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RELATION OF DENSITY AND SHEAR STRENGTH TO THE CLASSIFICATION OF HIGHWAY SUBGRADE AND FLEXIBLE BASE MATERIALS

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SYNOPSIS

From the data that have been secured it is concluded that soil classification systems for engineering purpose should be based on the anticipated ability of soils to support loads and that shearing strengths of soils when properly determined are as nearly related to supporting power as are any other soil characteristics. It is proposed to group all subgrade soils and base materials into six classes depending upon their shearing strengths as determined by triaxial compression tests and to use these materials in accordance with the best information available from practical experience and stress analysis. A chart for classification purposes and a tabulation for suggested use of the materials are presented. Data are also presented showing the effects of compacting moisture and density on shearing strengths and moduli of elasticity. It is also concluded that the indicator tests, such as soil constants and screen analysis, should be used as a basis for control of given sources but that design be based on classes of materials having shearing strengths that range between definite limits.

INTRODUCTION

During the past fifteen years at least twenty-five methods of classifying subgrade soils have been proposed. Most of these methods have utilized the soil constants and gradation of the materials as a basis for the classification system with the hope that these would indicate the required depth of pavement. Our own Department has devised two such systems which have served as a rough guide for determination of pavement depth but these classifications have been found to be strongly dependent upon small variations of grading and plasticity index. Plasticity index ranges from 0 to 4, 4 to 10, 10 to 14, etc., are apparently highly critical but even these cease to be significant on a national basis when cooperative studies between various laboratories in the states show that plasticity index results on a given sand-clay soil may vary between 3 and 11 and on a given silty soil between 3 and 9. Because of this and other reasons mentioned below such classification systems have not and probably never will be widely accepted. The following are other reasons:

1. Usually, the shapes and frictional characteristics of the aggregate portion are not considered.
2. Effects of variations in compaction of materials are not evaluated satisfactorily.
3. Any natural cementation is not considered.
4. Variation in depths of base to conform to requirements of various wheel loads are very approximate.

The following pages introduce a method of classifying soils on the basis of strength in lieu of the above methods, It is proposed that the soil constants and other simplified tests be utilized in the control of given sources of materials. The method of determining depth of pavements suggested is not an official Texas Highway Department method. The establishment of such a method is dependent upon future cooperative studies.

DISCUSSION

From the Highway Engineer's viewpoint there is little practical use for a soil classification which does not indicate those characteristics necessary to be considered in the design of soil foundations. The make up of a soil is of secondary importance to Engineers if they can properly determine whether or not it will carry the loads imposed upon it with the moisture condition to which it will be subjected in the roads; therefore, it is believed that subgrade soils and flexible base materials should be classified on the basis of strength. Accordingly, a chart has been developed which groups all soils and flexible base materials normally used in the top three feet of the roadway into six classes. The final determination of each class is dependent upon shearing strengths as determined by the triaxial compression test method proposed by the author at the 1946 annual meeting of the Highway Research Board 1) and the plotting of the rupture line at failure on the classification chart. A few pictures of the test apparatus are also shown in an article written for this conference entitled: "Improvement of Highway Subgrades and Flexible Bases by the Use of Hydrated Lime".

The following tabulation indicates the usefulness of soils as subgrades, subbases and bases for flexible types of highway pavements:

Special considerations should be given to conditions created by traffic at stop signs. In this thicknesses for classes 1, 2, 3, 4 and 5 need to be increased from 2 to 4 inches, and the use of light or inferior surfacing should be avoided. The depths below surface of road suggested in the above table, based on present information, suggest rather wide limits for the various classes. Further investigation should narrow these limits.

In using this type of classification system, the importance of moisture-density relations for compaction can be easily evaluated. For instance, dashed line A on the classification chart represents the strength of a given sand clay (PI=6) when compacted at Standard Proctor density of 111 lbs. of dry soil per cu. ft., properly dry-cured, wetted and tested. Line B represents the strength of the same material when compacted to 114 lbs. of dry soil per cu. ft. (103% of Proctor density) dry-cured, wetted and tested in the same manner as above. It may be noted that the classification of this soil changes with variations in density and that the required depth of coverage for this material also varies with the density. All indications are that all low volume change soils should be compacted to a density that is as high as is practicable. During normal light rolling conditions little difficulty has been encountered in obtaining densities that are from 2 to 3 pounds per cu. ft. greater than

