

Commonwealth of Kentucky

Department of Highways

AN EVALUATION OF DENSITY AND STABILITY TESTS
ON BITUMINOUS MIXES

by

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INTRODUCTION

During the past three years the Highway Materials Research Laboratory has experimented with bituminous aggregate mixes in an attempt to determine the densities that can be obtained through certain methods of compaction and the stability of the resulting mixes. The several investigations have resulted in the preparation and testing of approximately six hundred individual samples, most of which were designed to provide information as a guide for specifications on particular field projects.

Since most of the results of these tests have already been applied to field construction which cannot be permanently evaluated for some time to come, it is well that the data be analyzed on the basis of comparative results among the several mixes in order that the applicability of compaction methods and stability test procedures can be determined.

With that in view, this report has been prepared and some recommendations relative to future laboratory procedures have been listed. Neither the results nor the proposals can be considered conclusive until final comparisons are made between samples compacted in the laboratory and those cut from existing pavements in the field.

DESCRIPTION OF PROJECTS

The data are divided into three classes according to research project numbers. This is so since each project was established to serve a particular function. The earliest of these, Project B-12, was applied to various materials available for resurfacing of U. S. 62 in McCracken County, while the second, Project B-13, dealt with similar aggregates and bituminous materials proposed for use in the construction of U. S. 68 in Marshall County. As a result of these experiments and the desire to obtain basic information concern-

ing a greater variety of aggregates, the pure laboratory study in Project B-14 was inaugurated. Here the number of aggregates and the gradations were increased while the bituminous material (PAC-5) was held constant throughout.

Project B-12

In the summer of 1944 an experimental project for the purpose of determining the feasibility of using local gravels in Western Kentucky was incorporated in the program. Some preliminary tests were made in the laboratory but the materials used hardly corresponded with those eventually placed in the binder and surface courses of U. S. 62 in McCracken County. For example, four different types of bituminous material were used in the field construction whereas only two were applied to the laboratory tests. Also the gradation of the aggregate in all the laboratory tests corresponded only with that of the binder course in the field although a number of the combinations of the aggregates were similar only with the surface course. Consequently, the results from the laboratory were only remotely connected with the field conditions.

A copy of an excellent report by Mr. Lee P. Ryer, District Engineer at Paducah, is appended to this manuscript in order to record the details of the field project. None of the samples tested in the laboratory were taken from the field mixes; rather these were prepared by combining the aggregates and bituminous materials in the correct proportions just prior to the time the laboratory samples were compacted.

Project B-13

A second field test road in which Western Kentucky gravels were of primary interest was constructed on U. S. 68 in Marshall County during the summer of 1945. Here preliminary tests were made on aggregates from three separate pits with three different bituminous materials in an attempt to

evaluate the various pits as well as to estimate the most desirable percentages of bitumen. In the construction of the road, gravel was taken from the Penny Pit and final tests were made on samples of this aggregate combined with PAC-5, PAC-7, RT-12 and MC-5. All of these were used in the construction of the field project for base, binder and surface courses.

The maximum size of aggregate in this experiment was smaller than that for the McCracken County project in that 100 percent of the material passed the 1 inch sieve and the percentages of bituminous material investigated in the laboratory were about the same as those that had been tried in the laboratory tests for the McCracken County project. A brief account of the field test road in Marshall County is included in the appendix at the close of this report.

Project B-14

After completing the laboratory tests and constructing the pavements included in Projects B-12 and B-13, the Department was interested in determining the effect of compaction on aggregates available in other sections of the state. Consequently, tests were arranged for river gravel and sand, limestone and sand, limestone, and slag. In addition, the gradation of the materials were varied in some instances and particular effort was made to confine some of the tests to base, binder, and surface courses as provided in the specifications for these materials. Asphalt cement, PAC-5, was used in all tests in amounts varying from four to ten percent.

