Field Compaction Tests on Lean Clay Soil

Essais de compactage d'un sol argileux maigre

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Summary

The results of field compaction tests on a lean clay soil are presented. Field test sections were constructed with a range of moisture contents and compacted with different numbers of passes of compacting equipment. Sheepsfoot rollers were used having a 250-psi contact pressure and roller foot areas of 7, 14, and 21 sq.in. A four-wheel, rubber-tired compactor also was used; tire inflation pressures were 50, 90, and 150 psi.

It is concluded that the 14-sq.in. foot appeared to be the optimum foot size for the sheepsfoot roller, although no significant differences were noted in maximum density for the three foot sizes. Increasing the tire inflation pressures of the rubber-tired roller resulted in substantial increases in maximum density of the lean clay soil.

Sommaire

Dans cette étude les résultats d'essais de compactage sur place d'un sol argileux maigre sont exposés. Les auteurs ont préparé sur place des sections d'essais de sols avec différentes teneurs en eau et les ont compactées en les soumettant à différents nombres de passes du matériel de compactage. A cet effet, ils ont employé des rouleaux pieds de moutons ayant une pression de contact de 250 livres/pouce carré, la surface de contact de chaque pied étant de 7, 14 et 21 pouces carrés, ainsi qu'un rouleau sur pneumatiques gonflés à une pression de 50, 90 et 150 livres/pouce carré.

Il a été conclu que, pour le rouleau pieds de moutons, la surface qui semblait donner le meilleur rendement était de 14 pouces carrés, encore que la différence observée entre les densités maximum ne fût pas importante entre les trois surfaces de pieds mises à l'essai. Une augmentation du gonflement des pneus du rouleau a produit une augmentation considérable de la densité maximum du sol argileux maigre.

Introduction

Field soil compaction studies have been conducted over a period of several years for the Corps of Engineers at the Waterways Experiment Station. These studies have provided much valuable information on the numerous factors which influence the compaction of soils when using sheepsfoot rollers or rubber-tired rollers. The results of previous studies have been published elsewhere (see *Turnbull* and *McFadden* (1948), WES (1949, 1950, 1951).

Briefly, they have included tests using sheepsfoot rollers on lean clay and clayey sand soils in which the controlled test variables were a range of foot contact pressures, number of passes, and water content of the soil. Rubber-tired compacting equipment has been tested on the two soils mentioned in the preceding sentence and on a sand. Controlled test variables have been weight of rollers, tire pressures, number of passes, and moisture content of the soil.

The tests described in this paper are the latest ones performed in the continuing soil compaction investigation and comprise field compaction tests on a lean clay soil using a sheepsfoot roller and a rubber-tired roller. Specifically, the sheepsfoot roller tests were to provide information on the effect of increasing the roller foot size while keeping the unit contact presure constant. Tests on the rubber-tired roller were primarily for the purpose of evaluating the effect of increasing the tire pressure while maintaining the same tire contact area. All tests were performed on specially constructed test sections of a lean clay soil as described later.

Equipment

The sheepsfoot roller used in compacting the test sections was of the dual-drum oscillating type. Each drum was 60 in. in diameter and 66 in. long. There were 120 feet per drum (30 rows of 4 feet each) and the shanks were about 7 in. long. Roller foot sizes of 7, 14, and 21 sq.in. were used; the larger feet were obtained by welding steel plates to the standard

Fig. 1 Rubber-Tired Roller
Rouleau sur pneumatiques

7-sq.in. foot with which the roller was equipped. The roller weight was adjusted for each foot size to provide a constant contact pressure of 250 psi assuming only one row of feet in contact with the soil. A D-8 tractor was used to pull the roller.

The rubber-tired roller had a rated total load capacity of 100,000 lbs. It had four rubber tires spaced about 29 in. center to center across the center of the machine. This spacing was such that two passes of the eqiupment gave approximately one complete coverage of the area. The tires were mounted in pairs on rocking beams which permitted the wheels to maintain contact over uneven ground. Tire sizes were 18.00 × 24, 24 ply, for 50 and 90 psi pressures and 16.00 × 21, 25 ply, for 150 psi pressure. Loadings and pressures for the various test conditions are given in Table 1. The rubber-tired roller was pulled by a D-8 tractor (Fig. 1).

