IX b 15

FIELD COMPACTION TESTS

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SUMMARY

The results of field compaction tests on a clayey sand show small increases in maximum density with increase of pressure intensity of the sheepsfoot roller, and with increase of rubber-tired wheel load under constant contact pressure. For a lean silty clay no increase of maximum density was obtained with increasing pressure intensity of the sheepsfoot roller, while increasing the load on rubber-tired wheels under constant contact pressure showed small increases in maximum density. For the lean silty clay in was found that, relative to the laboratory compaction curve, the field compaction curve was materially closer to the zero air voids curve for both types of compaction equipment. This was true for the clayey sand only to a minor degree.

In interpreting the test data presented herein the reader is cautioned that they apply to particular test conditions and that the results for other test conditions might be different since the results obtained for any roller depend not only upon the characteristics of the roller itself but also upon the test conditions which include type of soil, water content, number of passes, thickness of lift, and many other factors.

INTRODUCTION

The Waterways Experiment Station, under the direction of the Office, Chief of Engineers, is conducting a continuing investigation of the compaction of soils under field conditions. A number of variables affect the compactions of soils. The characteristics of the soil and water content at the time of compaction are important variables regardless of the type of compaction equipment used. For sheepsfoot rollers the other important variables are: (1) total weight of roller and contact pressure, (2) area and shape of feet, (3) number of passes of roller, and (4) thickness of lifts. For pneumatic tired rollers the important variables, aside from soil type and water content, are (1) contact pressure, (2) contact area, (3) number of passes of roller, and (4) thickness of lifts. The optimum moisture and density for field compaction may vary not only with the type of soil but with the variables mentioned above.

In these tests the effect of water content and weight of roller has been determined on two soils and all other variables held constant as nearly as practicable. To a limited extent the effect of the number of passes has been studied, but no data are presented, While the comprehensive testing program is incomplete, it is believed that the results obtained to date are of interest.

PURPOSE

The purpose and intent of this paper is to report the factual results of certain specific compaction tests which will supplement the all too meager fund of data on field compaction of soils and its correlation with laboratory compaction and testing. It is not intended or thought that the data or information contained herein can be generalized. A large volume of work must yet be accomplished, covering the full range of test and construction variables and on a complete range of representative soil types from over the entire country before generalizations can be made.

GENERAL FEATURES

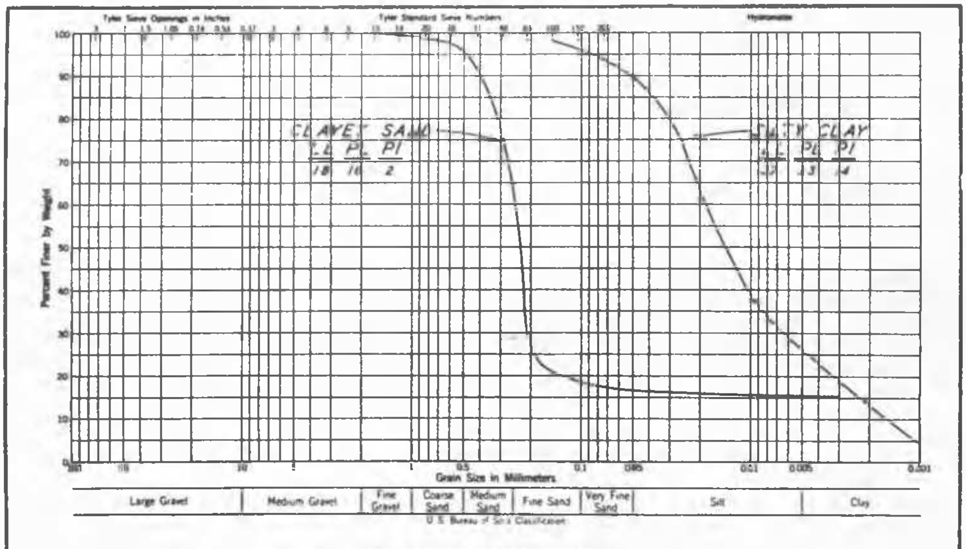
Full-scale field compaction tests have been completed on two soils, a clayey sand typical of many subgrade soils found in the southeastern United States, and a lean silty clay. The grain size distribution curves and other classification data are shown on Fig. 1. Water content-density data from conventional laboratory compaction tests are shown on Fig. 2 for the clayey sand and on Fig.3. for the silty clay.

