estimated 0.001 pound.

2. Inspect the core for side voids. Where side voids occur, not due to loss of material during coring, fill the void with paraffin and trim off all excess paraffin with a sharp blade. Side voids in the specimen, caused by a loss of material from coring, and voids in the top and bottom surfaces should not be paraffin filled. Usually only a small amount of paraffin, if any, is required. Determine the weight of paraffin used.

3. Using the procedures of Section E, Procedure for Pressure Wetting of Black Base Specimens, above, pressure wet the core.

4. Remove the core from the pressure vessel, blot off excess water and weigh to the nearest estimated o.001 pound.

5. Record this data on Figure 12.

6. Using the procedures under Section C, Procedures for Determining Specific Gravity, the volume of the pressure wetted specimen must be determined.

a. Afrer the zero water determination has been made and just prior to entering the wet core into the zero water, weigh the wet core again. It will weigh less, due to evaporation and exudation.

(Insert Figure 12 - whole page)

b. Record this weight and determine the volume of the wet core by the procedures set forth above. Record volume.

c. Correct the volume obtained above by adding the difference between the two weights. (Weight from Paragraph 4, less weight from Paragraph 6a, above.)

d. Obtain the dry weight of the core and record.

e. Determine the density of the core in pounds per cubic foot as follows:

Density, lb per cu ft =

$$\frac{\text{Dry Weight of Core, Pounds}}{\text{Volume of Core in Cu Ft}}$$

Where: Volume of core in cubic feet equals volumetric pounds of solids displaced (or pycnometer determination) divided by 62.4.

f. Determine the combined specific gravity of the specimen as follows:

Combined Specific Gravity =

$$\frac{\text{Dry Weight of Core, Pounds}}{\text{(Corrected Volume)} - \text{(Wet Weight Saturated} - \text{Dry Weight)}}$$

Where: Corrected volume is in volumetric pounds of water in obtaining 6c, above.

g. Determine the zero air voids density, ZAVD, as follows:

ZAVD for core, lb per cu ft =

62.4 x Combined Specific Gravity

h. Determine the percent voids in the core as follows:

$$\text{Percent Voids} = \left(1 - \frac{\text{Core Density}}{\text{ZAVD}}\right) \times 100$$

i. When the specific gravities of the soil and asphalt are known, the percent asphalt in the mix can be determined by use of the pressure pycnometer by obtaining the combined specific gravity, of a core or specimen, by the procedures above. The percent asphalt can be calculated using the formula below.

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

Where: G_1 = Specific gravity of soil

G_2 = Specific gravity of asphalt

CG = Specific gravity of combined materials

7. Control tests for percent density and asphalt content.

a. Obtain a sufficient amount of fresh field mix to make several 6- by 8-in. specimens. Place the material in heat retention containers during transit and in a 230 F oven after arrival at the laboratory.

b. Using a sample splitter or other accepted methods, cut out enough fresh mix for a 6- by 8-in. specimen in a mixing pan and place the pan in the small electric drying oven and raise the temperature of the mixture to 260 F ± 20 F.

c. Using the procedures described in steps 7 through 29 of Part II, above, compact the material and obtain its void content. If the material was mixed using the field optimum asphalt content ± 1/4 percent, at least two more specimens should be molded using greater asphalt contents of, say, 10 to 20 percent more than is already in the mix. In any case, one specimen should have a minimum of 1/2 to 1 percent more asphalt than the original design optimum asphalt content. If field mixtures contain less than field optimum content, an additional rich point or two may be required.

d. Take the original AVR data obtained in Part II and construct the AVR design curve similar to the heavy line given in the example on Figure 13. Then plot the percent voids vs. asphalt for the specimens molded, above.

e. Through the leanest point determined in step c (preferably the average of two or three specimens), draw a line parallel to the lean leg of the original AVR curve. Through the average of the richer points, draw a curved line parallel to the rich or fat leg of the original AVR curve. (It is possible to have intermediate points on either leg.) The intersection of these lines is the optimum asphalt for the field mix. See example in Figure 13. If the aggregates retain moisture after spreading and prior to rolling, it may be necessary to reduce the optimum asphalt content in some proportion to the moisture content retained.