MATERIALS AND PROCEDURES

In preparing the laboratory samples for densities and stability analyses the materials from various sources were treated in diverse ways in accordance with their origin. For example, the gravels proposed for use in Projects B-12 and B-13 were prepared for test only by excluding the material

larger than the maximum size specified or by combining the sand, lime, or Portland cement in the amounts that were previously determined. On the other hand, in Project B-14 the aggregates were crushed where necessary and in all cases separated into fractions required to produce an aggregate gradation within the limits of coarse, medium, and fine gradings for Class I surface material or appropriate gradations for base, binder, and surface courses. All the physical properties of the aggregates were determined elsewhere in order to make certain that the materials were acceptable under existing specifications.

Tests for bulk specific gravity were made on the aggregate to provide a means for determining the percentage of solid volume density for the compacted mixes. As in the case of the aggregates, tests on bituminous materials were performed elsewhere and only the specific gravities were used as a basis for computation in the laboratory test results.

The initial step in the preparation of laboratory samples consisted of heating the aggregate and the bituminous materials to appropriate temperatures that varied with aggregate gradation and type of bitumen (aggregate 265-300°F; bitumen 225-275°F). These were then combined and mixed by hand for a period not exceeding two minutes. Immediately upon completion of the mixing operation amounts of the material for individual specimens were placed in separate molds, and the temperature of the mixes was permitted to drop to approximately 225°F before compaction was started. Each of the molds was 4" in diameter and 2-3/4" in height.

Compaction was done by a standard procedure as follows:

- (1) Fifteen blows with an 18 pound weight dropped for a distance of 18 inches.
- (2) Collar removed and sample cut approximately flush with the top of the mold.

- (3) Ten additional blows with the hammer.
- (4) A static load of 7,000 lbs. (approximately 550 lbs. per square inch) applied for a period of two minutes.

The samples were then cooled in the molds over night and removed by compression with a piston and hand driven jack. Curing of the materials varied with the type of bituminous material, those containing cut-back asphalts being exposed to room temperature for a period of two weeks and all others being cured under the same conditions from twenty-four to forty-eight hours.

When the samples were ready for the stability tests, they were placed in a water bath at 140°F (+ 1°) for one hour after which they were removed and broken in the stability machine immediately.