Sheepsfoot and rubber-tired rollers were used in these tests. The sheepsfoot roller was a double drum oscillating type, each drum having 30 rows of feet with 4 feet per row. The contact area of each foot was 7 sq in. Pressures of 250, 500, and 750 psi were used in these tests and were obtained by varying the amount of water and Baroid in the drums. The roller was towed by a D-8 tractor and, in order to evaluate the effect of the tractor, a fill was constructed using the tractor alone to accomplish compaction. The number of passes of the tractor was equivalent to that in the sheepsfoot rolled sections.

Rubber-tired wheel loads of 10,000, 20,000, and 40,000 lb were developed by loading heavy earth-moving equipment until the desired wheel loads were obtained. The contact area increased with increasing wheel load, and the contact pressure under all wheel loads remained practically equal at about 65 psi. A 1500-lb double wheel roller was not used as very little increase inflation pressure was used in the construction of one test fill.

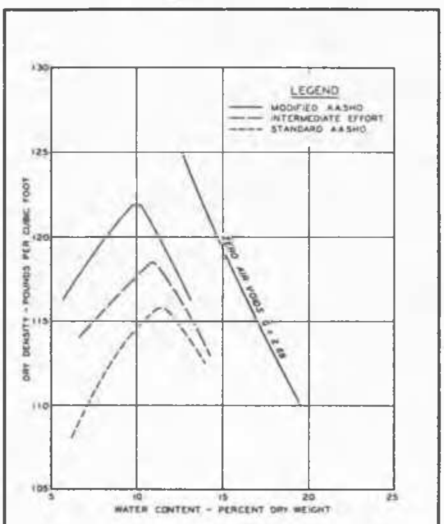
For the clayey sand test fills, the 750-psi roller was not used as very little increase in density was obtained when the pressures were increased from 250 to 450 psi. Similarly, the 10,000-lb wheel load was not used since almost identical densities were obtained from the 20,000 and 40,000-lb wheel loads. With reference to the silty clay fills no section was constructed using the wobble-wheel roller.

The number of passes of the rolling equipment was not set up as a variable in these tests. The amount of rolling used was that which by prior test trial gave somewhat less than Standard AASHO density with the equipment operating at its lightest weight; that is, 250 psi for the sheepsfoot rollers and 10,000 lb for the rubber-tired wheel loads. The soil was compacted in 6-in. lifts, as this thickness of lift is widely used in the construction of rolled fills.



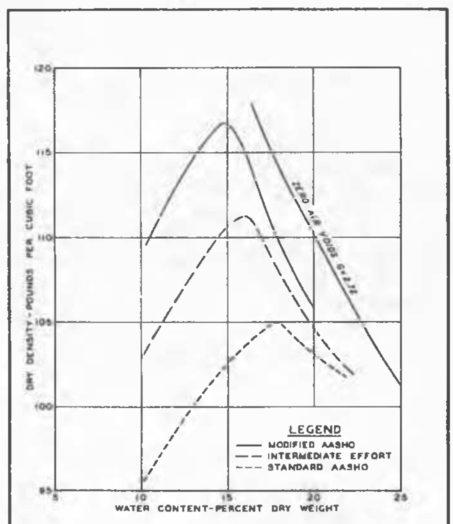
CLASSIFICATION DATA

FIG. 1



LABORATORY COMPACTION DATA FOR CLAYEY SAND

FIG. 2



LABORATORY COMPACTION DATA FOR SILTY CLAY

FIG. 3

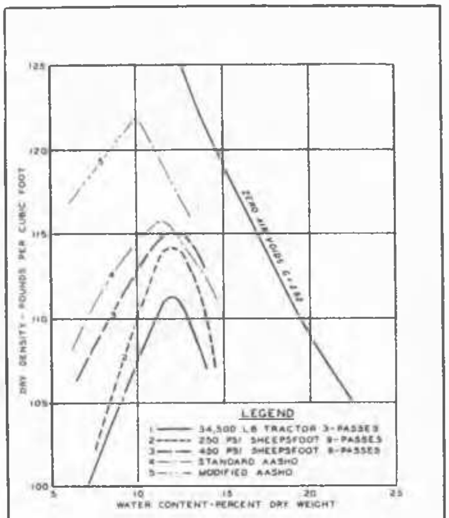
CONSTRUCTION OF FILLS

Test fills were made 100-125 ft in length, 30-40 ft in width, and 4-5 ft in height. These relatively large fills permitted the operation of full scale construction equipment. The soil was processed to the desired water content in a separate area, hauled to the site of the test fills in dump trucks, and spread by bulldozers.