Note: Depending on the material, the curves may or may not cross or intersect one another. This makes no difference and should be of no concern. Small changes in gradation or blowing out of plant fines, etc. may cause the new curve to go right, left, up or down slightly from the original curve. Changes of over one percent in any of these directions may indicate the need for a new design curve. When the points are plotted from molding the field mixes and they fall to the right of the original AVR curve, the richer points should be spaced at greater increments of asphalt, usually, than those falling to the left.

f. The minimum allowable percent density in black base varies with compactability of materials. The range of percent density for most materials is from about 93 percent to 96 percent.

The minimum allowable percent of gyratory density to be obtained in the field shall be determined from the formula:

$$\text{Min. Percent Density} = 96.5 - \frac{\text{Percent Gyratory Voids}}{4}$$

Where: Gyratory voids are determined from fresh field mixes

The fresh mixes from the field should be taken, transported while hot and gyrated (molded) to insure that the mixture has not changed significantly. When cores are taken and the density determined in pounds per cubic foot, then the actual percent in place density shall be determined as follows:

Percent Actual in place density in field =

$$\frac{\text{Density of Core, lb per cu ft}}{\text{Gyratory Density, lb per cu ft}} \times 100$$

Cores should be taken and the "minimum allowable" and the "actual" percent density of black base should be determined a minimum of once per lane mile.

The nuclear density gauge or other methods, which are well correlated at above suggested intervals, may be used on the roadway during rolling as a rapid check on density, or percent density, while the mix is still hot and can be further densified as needed. The method used should be verified by coring once per lane mile. When the nuclear density gauge is being used, and has been well correlated with cores, the pressure pycnometer can be used on the fresh mix to determine the combined gravity of the mixture. The percent voids can then be calculated using the formula

$$\text{Percent Voids} = 100\left(1 - \frac{\text{Nuclear Density}}{62.4 \times \text{Comb. Sp. Gr.}}\right)$$

and

Percent Density =

$$\frac{\text{Nuclear Density, lb per cu ft}}{\text{Gyratory Density, lb per cu ft}} \times 100$$

g. When the specific gravity of the soil and asphalt is known, the percent asphalt can be found from a fresh mixture using the pressure pycnometer and the formula in Paragraph 6i, above. The percent asphalt should be determined once per lane mile minimum.

8. For reporting purposes summarize the testing data on Table No. __, Figure 14.

General Notes:

The use of the pressure pycnometer for determining specific gravities is based on the fact that air, and any other gases in the material being tested, is absorbed in the water at pressures well below the 1200 psi being applied. Also at 1200 psi, water is forced into the voids of the material to completely saturate it. This occurs much faster in some materials than others and is particularly noticeable in specific gravity determinations when the dial indicator needle continues to move while under 1200 psi pressure, even after 15 minutes. Therefore, in order to expedite the determination of the combined specific gravity (or asphalt determination) of a fresh field or plant mix of bituminous mixture (or a core taken from the pavement), it may be important that the material be well broken up and placed loose in a plastic bag in the pycnometer. The final reading on the dial indicator should not be taken until movement of the dial hand stops, even though fifteen minutes has been exceeded.

Occasionally when first beginning to gyrate some black base materials (usually made from fine grain soils), the mold may turn instead of gyrating when 35 psi gauge is applied. If this occurs, the operator should immediately increase the pressure to 69 psi gauge rather than letting the mold turn for two minutes. Should the mold continue to turn at 69 psi gauge, then increase the pressure to 104 gauge and accomplish all gyration at this pressure. In the event that the mold will not gyrate at 104 psi gauge, and will only turn, the operator should discard the specimen and remake the mixture using a greater amount of soil. The first amount is so loose in the mold that it will not gyrate at 104 psi gauge and this indicates a much shorter specimen than 8 inches high even if gyration could be accomplished.

