

Commonwealth of Kentucky
Department of Highways

PROPOSED FIELD AND LABORATORY STUDY
of
FLEXIBLE PAVEMENTS

by

The Highway Materials Research Laboratory
Lexington, Kentucky

March, 1946

(Project B-15)

Research into the problem of the design and control of flexible pavement construction has resulted in the use of empirical and arbitrary solutions consisting of general theories for determining pavement thickness, gradation of aggregate, percent of bitumen, base requirements, etc. A desirable method would be one that is applicable to all aggregate, bitumen, and subgrade conditions. Until such a procedure is available, a determination of the best application and a research study as to the proper significance of existing procedures are the immediate problems of highway engineers.

In order to evaluate present methods as applied to the problems specific to Kentucky, a study is proposed that is designed to arrive at the most satisfactory solution using materials locally available. By correlating past endeavors of the Highway Research Laboratory, other highway and research experiences, and new studies in the field and laboratory, it is reasonable to anticipate that performance characteristics will be predictable for the various aggregate-bitumen mixtures.

PREVIOUS INVESTIGATIONS

An unpublished report on Research Project B-3 (carried out in 1941) presents an interesting circular track study. In the investigation a compari-

son was made between a sandstone (99% loss after 500 revolutions in Los Angeles abrasion test; 56.9% loss at 5 alternations in sodium sulphate soundness test) and a limestone (28% loss after 500 revolutions in Los Angeles abrasion test; 1.6% loss at 5 alternations in sodium sulphate soundness test). The conditions were the same for each and the following statements were made in the summary:

- (a) The sandstone showed no surface ravelling or stripping, the limestone failed to the point when the surface was no longer serviceable.
- (b) In the base, limestones showed approximately 75% stripping, the sandstone 2%.
- (c) After 40 cycles of freeze and thaw, there was serious disintegration in the limestone, none in the sandstone.
- (d) The sandstone showed three to five times the skid resistance as the limestone.

A study of bituminous construction using sandstone aggregates was reported (4) to the Board on January 14, 1943. The gradation, bitumen content, and performance of various sections of Kentucky Route 40 were noted in two inspection trips within a year after construction. From this study the investigators concluded that: (a) Bitumen content of sandstone-bitumen mixtures should lie between 8.5% and 9.5%. (b) For surface material all aggregate should pass the #4 sieve.

Another investigation by Messrs. Curtis Cantrill and Cary Burns (6) was reported on March 5, 1945. This covered a laboratory investigation of three types of aggregates: river sand and gravel; limestone; and slag. Variables included the percent bitumen, gradation, and the aggregate. The tests consisted of the Marshall Stability and Flow test, degree of density and permeability. Some of their conclusions were: (a) Percent bitumen and gradation

may be determined by the Stability and Flow test. (b) By testing for stability in water, selection of aggregates can be made. (c) Open gradation of river gravel, sand, and limestone combinations is unsatisfactory, but limestone or slag aggregates with open gradation are satisfactory. (d) Percent bitumen and gradation are two principal factors for stability and permeability. (e) Type of aggregate controls gradations for mix.

In February, 1946, Messrs. Cary Burns and L. E. Gregg reported an analysis of Marshall stability tests (5) run in the laboratory during the past year. The tests were run largely in conjunction with field studies but no correlation was possible at the time the report was written. The conclusions were: (a) Physical characteristics that affect volumetric and weight relations should also be considered when comparing mixes, rather than solely considering densities. (b) Stability test, as used, had little significance for rounded aggregates. (c) Flow and permeability values should be obtained more accurately. (d) Additional tests are needed using other stability tests, and all should be correlated with field performance.

For controlling mixtures, there are other types of stability tests that have been used to some extent, these include: Hubbard-Field (16), Hvem stabilometer (18), and triaxial compression (29). All have been tried, with variable success, by various state highway departments.

Numerous investigators have attacked the problem of flexible pavement design by considering the subgrade reaction (24), (26), (15). Mr. H. G. Spangler (25) has used carbon discs to determine vertical stress under flexible surfaces. In the same type endeavor Mr. A. T. Goldbeck (10) applied pressure cells. Messrs. W. S. Housel (15) and Prevost Hubbard (16) have used field loading tests to determine the compressibility of the soil in order to design the surface thickness. Messrs. F. J. Woodsmall (30) and R. F. Baker (2) attempted to calculate the shearing and principal stresses by photoelastic

methods. However, no exact design is yet available, and, in the study of subgrade reactions, research is still needed.

SCOPE

The proposed investigation is to include field studies, laboratory studies of various stability tests, laboratory studies using the circular track, and photoelasticity research. Through the development of the coring bit by Mr. Cary Burns, of the Highway Materials Research Laboratory, a useful tool is available for use in testing existing pavements. Although a great number of cores have already been studied, there is not a sufficiency of data to establish a definite relationship between results in the laboratory and performance in the field. In addition, a good basis does not exist for evaluating the stability procedure nor the measurements which have been made.