The 100-125 ft length of fill was divided into 4 or 5 sections, each section having a different water content. The range of water contents was fixed so as to bracket the optimum water content developed by laboratory compaction. Thus, by rolling the fill from end to end, it was possible to develop a water content-density curve from field compaction similar to those developed in the laboratory. It should be noted that by compacting the soil in the field over a wide range of water contents, the best compacting moisture was obtained for the soil for a particular roller and number of passes.

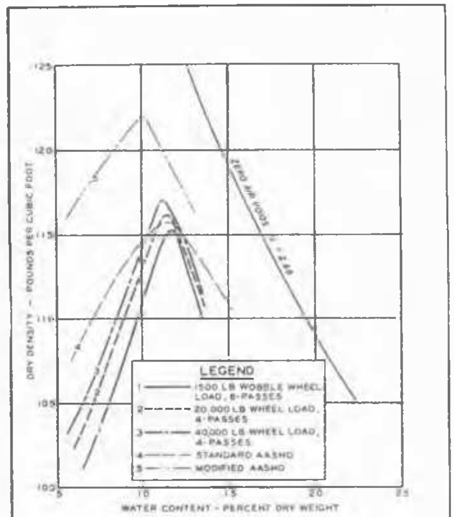
SAMPLING

Practically all sampling was accomplished in test pits, samples being secured at depths of 1, 2, and 3 ft. Samples were not taken nearer than 1 to 2 feet from the original ground surface as it was felt that the densities in this portion of the fill may have been affected by the subgrade. In general, several meth-



COMPARISON OF FIELD AND LABORATORY COMPACTION FOR CLAYEY SAND

FIG. 4



COMPARISON OF FIELD AND LABORATORY COMPACTION DATA FOR CLAYEY SAND

FIG. 5

ods of sampling were employed depending on the purpose for which the sample was to be used. From 10 to 15 samples were taken in each different water content section at each of the three depths. The sampling methods will not be described in detail here. However, it is desired to point out that the findings of this investigations are based on the results from a large number of samples.

DENSITIES DEVELOPED IN CLAYEY SAND FILLS

The densities developed in the clayey sand test fills are shown on figure 4 for 9 passes of the sheepsfoot rollers and on figure 5 for 4 passes of the rubber-tired rollers. Before discussing these data it is desired to again call attention to the fact that all variables affecting compaction have not been investigated at this time. The densities shown by figures 4 and 5 were obtained under certain test conditions and do not represent the maximum densities that may be obtained with this particular soil and compaction equipment. For example, the number of passes of the rollers, and the height of lift were deliberately held constant in these tests in order to evaluate the effect of the contact pressure of the sheepsfoot roller and of contact area, and therefore the total load, of the rubber-tired rollers. An increase in the number of passes of the rollers or a decrease in the height of lift would in all probability result in higher densities.

To facilitate comparison with laboratory compaction, the water content-density curves from Standard and Modified AASHO effort are also shown on figures 4 and 5. It can be noted on figure 4 that 9 passes of the 250 psi sheepsfoot roller developed a maximum density about 2 lb per cu ft less than produced by the Standard AASHO effort and that increasing the roller weight from 250 to 450 psi resulted in increasing the maximum density by about 1 lb. However, an increase in density of from 2 to 6 lb per cu ft was obtained with the heavier roller at water contents dry of optimum. It can also be noted that 3 passes of the tractor alone developed a density equal to about 96 per cent of the maximum density developed by Standard AASHO effort.

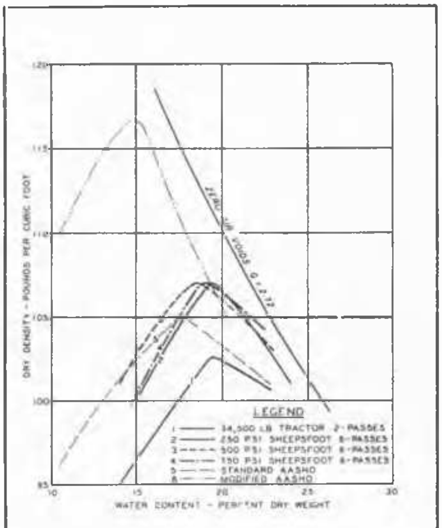
Figure 5 shows that the 1500-lb wobble-wheel roller, the 20,000 and the 40,000-lb wheel load developed densities within about 1 lb of each other, with the wobble-wheel being the lowest, and the 40,000-lb load the highest. The data resulting from compaction by the wobble-wheel roller are not directly comparable with the data developed by the 20,000 and 40,000-lb wheel loads, as the fill constructed by the wobble-wheel roller was built in 3 in. lifts and received 6 passes, while the fill constructed by the heavier rollers was on the basis of 6-in. lifts and 4 passes.