Table 1 Loadings and pressures

Tire Inflation Pressure psi	*Wheel Load lbs.*
50	15,800
90	25,000
150	31,250

Test Sections

The test sections for both rollers were constructed in 5 lifts, each having a compacted thickness of 6 in., making a total height of 30 in. The sections were divided into units 25 to 30 ft. long; each unit was placed at a specific water content and was given a specific number of passes of one of the rollers. A sufficient number of units was constructed to provide a range of 3 to 5 water contents bracketing the optimum value. Similarly, units were constructed for each water content range for 6, 12, and 24 passes of each of the three foot sizes of the sheepsfoot roller and for 4, 8, and 16 coverages of the three tire pressures of the rubber-tired roller. In all, 69 test units were constructed for this series of investigations. The tests sections were built in a weather-protected shelter so as to permit construction of the fills under controlled conditions.

Sampling and Testing of Soils

After the completion of rolling on the test sections, a test pit was dug in the center of each unit. From 6 to 10 undisturbed samples were taken from approximately the midheight of the compacted fill in each test pit for moisture and density determinations. Unit weights were obtained by displacement in water after coating the specimens with paraffin. Representative disturbed samples of the soil were also obtained for laboratory compaction tests. In addition, field-in-place California bearing ratio tests were performed in each pit and undisturbed samples were taken for laboratory strength tests. Results of the latter two tests are outside the scope of this paper and are not discussed. Grain size analyses and Atterberg limits tests were also performed on the soils (Fig. 2).

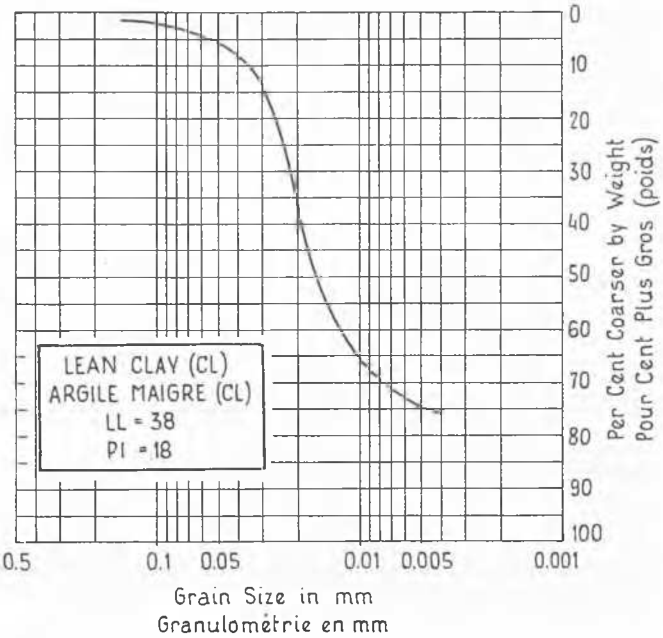
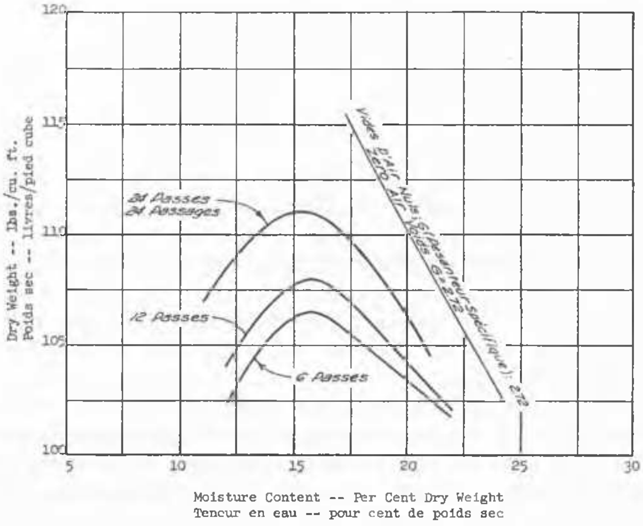