The contemplated field studies will consist of examining pavements in service for some period of time and those under construction. Cores will be extracted and comparative measurements made of unit weight, degree of density, stability, and other tests that may prove applicable.

The laboratory studies on stability tests are designed to compare the several methods of measuring stability of bituminous mixtures used in flexible pavement construction. These stability tests will include Marshall, Hubbard-Field, triaxial, and Hveem Stabilometer. Comparison will be made on laboratory mixtures, varying aggregate, percent bitumen, curing, compaction, and other applicable construction variables. A study of the physical characteristics of the aggregates such as, soundness, abrasion, and stripping qualities is contemplated.

The circular track will be used to obtain an accelerated performance test of the many variables in flexible pavements. The nature of the apparatus facilities the evaluation of the subgrade as to the type of material, compaction,

moisture content and weather change. The pavement can be studied as to the effect of the type of aggregate, amount and type of bitumen, weather change, thickness, traffic, stability, unit weight, and degree of density.

The use of photoelasticity for studying vertical stresses under flexible pavements has several advantages. First, the transparency of the gelatin permits the investigator to see the stress conditions existing in the subgrade. Secondly, the actual values of the shearing resistance and vertical stresses can be calculated. There are two necessary assumptions, however, that are distinct disadvantages as applied to highways; namely: (a) That the subgrade is a homogeneous, isotropic material (same stress properties in all directions) and, (b) That no longitudinal stress distribution exists.

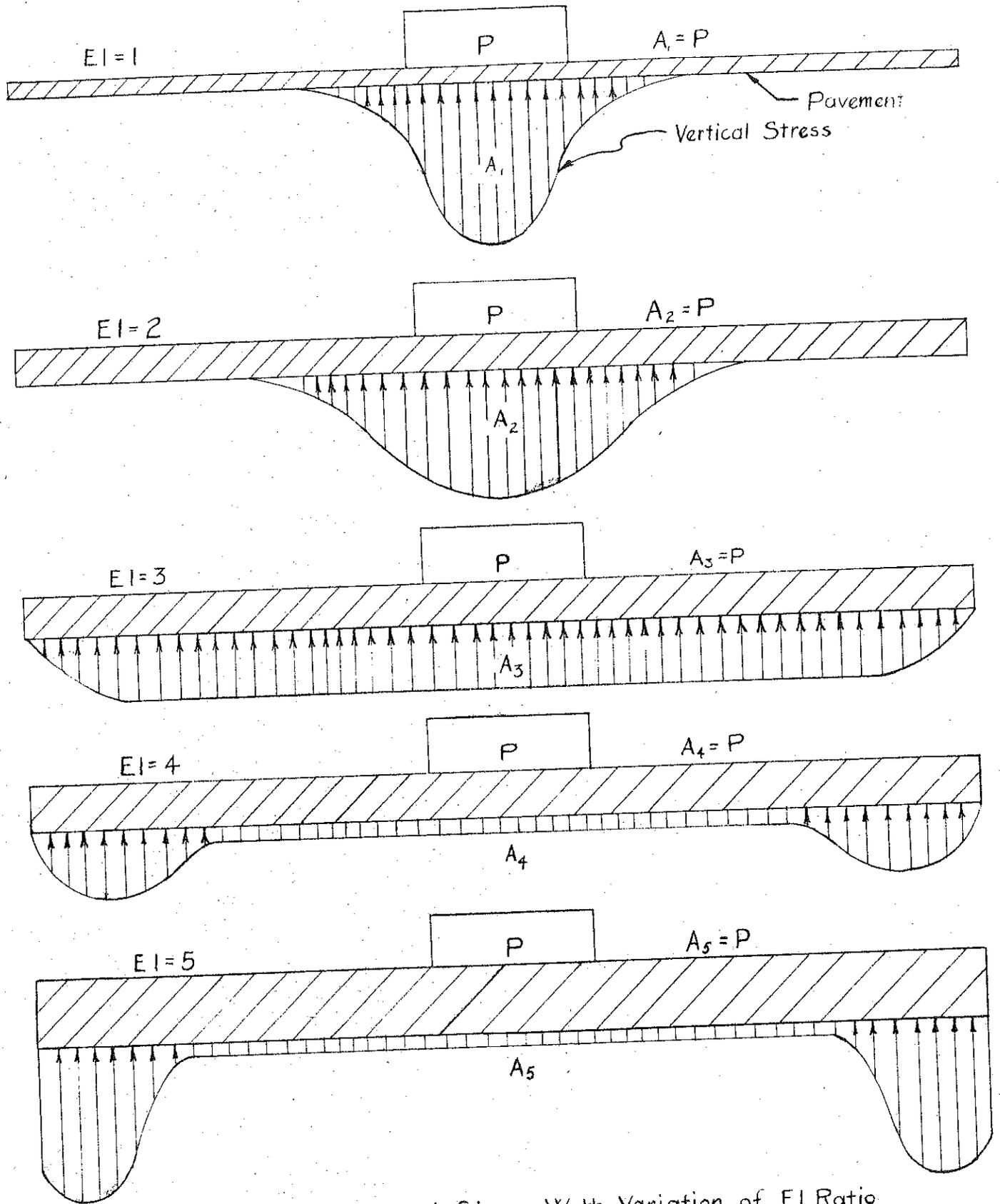
With these possibilities and limitations in mind, important indications and perhaps solutions are possible. To illustrate the research approach, Figure 1 shows the change in vertical stress with a variation of the EI, or stiffness, ratio between the pavement and subgrade. By keeping the EI ratio of the photoelastic setup compatible with the EI ratio of pavement and subgrade, the author believes that fundamental relationships can be developed that will greatly simplify the procedure for designing the depth of subgrade treatment and the thickness of base and pavement slab.