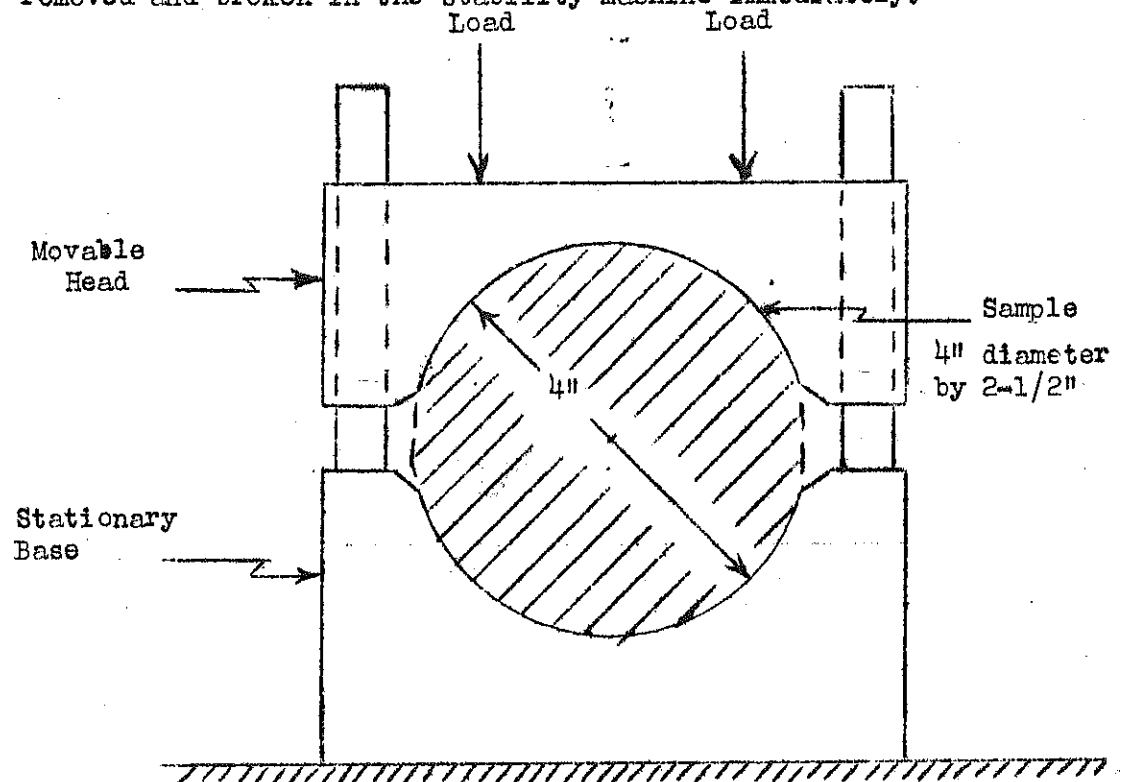


Fig. 1 - Stability Test Apparatus

For those samples that were tested in air at 140° F the procedure was varied only to the extent of exposing the mixes in an oven for an hour just prior to the loading operation.

In all the stability tests the specimens were placed in a split

mold 4" in diameter and loads were applied radially by a mechanical jack. The amount of load was measured by a proving ring and the rate of load application was not specific. All tests, regardless of the ultimate stability of the mix, were performed as rapidly as the loads could be applied with this equipment. Flow values represented by the deflection of the samples were determined through a plunger and sleeve attachment on the mold.

Permeability measurements on selected samples consisted of sealing specimens within a funnel by means of heated paraffin. A constant head of water was then maintained above the sample for a period of twenty-four hours and the amount (in pounds) of water that had percolated in that time interval was determined.

RESULTS

Any group of data influenced by several variables is difficult to analyze for specific relationships. Such is the case with the results tabulated in Table I. For this reason, a general differentiation has been established in Table II where the data are considered without respect to bitumen content or gradation of aggregates.

One of the most outstanding points established by these general relationships is the disparity between the weights per square yard and percentages of solid volume density. This, of course, is dependent upon the specific gravities of the aggregates, a factor which accounts for mixes with low weights yet contrastingly high degrees of density. This fact can be appreciated by comparisons between the listings for limestone and slag aggregates (Project B-14) in Table II, and the illustrations and computations made on page 7.

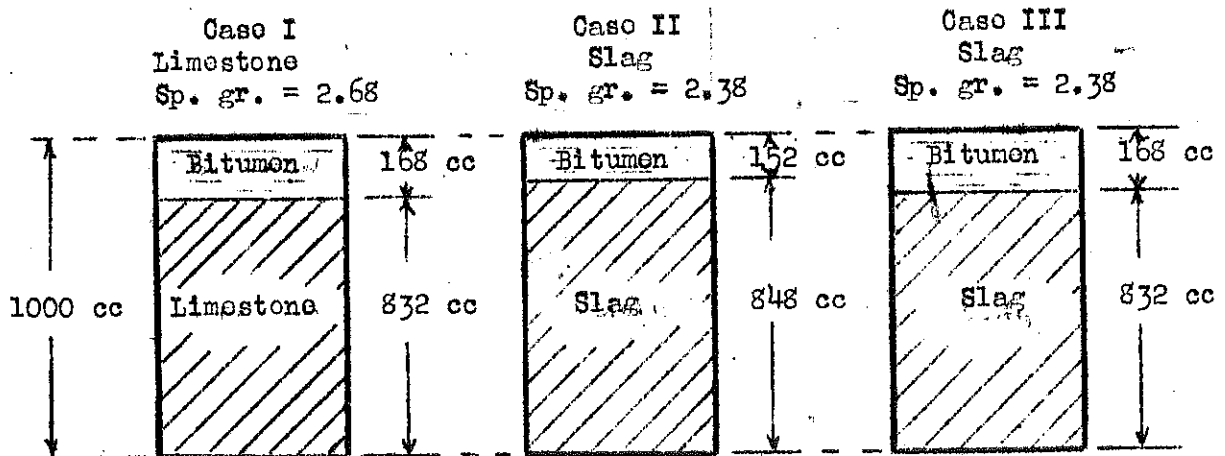
In general, the weights per square yard for all mixes containing gravel and slag aggregate were quite low. However, the ratings for these