Fig. 2 Classification Data
Données sur la granulométrie

Moisture and Density Data

The inclusion of test section units having different water contents resulted in a range of water contents and densities for each field test condition. These data were plotted and a



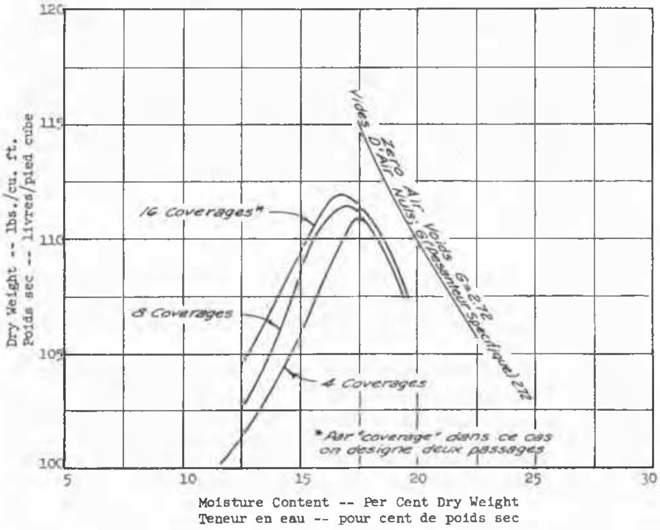
Roller foot area 21 sq. in., contact pressure 250 lb./sq. in.
Surface de contact de pied du rouleau: 21 pouces carrés. Pression de contact 250 livres/pouce carré

Fig. 3 Field Compaction Curves—Sheepsfoot Roller
Courbes de compaction sur le terrain par rouleau pieds de mouton

smooth curve of best fit drawn through the points, thus providing a field compaction curve showing the relationship between moisture and density. Some scatter of the plotted data was noted, as is to be expected for field tests of this type. However, the field compaction curves are believed to be reasonable. Field compaction curves for 6, 12, and 24 passes of the 250-psi sheepsfeet roller with the 21-sq.in. foot area are shown on Fig. 3; these data are typical of those obtained with the 7- and 14-sq.in. feet. Similar field compaction curves are shown on Fig. 4 for 4, 8, and 16 coverages of the rubber-tired roller at 90-psi tire inflation pressure; these data are typical of those obtained for the 50- and 150-psi tire pressures.

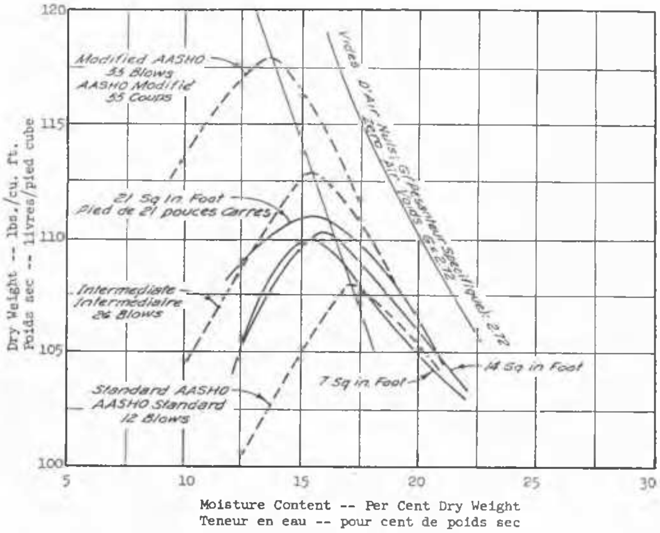
Discussion of Results—Sheepsfoot Rollers