PROCEDURE

The study will be divided into four general parts for separate investigations. Insofar as is possible, all phases of the work will be progressing concurrently.

PART I - FIELD STUDY

In an attempt to obtain a wide range of bitumen-aggregate combinations, cores will be taken from bituminous pavements throughout the state. Figure 2 indicates some of the initial sections that will be studied. After



Change In Vertical Stress With Variation of EI Ratio
 Fig. L

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PRELIMINARY LIST OF BITUMINOUS PAVEMENTS TO BE TESTEDDistrict 1

Route No.	County	Location	Length Miles	Type Surface	Year Constructed
SR 85	Union	Sullivan-Providence	1.5	Rock Asphalt	1942
US 45	McCracken	Paducah-Mayfield	6.4	Bit. Conc. I	1942
SR 85	Webster	Sullivan-Providence	8.0	R.A. Seal	1943
US 60	Livingston	Smithland-Maryland	4.6	Bit. Conc. I	1943
US 25-E	Union-Webster	Morganfield to Wanamaker	15.0	Bit. Conc. I	1944

District 2

SR 85	McLean	Sacramento-Madisonville	2.7	R.A. Seal	1942
Various	Allen-Edmonson Logan-Simpson- Warren	Various	43.8	Bit. C-1 & A-2	1944

District 3

US 31-E	Larue	Hodgenville-New Haven	9.8	R.A. Seal	1942
US 31-E	Spencer	Louisville-Bardstown	2.6	R.A. Seal	1943
US 31-E	Bullitt	Louisville-Bardstown	4.4	R.A. Seal	1943
US 31-W	Hardin	Elizabethtown-Ft. Knox	1.3	Bit. Conc.	1943
US 42	Oldham	Goshen to Henry Co. Line	8.2	Bit. Conc. I	1943
US 60	Meade	Grahamton to Brandenburg	10.9	Bit. Conc. I	1944

District 4

SR 55	Henry	New Castle-Shelbyville	5.9	R.A. Seal	1943
SR 22	Henry	New Castle-Frankfort	5.4	R.A. Seal	1943
US 25	Grant-Kenton	Dry Ridge-Williamstown	3.5	Bit. Conc. I	1943
	Campbell	Newport-Claryville Rd.	0.7	Bit. Conc. I	1943
SR 20	Boone-Kenton	Covington-Petersburg	5.3	Bit. Conc. I	1944
	Bracken	Berlin-Augusta	16.2	Bit. A-2	1944

District 5

SR 11	Powell-Montgomery	Clay City-Mt. Sterling	7.9	Bit. Conc. I	1942
US 150	Boyle	Danville-Stanford	9.3	R.A. Seal	1943
US 60	Bath	Mt. Sterling-Owingsville	6.3	Bit. Conc.	1941
US 27	Fayette	Lexington-Joyland	1.8	Bit. Conc. I	1943

District 6

SR 40	Martin	Inez-Paintsville	5.4	Bit. Conc. (Slag)	1941
SR 40	Johnson	Inez-Paintsville	3.1	Bit. Conc. (SS)	1941
SR 10	Lewis	Vanceburg-Fullerton	14.7	Bit. Conc. I	1941
US 23	Boyd	Cattlettsburg-Louisa	1.5	Bit. Conc. I (Slag)	1943
US 23	Lawrence	Louisa	1.1	Bit. Conc. H (Slag)	1943
US 60	Boyd	Princess-Bellefonte Jct.	10.5	Bit. Conc. I	1943
Various	Floyd-Letcher	Various	65.9	Bit. C-1 & A-2	1944

District 7

US 25	Laurel	London-Corbin	3.5	R.A. Seal	1943
US 150	Lincoln	Danville-Stanford	9.3	R.A. Seal	1943
US 150	Lincoln	Stanford-Crab Orchard	10.5	R.A. Seal	1943
US 25-E	Bell	Pineville-Middlesboro	3.0	Bit. Conc.	1943
US 25-E	Knox	Barbourville-Pineville	5.6	Bit. Conc. I	1944
US 25-E	Knox	Corbin-Barbourville	2.0	Bit. Conc. I	1944

each core has been taken, a field density of the specimen will be determined. Special attention will be given to failures (rutting and shoving) versus good performance. In the case of new construction, cores will be taken immediately following construction and at various intervals thereafter in order to evaluate the effect of weather and traffic. After each pavement sample has been taken, it will be returned to the laboratory for investigation, the total number of cores to be drilled is indefinite.