Comparison Between Bituminous - Aggregate Mixes
on the basis of
Weight and Volumetric Relationships

The following illustrations and calculations show the comparative weights and volumes of constituents in bituminous - aggregate mixes proportioned so that:

- I - Bitumen is 7% by weight in combination with limestone.
- II - Bitumen is 7% by weight in combination with slag.
- III - Bitumen occupies same percentage of volume in combination with slag as it did in Case I when combined with limestone.

Sample in each instance = 1000 cc of mix



Case I - $W =$ total weight of mix

$$\text{Volume} = 1000 \text{ cc} = \frac{\text{weight of limestone}}{\text{sp. gr. of limestone}} + \frac{\text{weight of bitumen}}{\text{sp. gr. of bitumen}} = \frac{0.93W}{2.68} + \frac{0.07W}{1.0}$$

$$1000 = 0.347 W + 0.07W$$

$$W = \frac{1000}{0.417} = 2398 \text{ gm. of material}$$

$$\text{Weight of: Limestone} = 0.93 \times 2398 = 2230 \text{ gm.}$$

$$\text{Bitumen} = 0.07 \times 2398 = 168 \text{ gm.}$$

$$\text{Volume of: Limestone} = \frac{2230}{2.68} = 832 \text{ cc}$$

$$\text{Bitumen} = \frac{168}{1.0} = 168 \text{ cc total}$$

Case II - W = total weight of mix

$$\text{Volume} = 1000 \text{ cc} = \frac{\text{Weight of slag}}{\text{Sp. gr. of slag}} + \frac{\text{Weight of Bitumen}}{\text{Sp. gr. of Bitumen}} = \frac{0.93W}{2.38} + \frac{0.07W}{1.0}$$

$$1000 = 0.397W + 0.07W$$

$$W = \frac{1000}{0.461} = 2169 \text{ gm. of material}$$

$$\text{Weight of: Slag} = 0.93 \times 2169 = 2017 \text{ gm.}$$

$$\text{Bitumen} = 0.07 \times 2169 = 152 \text{ gm.}$$

$$\text{Volume of: Slag} = \frac{2017}{2.38} = 848 \text{ cc}$$

$$\text{Bitumen} = \frac{152}{1.0} = 152 \text{ cc total}$$

Case III -

In order to have same percentage of voids-filled, as in Case I, the volume of bitumen must be 168 cc, so:

$$\text{Volume} = 1000 \text{ cc} = \frac{\text{Weight of slag}}{2.38} + \frac{168}{1}$$

$$\begin{aligned} \text{Weight of Slag} &= 2.38 (1000 - 168) = 1980 \text{ gm.} \\ \text{Weight of Bitumen} &= 168 \text{ gm.} \\ \text{Total Weight} &= 2148 \text{ gm.} \end{aligned}$$

$$\text{Percentage of Bitumen} = \frac{168}{2148} = 7.8\%$$

SUMMARY:

Case	Aggregate	Pct. of Bitumen	Weight of Aggregate 1000 cc volume of mix	Total Weight of Mix
I	Limestone	7	2230	2398
II	Slag	7	2017	2169
III	Slag	7.5	1980	2148

materials were increased somewhat when comparisons were made on the basis of solid volume densities. Even then the densities of the gravel mixes were hardly above average for the combined groups.

The results of stability tests show that only the mixes containing limestone and slag aggregate had a great amount of resistance to loads applied in the Marshall stability tests. All of the samples composed almost entirely of gravel, sand or other rounded aggregates were exceptionally low in stability value and, in fact, almost half the specimens had stability numbers less than 300 pounds per square inch - a criterion sometimes used* for estimating the adequacy of bituminous mixes.