Class of Mat'l.	General Description of Material	Depth of Pavement (Base and Surfacing)					
		8,000 Wheel Load		12,000 Wheel Load		16,000 Wheel Load	
		High E x) Base Course	Low E x) Base Course	High E Base Course	Low E Base Course	High E Base Course	Low E Base Course
1	Good flexible base material	Good- light bituminous surfacing acceptable.					
2	Fair flexible base material	One to four inches of bituminous surfacing or a stable layer of class 1 material covered with a good light surfacing.					
3	Borderline base and subbase materials	3-8"	4-10"	4-10"	5-12"	4-12"	6-14"
4	Fair to poor subgrade	8-13"	10-16"	10-15"	12-20"	12-18"	14-23"
5	Weak subgrade	13-17"	16-21"	16-21"	20-26"	18-24"	23-30"
6	Very weak subgrade	17"+	21"+	21"+	26"+	24"+	30"+

x) High modulus E = appr. 20,000 and low modulus E = appr. 6,000 used in stress computations. Values of 20,000 are about the maximum found for natural·base materials. The above table probably is not applicable to the use of base materials which have been treated so as to have higher moduli.

100% of Standard Proctor density.

In the case of clay soils with high volume change characteristics the desirable density for compaction can be determined by testing the soil at several densities as is shown by the dashed lines C, D and E on the classification chart for a soil that has a plasticity index of 45. The strength of this soil when compacted at Proctor optimum moisture and density (87 lbs. per cu. ft.) and wetted by capillarity is represented by curve C. Another set of specimens were compacted at the optimum moisture content for a compactive effort capable of producing a density of 90 lbs. per cu. ft. and after wetting gave the results shown by curve D. A third set of specimens was compacted at the optimum moisture content for a compactive effort capable of producing a density of 92 lbs. per cu. ft., wetted and tested to obtain curve E. From a comparison of these curves it can be clearly seen that the specimens molded at the intermediate density had the highest final strengths. This substantiates the belief by some that high swelling upper layers of clay subgrades can be over-compacted or at least high density sometimes cannot be retained. It has been observed that no extra strength can be expected by increasing the density of soils so that they are susceptible to over 6 to 8 per cent of volumetric swell. This amount of swell through a thick layer would be very undesirable but is unlikely due to restraint of surcharge loads.

The control of moisture during and following compaction will also do much to reduce the swelling properties of highly expansive clays. Tests to date indicate that per cent volumetric swell of expansive soils can be held below 6 to 8 when the moisture content of the soil at time of paving is not more than 3 to 6 per cent below the Standard Proctor optimum moisture content and that the density is not more than about 7 pounds per cu. ft. above that of the Standard Proctor optimum density.

It is common knowledge that the magnitude of the initial deflection of a soil mass under traffic immediately after compaction is strongly affected by the compacting moisture content and its relation to optimum moisture. Perhaps it is not so well known that the deflection characteristics which exist after drying and re-wetting are strongly influenced by the relation between optimum moisture and the actual moisture content at the time of compaction. Stress-strain curves numbered 1 and 2 shown in Figure 2 illustrate this point. The specimen for curve 1 was molded at a moisture content that was .8 of one per cent below the optimum (8.0%) for the compactive effort being used, partially dried, wetted by capillarity and tested. The specimen for curve No. 2 was molded out of the same soil at a moisture content of one per cent above optimum and treated the same as the above specimen; that is, dried to between 3.1 and 3.6% moisture, wetted by capillarity and tested. The initial density of these specimens was approximately 132 lbs. per cu. ft. or about 2 lbs. below optimum. Attention is directed to the fact that specimens for curves 1 and 2 contained approximately the same moisture content when tested and that their moduli of elasticity in compression vary greatly. These tests are typical of many which indicate that compacting soils on the "wet side" of optimum moisture will lead to increased deflections of pavements even though the subgrades are not overstressed.

CONCLUSIONS

It is concluded that the soil constants and other indicator tests give a basis for control of given sources of materials but that highway subgrade and base soils should be classified on the basis that is most easily utilized in foundation and pavement design. It is believed that the most practical classification system can be obtained by determining shearing strengths on specimens prepared according to a definite procedure which complies with actual field conditions as nearly as possible.