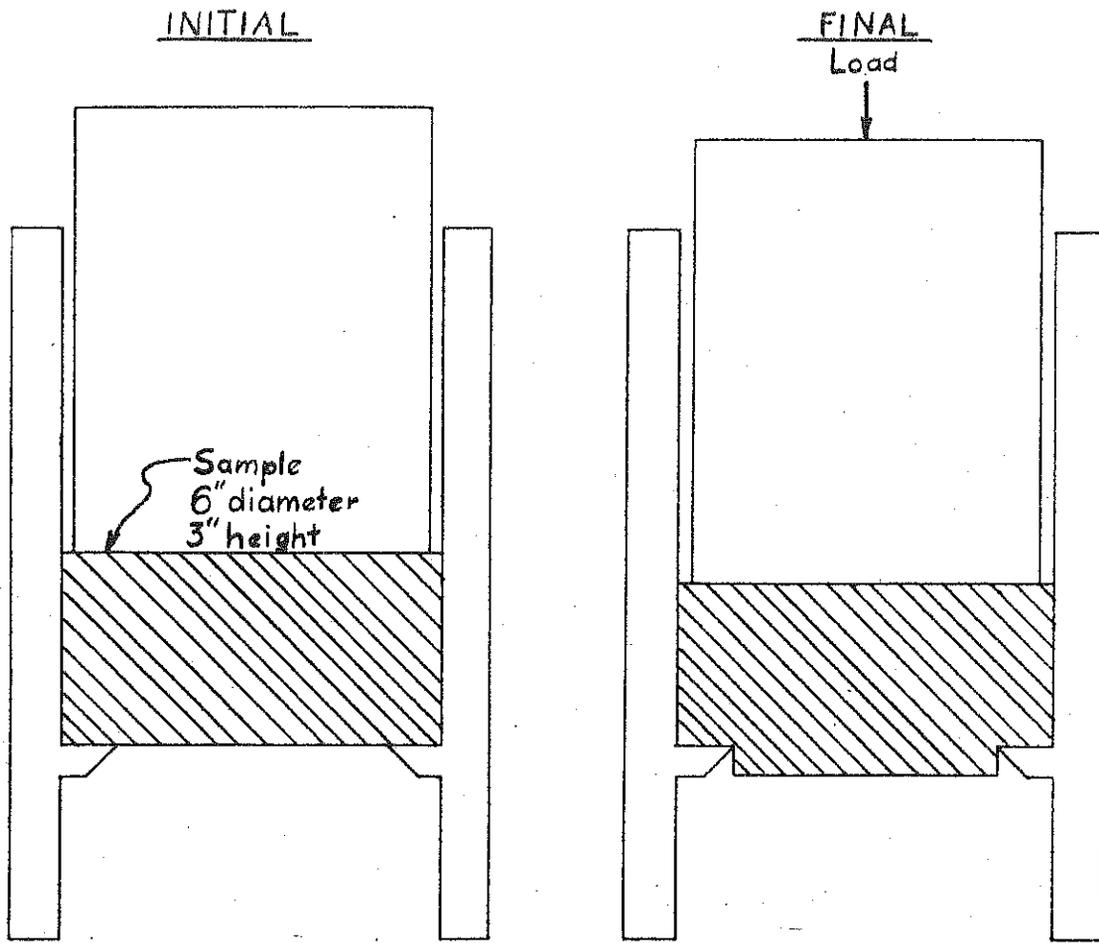
In order to properly evaluate the performance of the pavement, it will be necessary to check the base and subgrade. After bituminous cores have been obtained, samples of the material beneath the pavement will be taken and field density determined. In the laboratory, the soil sample will be tested for routine soil characteristics. Consideration will be given to the theory of Messrs. Hubbard and Field (16) in which they state that 0.6 inches of pavement deflection will cause surface failure of bituminous pavements regardless of non-failure of the subgrade. A check of this theory will be of value in the design and control of flexible pavements.