Some of the large gyratory compactors have been modified with a different height measuring device. This device is front mounted at the bottom of the cover bonnet and has a steel strap mounted perpendicular to the machine platen to support the measuring dial. The magnetic height measuring yoke is provided with a flat smooth surface to make contact with the dial stem when the yoke is in position. The "zero" setting for this new device is the same as that described under Calibration of Equipment. The advantage of the new device is that it is placed in position as soon as the loose material has been shortened enough by gyration to place the measuring yoke on top of the top gyrating head. This is usually no later than the end of the first two minutes of gyration at 35 psi gauge pressure.

The height of specimen can be read directly at any desired time and, if desired, a time - density curve can be calculated and plotted.

The procedure for gyration is the same as described in Part II, paragraph 10 through 16 except that the new measuring device is placed in position as described above, and the end point as described in old paragraph 13 is reached when the rate of dial decrease is not greater than one division (.001 inch) in five revolutions of the platen. From the beginning, all dial readings are decreasing values until the end point is reached. It should be noted that during gyration that the dial needle will fluctuate some five to ten points on the dial during the latter stages of gyration but as the gyration nears the end (density nearing the maximum) the minimum reading of the dial needle approaches the same reading. This end point is easier to recognize by the operator and may save gyration time. After the 500 psi static load has been placed on the specimen and its end point determined, then continue the procedure as described beginning with Part II, paragraph 18.

When determining the percent asphalt through the use of the pressure pycnometer (see Paragraph 6i, above) it is suggested that the sample, pycnometer and water be at, or near, 90 F. More accuracy can be obtained by mixing test size batches of aggregate and known asphalt content, and determining the combined specific gravity (and asphalt content) at, say, 75 F, 90 F and 110 F. From these data the temperature giving the most accuracy can be extrapolated.