DENSITIES DEVELOPED IN SILTY CLAY FILLS

The densities developed in the silty clay fills by 6 passes of the sheepsfoot rollers and 2 passes of the tractor alone are shown by figure 6. It is at once apparent that 6 passes of the 250-, 500-, and 750-psi rollers developed almost identical maximum densities. Also the field curves lie nearer to the zero air voids curve than do the curves resulting from laboratory compaction effort. The maximum densities resulting from compaction by 4 passes of the 10,000-, 20,000-, and 40,000-lb wheel loads are within a range of slightly greater than 1 lb per cu ft and are shown by figure 7. The results are quite similar to those from the sheepsfoot roller sections except that the maximum density is about 2 lb per cu ft higher.

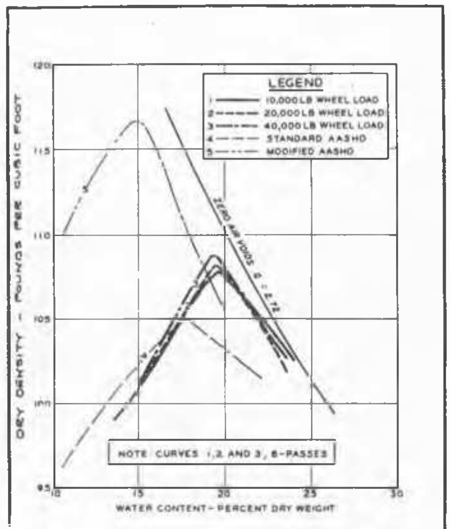
DISCUSSION OF RESULTS

The extension of test results to actual field conditions must be carefully made. Therefore particular care was taken in this investigation to insure that the sheepsfoot and rubber-tired rollers were operated on the test section just as they would be on a construction project so that there could be no question as to the applicability of the test results. At some water contents, the penetration of the roller feet was perhaps greater or less than that occurring in actual practice, but the fact that a complete water content-density compaction curve indicating a point of maximum density was obtained in the field for the par-



COMPARISON OF FIELD AND LABORATORY
COMPACTION DATA FOR SILTY CLAY

FIG. 6



COMPARISON OF FIELD AND LABORATORY
COMPACTION DATA FOR
SILTY CLAY

FIG. 7

ticular roller and number of passes shows that the normal operating conditions were obtained.

It might reasonably be expected that an increase in the pressures exerted by sheepsfoot rollers from 250 psi to 750 psi, and an increase in rubber-tired wheel loads from 10,000 to 40,000 lb would result in an appreciable increase in the densities developed by these rollers. However, this was not the case. Several factors are discussed that may account for the failure to develop materially higher densities with increasing foot pressure or wheel or load.

The nominal or rated pressure exerted by a sheepsfoot roller is customarily determined with one row of feet in contact with the soil. This condition seldom exists during normal operation. As the feet penetrate the soil, more feet come in contact with the soil and the intensity of pressure on the face of a foot is consequently reduced. Precise measurements of the amount of penetration of the feet of various weights of rollers were not made, but it was observed that the penetration increased with roller weight.

Thus, the pressure exerted by the rollers during normal operation was certainly less than the rated pressure, and it is possible that, due to the greater penetration of the heavier rollers, the actual pressure transmitted to the soil was essentially the same for all weights of rollers. If these observations are correct, then the various weights of sheepsfoot rollers might not be expected to develop densities in relative proportion to their weights.

Rubber-tired wheel loads were increased from 10,000 to 40,000 lb with only a slight increase in the maximum densities developed. However, it must be remembered that the contact pressures were approximately equal. Indications are that contact pressure may be materially more effective than total load in producing compaction in relatively thin lifts. While all data cannot be presented in this paper, it is desired to mention the fact that no significant change in density for either the sheepsfoot or rubber-tired roller was found with increasing depth. In other words, a given lift was not further compacted by the rolling of subsequent lifts. Each lift was apparantly compacted to a point such that the pressure of the roller, acting through an overlying lift and therefore reduced in intensity, was insufficient to cause further compaction.

Special attention is invited to figures 6 and 7 which show that the water content-density curves for the silty clay soil from field compaction fall appreciably nearer to the zero air voids line than do similar curves for laboratory compaction. This fact may have serious implications as it indicates that, for this particular soil, the results from laboratory tests are not in agreement with the results from actual field tests. If this lack of agreement is found for other soils, serious consideration must be given to the development of a laboratory compaction procedure that will more accurately predict the behavior of all soils under field conditions.