PART II - LABORATORY STUDIES

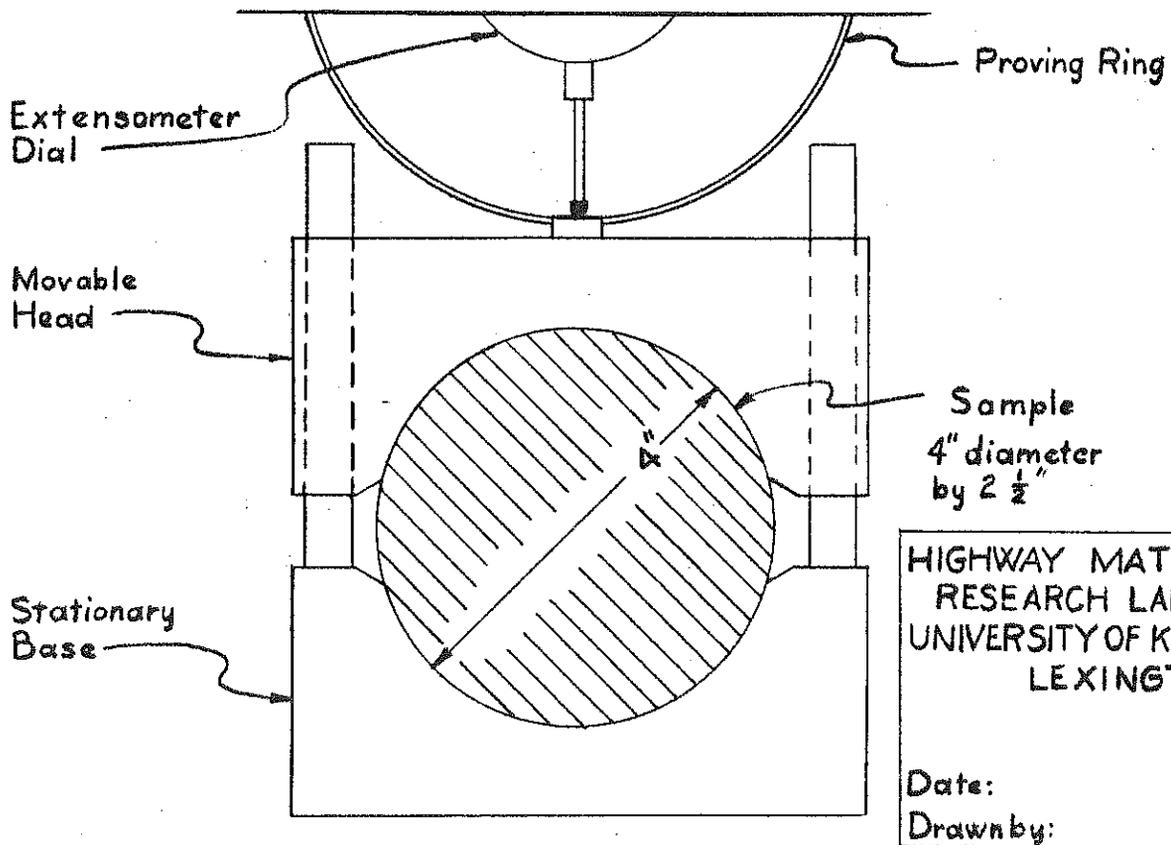
The laboratory studies will be conducted in close correlation with the field work. One of the first steps will be the development of a laboratory compaction method that will compare favorably with field compaction. However, the major part of the laboratory investigation will consist of numerous experiments with laboratory mixtures in which the following stability tests will be studied in detail:

Marshall Stability Test -

A sketch of the Marshall stability testing equipment is contained in Figure 3. The test consists of compressing a 4" diameter by 2-1/2" sample between two segments of a ring. The procedure calls for the temperature of the



Diagrammatic Sketch Of Hubbard-Field Stability Test



Diagrammatic Sketch Of Marshall Stability Test

sample to be 140°F, and is conducted both in water and in air. The criteria for stability has been set at 300 pounds (5).

Hveem Stabilometer Test -

A sketch of the stabilometer testing equipment is shown in Figure 4. The procedure consists of longitudinally loading, by means of a piston, a 4" specimen in diameter by 2-1/2" long, confined along its length by a rubber membrane through which a lateral pressure is applied by the use of a liquid. The piston load, the pressure in the liquid, and the deflection are the measure of stability of the sample.