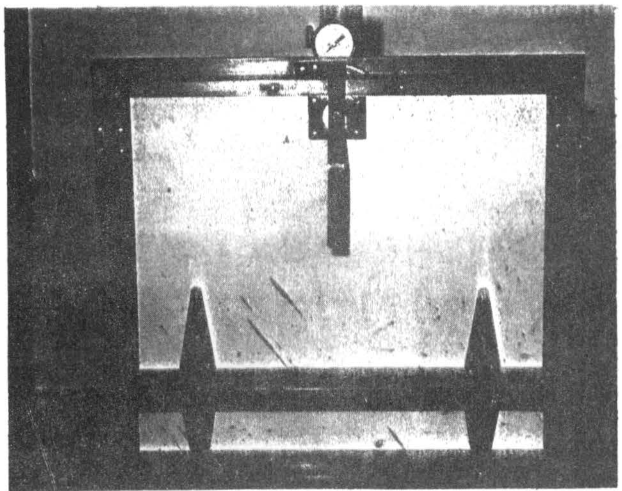


Figure 1. Small Electric Drying Oven

Figure 2. Mixing Specimen on Hot Plate

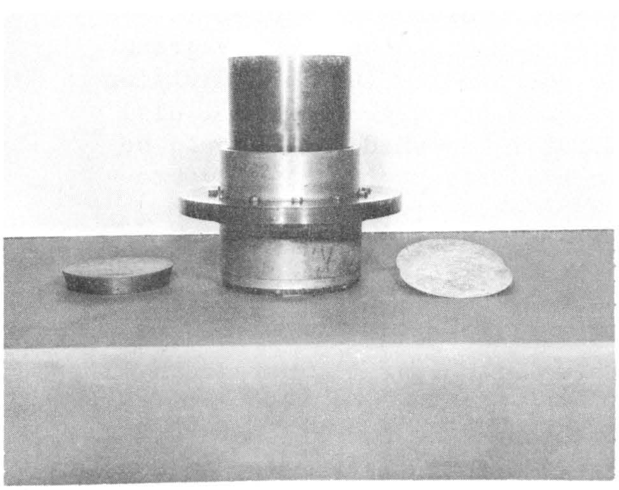


Figure 3. 6" x 12" Compaction Mold and Base Plate

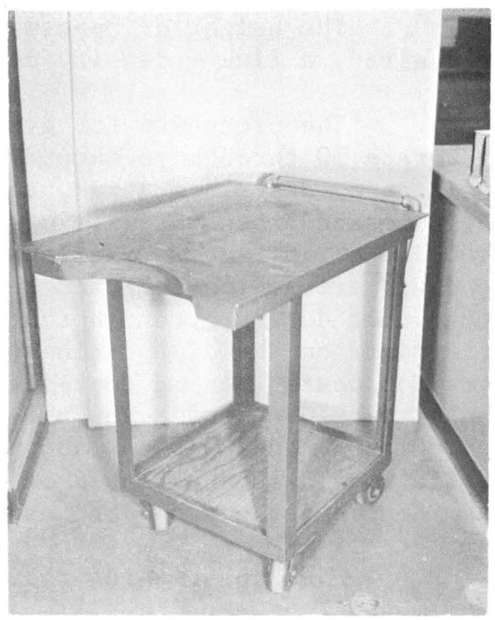


Figure 4. Caster Mounted Dolly

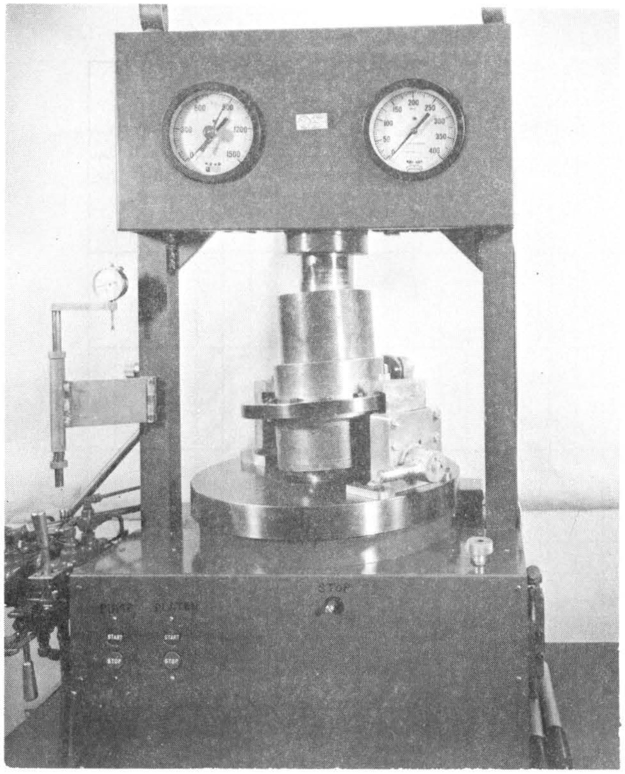


Figure 5. Motorized Gyratory Press and 6" x 12" Mold