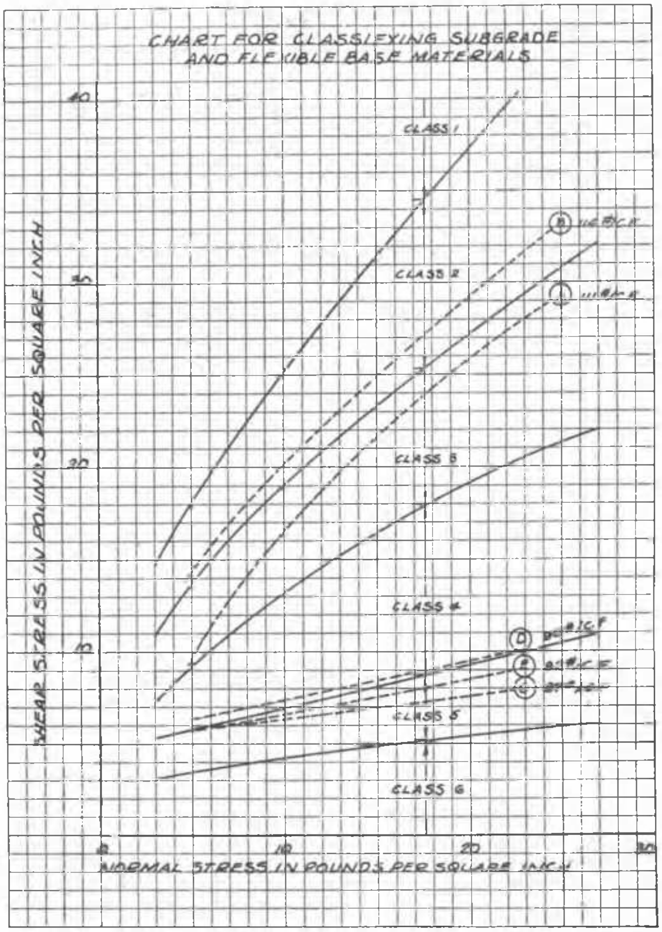

FIG. 1

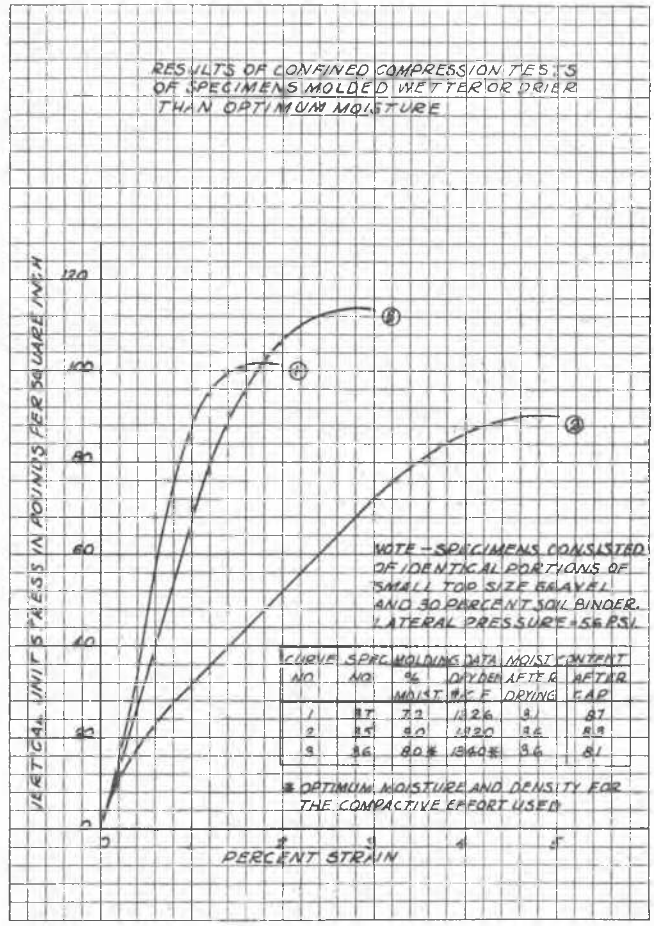

FIG. 2

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REFERENCES

1) "Progress Report on Development and Use of Strength Tests for subgrade Soils and Flexible Base Materials". Volume 26 of 1946 Highway Research Board Proceedings.

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