Hubbard-Field Stability Test -

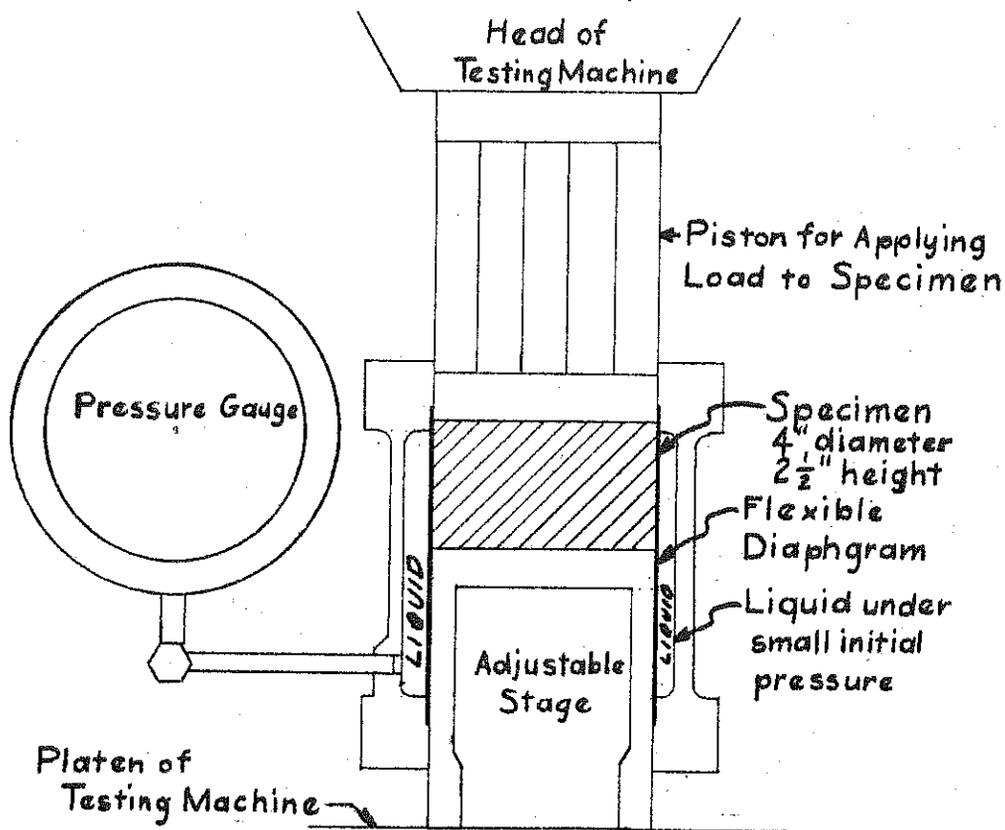
In figure 5, the equipment for the Hubbard-Field stability test is shown diagrammatically. For coarse mixes, the procedure calls for a 6" diameter by 3" sample at 140°F to be forced through an orifice; maximum pressure being the measure of stability. A value of 2000 pounds (16) has been arbitrarily set as the minimum value in order to insure no displacement under heavy concentrated loads.

Triaxial Compression -

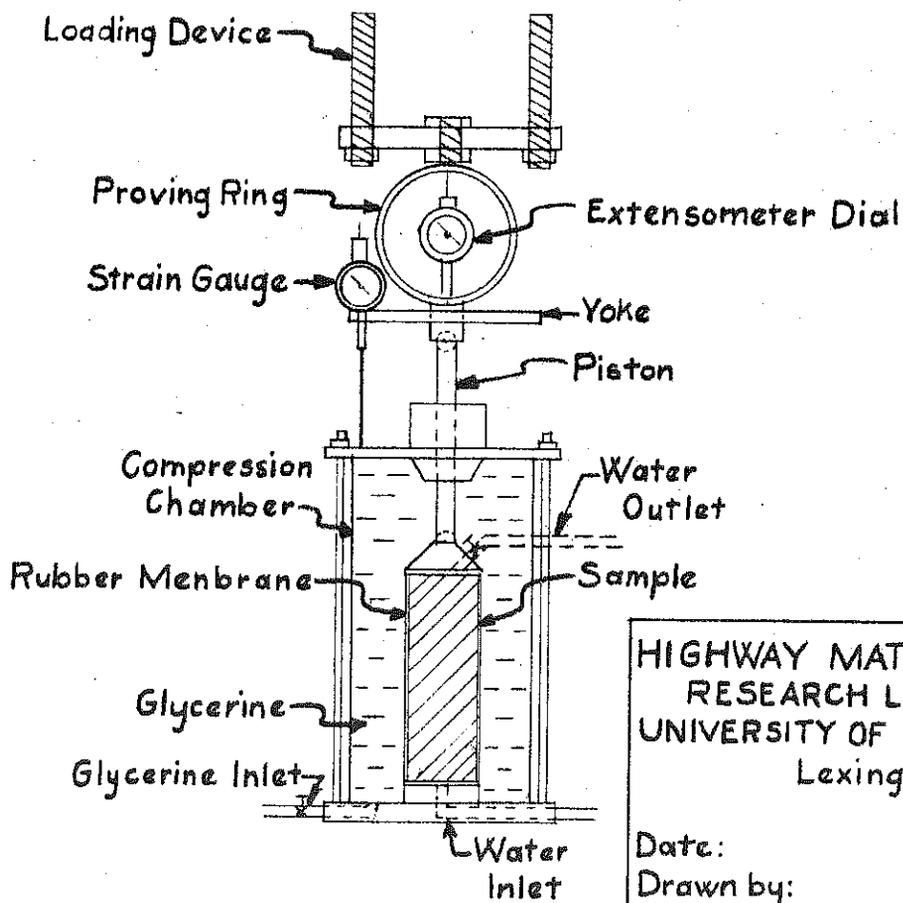
The triaxial testing equipment is shown in Figure 6. The sample as tested is 2.8" in diameter, 8" high and is encased in a rubber membrane. It is placed in glycerin, so that lateral loads can be applied. This lateral (fluid pressure) load is held constant while the vertical load is increased by increments. The vertical load versus the angle of internal friction are a measure of the stability of the mix.