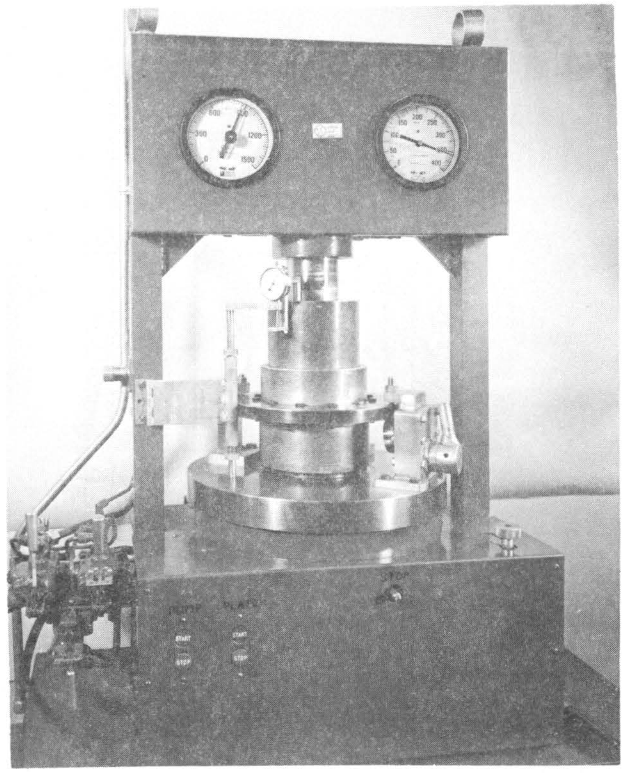


Figure 6. Measuring Height of Specimen

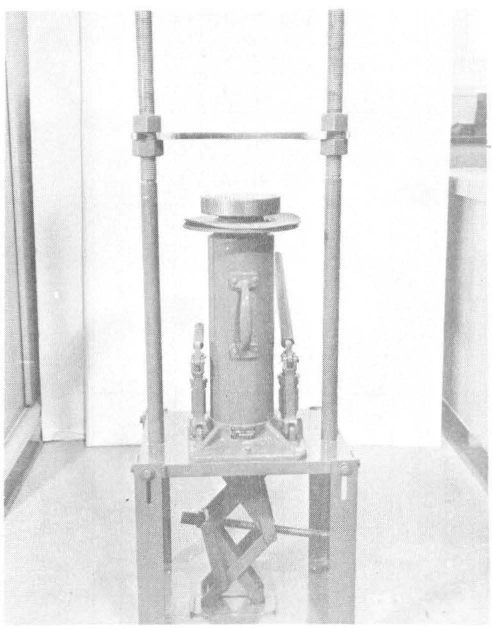


Figure 7. Ejection Press

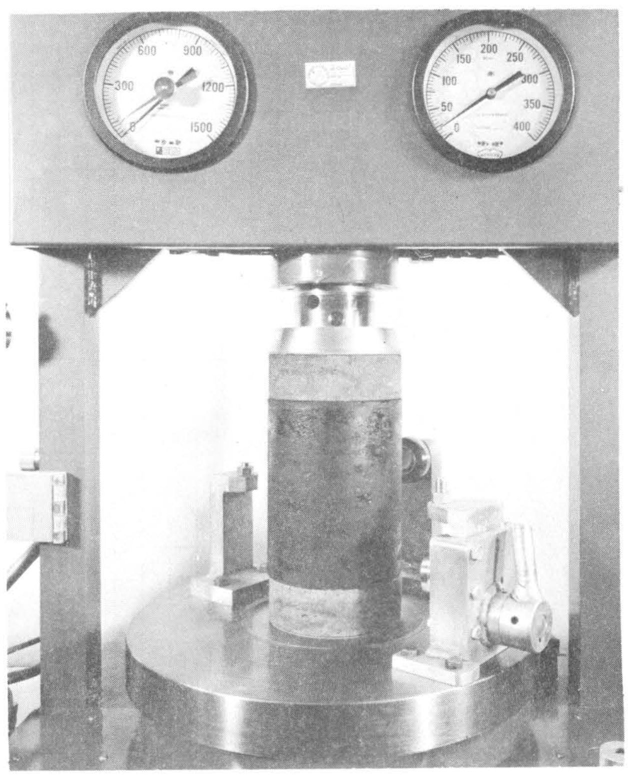


Figure 11. Motorized Testing Press Used in Testing Specimens

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															
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 8.