CONCLUSIONS

The soil compaction investigation is a continuing project so that general conclusions applicable to all soils cannot be made at this time. On the basis of the tests conducted to date it appears that the effectiveness of a sheepsfoot roller depends not only on the pressure intensity but on other characteristics such as foot area, spacing and shape of feet, and drum diameter. Also it is believed that the effectiveness and behavior of a sheepsfoot roller depends to a great extent on the soil type. The influence of contact pressure for pneumatic rollers must be investigated. Indications are that the thickness of lift and the number of passes are very important variables for both types of compaction equipment. Before final conclusions can be made on the effectiveness of compaction equipment all the above-mentioned variables must be studied.

Based on the work discussed in this paper, the specific findings may be summed up as follows: For a clayey sand a small increase in maximum density was obtained by increasing the pressure exerted by a sheepsfoot roller from

250 to 450 psi, and by increasing a rubber-tired wheel load from 20,000 to 40,000 lb with constant contact pressure. In the case of a lean silty clay, increasing a sheepsfoot roller from 250 to 500 and to 750 psi resulted in no increase of maximum density; and by increasing a rubber-tired wheel load with constant contact pressure from 10,000 to 20,000 and to 40,000 lb small increases in maximum density were obtained. For the lean silty clay it was found that, relative to the laboratory compaction curve, the field compaction curve was shifted toward the zezo air voids line for types of compaction equipment. This finding held for the clayey sand to a very minor degree.

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IX b 16

AIR ENTRAINMENT IN COMPACTED EARTH EMBANKMENT

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INTRODUCTION

The following data relates to the plastic condition which resulted from the surface compaction of earth fill at moisture contents in excess of the optimum content, as observed, from time to time, during the placement of several million cubic yards of rolled earth embankment for the Merriman Dam under construction by the Board of Water Supply at Lackawack, New York. This phenomenon was investigated by means of laboratory compaction tests, supplemented by visual and photographic examinations of soils compacted in both the laboratory and field at various moisture contents. Considering the approximate mechanics of dynamic compaction it is concluded that the plaetic, weaving behavior observed on the fill surface resulted from a temporary reduction in the relative shearing resistance of the soil, which in turn, was caused by the expansive pressure of entrapped air in the voids of the soil. Evidence is presented which indicates that intensive compactive effort expended while the soil is in this state does not produce additional densification.

MAIN TEXT

Soils for rolled fill purposes were obtained from a borrow pit located in a lateral moraine of glacial origin. Upon excavation, the materials were processed in a screening plant to remove stones larger than 5 inches, and thence hauled by truck to the embankment. This structure consists of a central relatively impervious core designated herein as "A," flanked by wide sections of materials not necessarily impervious, designated herein as "B."

Certain variable characteristics between A and B areas are as indicated below:

Area	Depth of Layer Before Compaction	Depth of Layer After Compaction	Passes of Tamping Roller	General Criteria for Soil Properties
A	7"	5"	14	To secure water-tightness
B	8"	6"	8	To secure slope stability

The tamping rollers, 60 inches in diameter and length, were of the two drum, articulated type, and exerted static pressures between 430 and 535 pounds per area inch of tamping foot, depending upon the loading of the drum.

Frequent sampling of the existing strata in the borrow with distribution by loading shovels, determined from early laboratory experiments, developed an average mixture of existing borrow materials for the A section, as follows:

Grain Size Distribution - Less Than 1/4 Inch (U. S. Bureau of Soils)	
Fine Gravel	7%
Coarse and Medium Sand	32%
Fine and Very Fine Sand	33%
Silt	18%
Clay	10%
Atterberg Limits	
Liquid	15%
Plastic	12%
Shrinkage	12%
Flow Index	4%

The permeability coefficient, pertinent to a dry density for the "A" material of 125 pounds per cubic foot, was measured as 8 feet per year, and a value of 33° was obtained for the angle of internal friction in direct shear tests of dense, saturated soils.

Due to an abundance of materials having "A" characteristics in the borrow there was some overlapping into portions of the "b" sections adjacent to the core. An opportunity, therefore, was afforded to observe densification and general soil behavior as a function of the amount of roller compaction employed in the two areas.

Fill moisture ranged between 7% and 10%, averaging 9.5% while the most favorable or optimum contents for 8 and 14 passes of the roller were about 8.8% and 3.2% respectively.

Two distinct types of soil behavior were observed during and subsequent to rolling. When the fill moisture was equal to or less than the related optimum content, the material compacted to a dense state in which it was hard and unyielding under traffic, and a high degree of