PART III - CIRCULAR TRACK

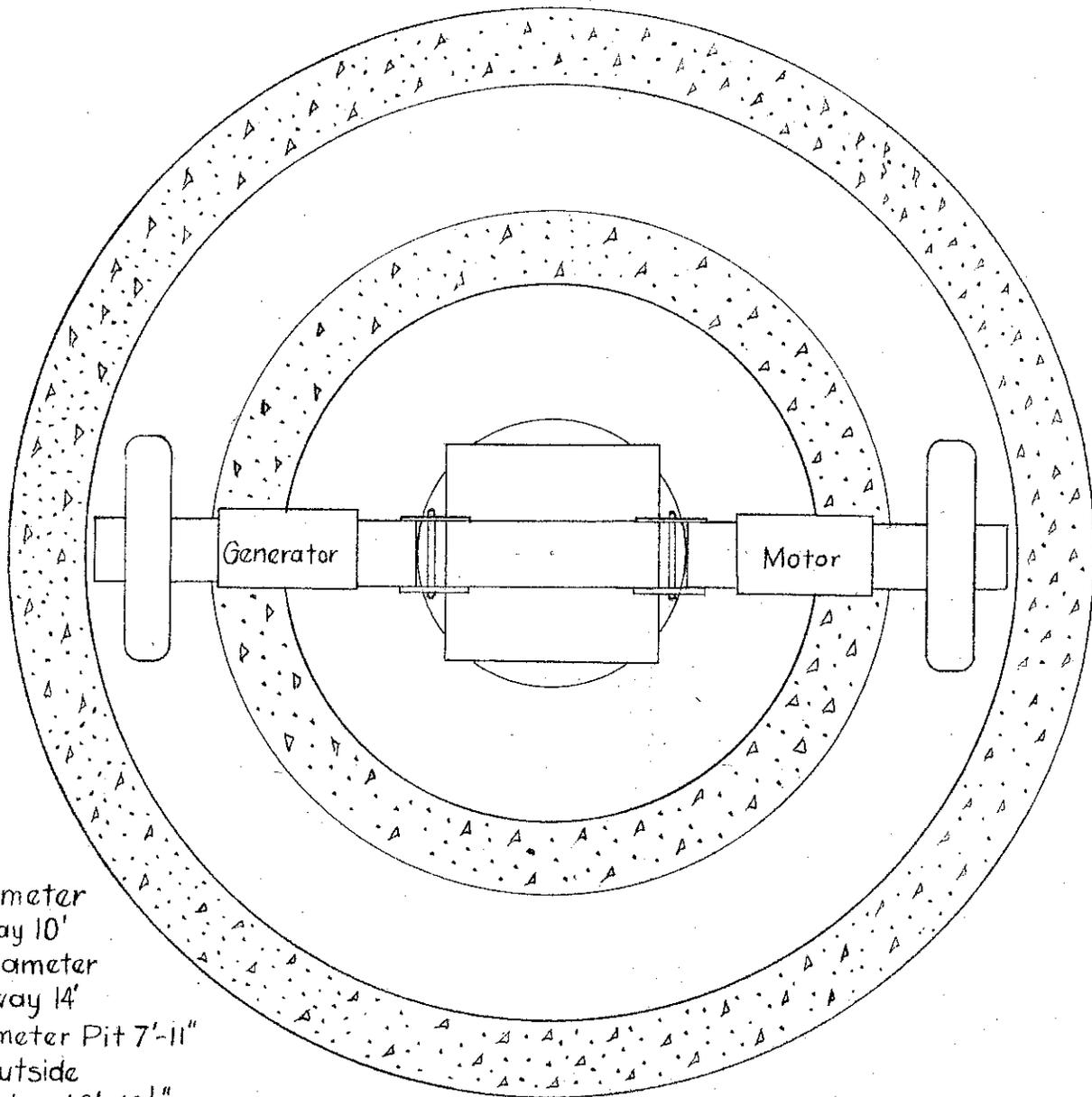
There are numerous variables in surface and subgrade that will be considered in the circular track (Figure 7) investigation. While the characteristics of the various bitumen-aggregate combinations will be of primary