As indicated in Table I, an optimum bitumen content was determined in tests on only twenty-five of the forty-one groups of materials despite the fact that maximum amounts of bitumen were seldom lower than 8 percent and often ran as high as 10 percent. Although there is no definite reason for believing that future tests and observations will not prove the high percentages of bitumen to be desirable, there is a possibility that optimum bitumen contents determined by stability measurements may be in excess of those actually necessary for satisfactory field performance. In the tests for Project B-12, for example, an optimum bitumen content was determined for about 50 percent of the cases and in each case these were 8 percent. As shown by Mr. Lee Furryear's report in the appendix, adequate performance may result from mixes with percentages of bitumen somewhat lower than that value.

Because of the great variety of materials investigated, it is hardly possible to make a general statement concerning the consistency of results obtained in the stability tests. In fact, the disparity of results between preliminary and final tests on pit run gravel from the Penny Pit (Project B-12)

*See P. 17 of "Stability Investigation of Bituminous Pavements", presented to the Research Board on January 14, 1946.

tend to indicate that results are not accordant. On the other hand, general differences among the results of tests on all the mixes with gravel from Western Kentucky may mean that there is a wide variation in the properties of samples obtained from separate locations and even from different points within one pit.

One notable example of agreement between results of tests on similar materials at different times can be noted in the data for samples with slag and limestone aggregate (Project B-14). The first determinations on these mixes representing surface courses with medium and fine aggregate gradations were made in 1944, while the second tests were performed in January of this year. The results of these tests extracted from Table I and listed separately in Table III show that there is only a slight difference between the results derived from independent determinations.

The flow values and permeabilities of bituminous mixes analyzed in accordance with the methods used for these studies are somewhat erratic. It is difficult to reach any conclusions concerning these values other than to state certainly that the results are general and that a revision of methods for making these determinations are desirable.

CONCLUSIONS

Conclusions based on the data as they have been analyzed herein can be only tentative. However, they provide a basis for planning future investigations and for making alterations in the procedures as they are considered to be necessary. Some of the most significant of these are as follows:

- (1) Comparisons between the mixes with different aggregate materials can not be based wholly on the weight of compacted material per square yard. The intrinsic proper-

TABLE III

COMPARATIVE RESULTS OF STABILITY TESTS MADE IN 1944 AND 1946 ON SURFACE COURSE MIXES

Aggregate	Gradation	Percentage of Bitumen	Stability Number Determined in	
			1944	1946
Limestone	Medium	6	869	817.5
		7	995	905
		8	1108(optimum)	1080
	Fine	6	906	922.5
		7	1365(optimum)	1305
		8	1002	1055
Slag	Medium	7	679	713
		8	768	805
		9	900(optimum)	899
	Fine	7	691	705
		8	790	823
		9	976(optimum)	940

ties of the aggregates which influence volumetric and weight relationships are important and have considerable bearing on the percentages of bitumen that should be incorporated in the mix. (This corresponds with past methods for proportioning on the basis of voids filled or surface area coated).

- (2) The stability tests used in these investigations probably have little significance when applied to water worn or well rounded aggregate materials. On the other hand, it appears to be consistent and produces results within reasonable limits when applied to mixes containing aggregates that are angular in shape and have appreciable shearing resistance.
- (3) Flow values, if of any significance at all, should be determined more accurately by use of strain gauges measuring to at least 1/100 of an inch deflection.
- (4) Although the method of measuring permeabilities of bituminous aggregate mixes as employed in these tests may be accurate, the measurements should be extended for a period of more than twenty-four hours in order to obtain a rating for fine graded and somewhat impermeable combinations. A result indicating zero permeability is doubtlessly misleading and of little consequence.
- (5) Further research should be conducted using both the Marshall stability test and other methods of rating bituminous mixes for inherent strength. Tests on samples prepared in the laboratory should be supplemented by tests on

cores representing pavements with good service records as well as pavements that have failed for reasons attributable only to the mix itself.