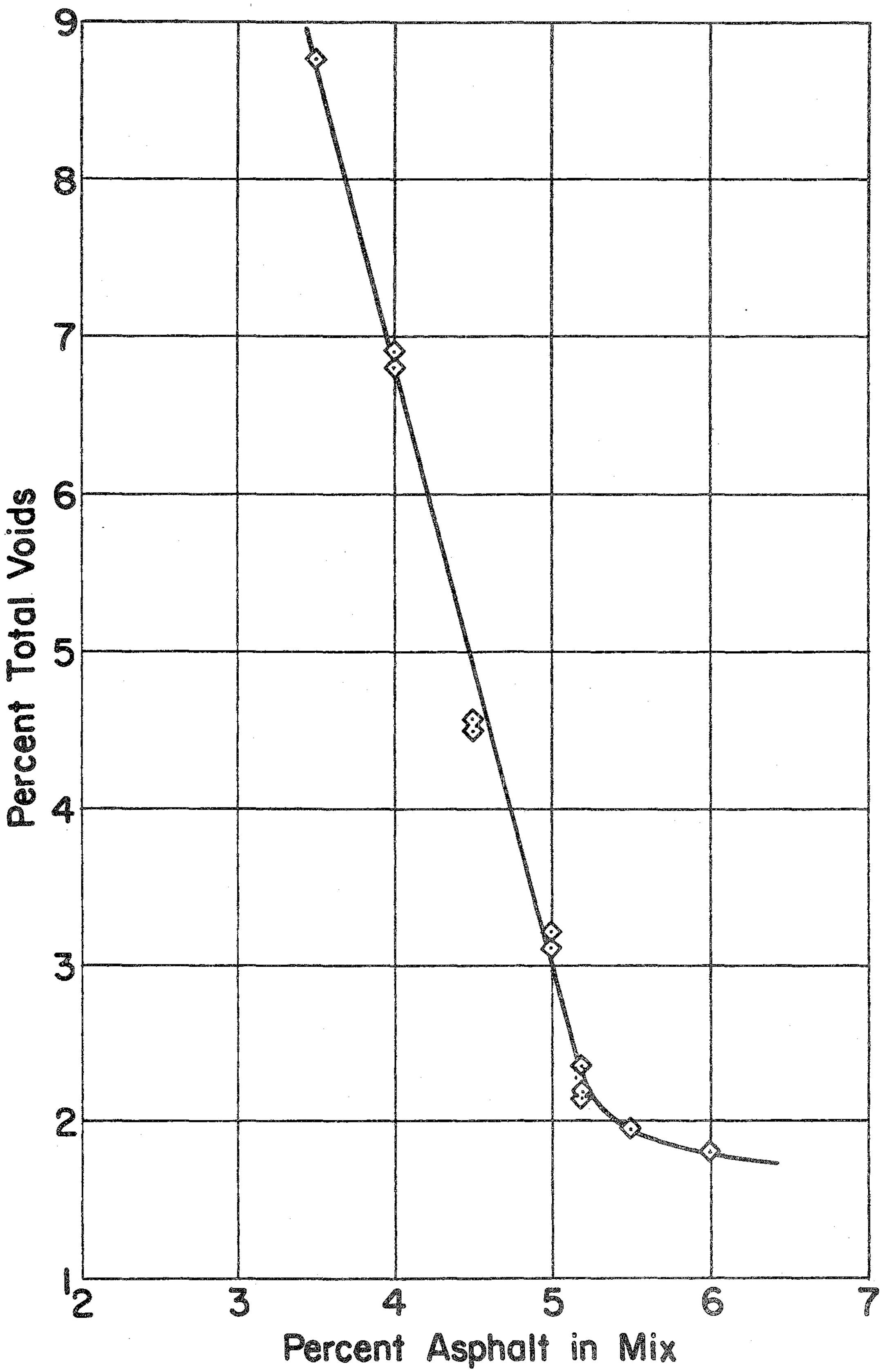

Figure 9. AVR Curve

BLACK BASE TESTING DATA WORK SHEET

Lab. No. ____________ Load Rate ________ in./min. Wet ________ Dry ________

Spec. No.	% AC-	Ht/Stones	Stones		Ht.	Circ.	Load		Temp. °F.	% H_2O
							PSI Gauge	On Spec.		

Figure 10. Black Base Testing Data Work Sheet

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 12.