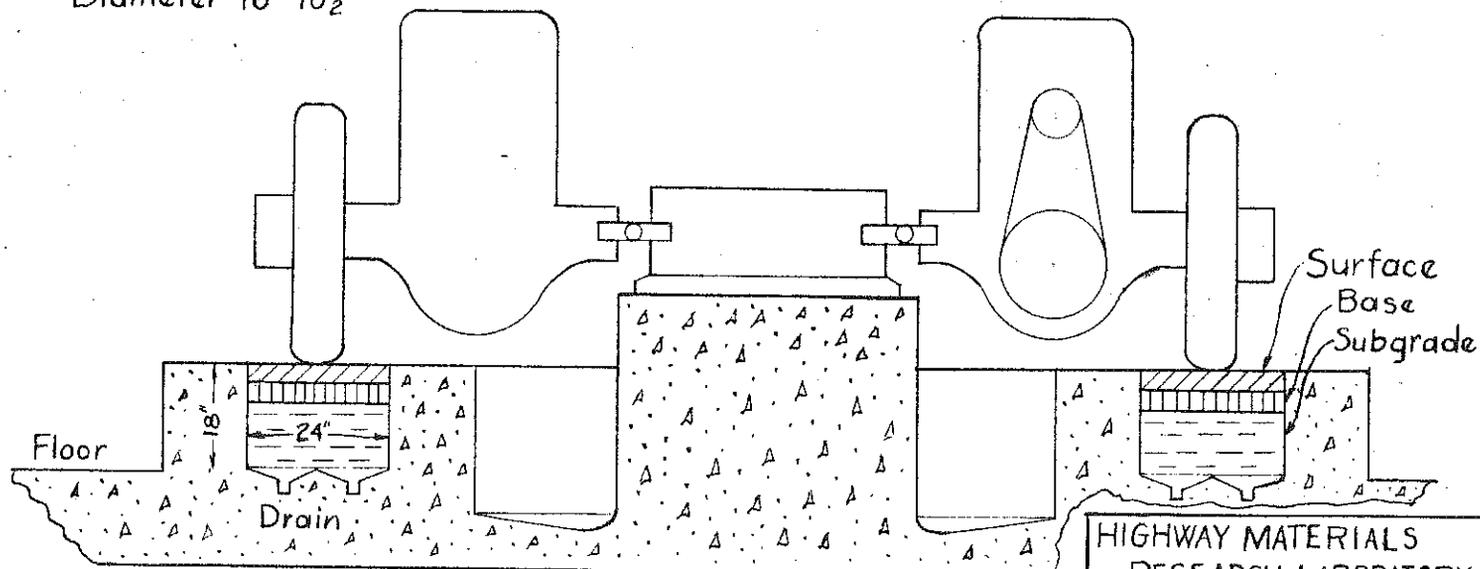
Diagrammatic Sketch Of Hveem Stabilometer



Diagrammatic Sketch Of Triaxial Compression Testing



Inside Diameter
 Roadway 10'
 Outside Diameter
 Roadway 14'
 Inside Diameter Pit 7'-11"
 Overall Outside
 Diameter 16'-10 $\frac{1}{2}$ "



Diagrammatic Sketch of a Circular Track
 Fig. Z

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concern, the action of the subgrade will be studied closely.

Initially, the track will be set up for calibration purposes. Sections of the track will be constructed of good subgrade and good surface, while other sections will be poor subgrade under good surface. In this way, some indication will be forthcoming as to time required for preparation of the track, time required for failure to develop, and other technique that will develop as the test proceeds.

The tests will be correlated with the field by taking sample cores of the pavement and subgrade of the track and obtaining the unit weight, degree of density, and stability of the surface; as well as the gradation, percent compaction and moisture content of the subgrade.

The performance of sandstone, both as a surface material and as a base, will be one of the first considerations. The action of the softer sandstone under weather, moisture, and traffic effects is a questionable factor requiring immediate attention.

PART IV - PHOTOELASTICITY

Initially, study and experimentation will be necessary to arrive at a method for casting a uniform, gelatin material (30). Various values of "E" for this material will be desirable also.

After the preliminary work, numerous tests, varying loads and the EI ratio of pavement and subgrade will be conducted. These tests should give a good picture of the stress distribution under flexible pavements. Additional work is scheduled in the soils laboratory to determine physical characteristics (such as "E" and shear).

A final step will be the solution to the problem arising from the basic assumption of the photoelastic analysis - that plane strain exists. Naturally, subgrade stress calculated under this assumption will be higher

than in a comparable case in the field. The answer to the problem may lie in additional photoelastic studies or may necessitate assumptions as to the amount the stress should be reduced.

MATERIALS

The materials to be tested can be generally classed as follows:

1. Aggregates

- (a) limestone
- (b) river sand and gravel
- (c) slag
- (d) sandstone

2. Bituminous products

- (a) asphalt cements
- (b) asphalt emulsions
- (c) asphalt cut-backs
- (d) tars

EQUIPMENT

All of the equipment known to be needed is on hand or available. The core drill for pavement specimens is the one developed by Mr. Cary Burns. The stability testing apparatuses are on hand. The circular track in the laboratories needs finishing touches to be ready for operation, and the photoelastic equipment is available through the University.

SUMMARY

1. A rational, dependable method is needed for the design and control of flexible pavement construction using the materials available in Kentucky.
2. A study combining (a) field studies based on pavement cores, (b) laboratory studies of stability tests, (c) accelerated traffic and weather-

ing test using the circular track, and (d) photoelastic analyses should result in the development of a design and control method applicable to Kentucky materials.

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