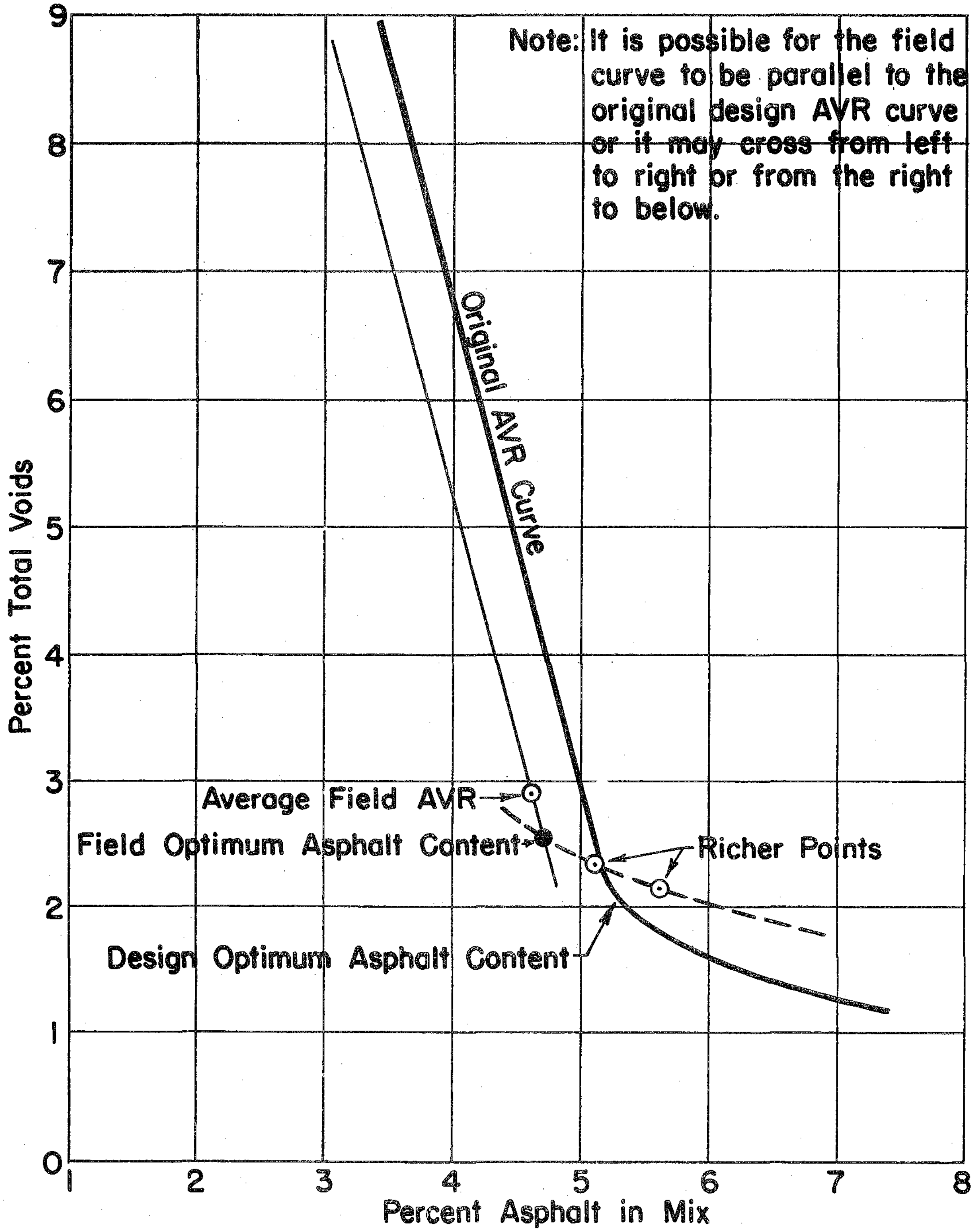

Figure 13. New AVR Curve

TABLE NO. ___

Lab. No. ______________ County ________________________ Highway __________________

Project ____ Identification ____________

Material ________________________________ Description ______________________________

____

____

Speci-men No.	Percent Asphalt in Mix	Dry Den. lbs./cu.ft.	% Total Voids	140°F Unconfined Strengths Wetted .15"/min.	140°F Unconfined Strengths Wetted 10"/min.	140°F Unconfined Strengths Dry .15"/min.	°F Test Temp.	% Moist. from Pres. Pyc.	% Moist. at Test

File 9.423

Figure 14. Table No. ___