There was a gradual increase in the maximum density of soils compacted with the sheepsfoot rollers as the number of passes increased from 6 to 24. In general, the roller with three different foot sizes showed a density increase of 4 to 6 lbs. per cu.ft. between 6 and 24 passes. This increase in density was associated with a decrease in the field optimum water content which amounted to about 3 per cent for the 7-sq.in. foot, 2 per cent for the 14-sq.in. foot and less than 1 per cent for the 21-sq.in. foot. Field observations of the behavior of the rollers indicated that all three foot sizes walked out during compaction between 6 and 12 passes of the equipment for water contents at and dry of the field optimum. For water contents wet of field optimum, none of the rollers walked out during compaction. This behavior is consistent with the concept that the bearing capacity of the soil is a governing factor in the behavior of sheepsfoot rollers (WES, 1951). Inasmuch as the three rollers all were loaded to provide a contact pressure of 250 psi, the similarity of their behavior is not unexpected. In this particular case for water contents at and dry of optimum the soil being compacted had a bearing capacity sufficient to permit the rollers to walk out, whereas at water contents wet of optimum the soil did not have sufficient bearing capacity to support the roller feet and they did not walk out.



Wheel load 25,000 lbs. Tire inflation pressure, 90 lbs./sq. in.
Charge par roue: 25,000 livres. Pression de gonflement des pneus: 90 livres/pouce carré

Fig. 4 Field Compaction Curves—Rubber-Tired Roller
Courbes de compaction sur le terrain par rouleau sur pneumatiques



LEGEND -- LÉGENDE

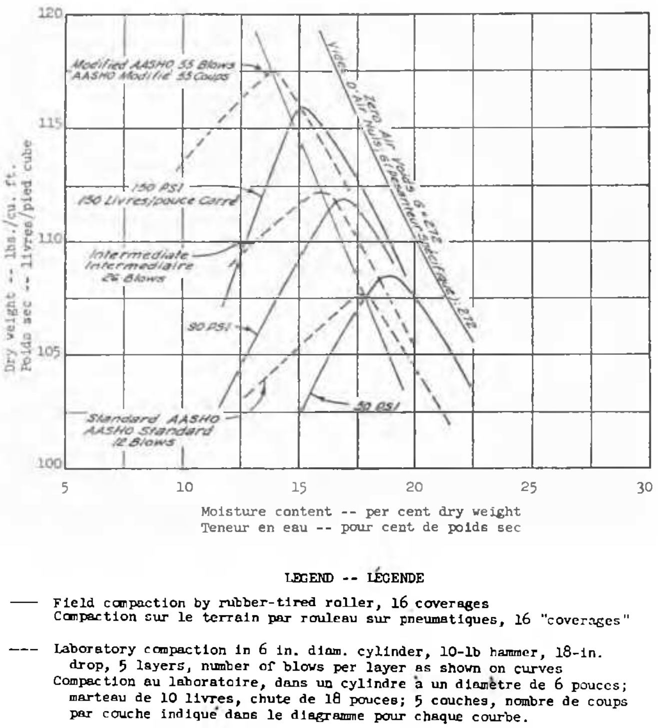
——— Field compaction by 250-psi sheepsfoot rollers, 24 passes
Compaction sur le terrain par rouleaux "pieds de mouton" d'une pression de 250 livres/pouce carré, 24 passages

--- Laboratory compaction in 6-in.-diam. cylinder, 10-lb. hammer, 18-in. drop, 5 layers, number of blows per layer as shown on curves
Compaction au laboratoire, dans un cylindre a un diamètre de 6 pouces; marteau de 10 livres, chute de 18 pouces; 5 couches; nombre de coups par couche indiqué dans le diagramme pour chaque courbe.

Fig. 5 Comparison of Laboratory Compaction with Field Compaction by Sheepsfoot Rollers
Comparaison entre la compaction au laboratoire et la compaction sur le terrain par rouleaux pieds de mouton

Fig. 5 shows a comparison of the field compaction curves obtained by 24 passes of the 250-psi sheepsfoot rollers with the compaction curves obtained in the laboratory using standard AASHO, modified AASHO, and an intermediate effort. It is seen that the three sizes of roller feet produced essentially the same field compaction results. A slight increase in density was noted for the 21-sq.in. foot over the 7- and 14-sq.in. feet. It will be noted that the 250-psi sheepsfoot rollers achieved field densities in excess of standard AASHO laboratory compaction but somewhat below the intermediate laboratory compactive effort which is approximately equivalent to 95 per cent of modified AASHO density. These results imply that the roller foot size, within the range tested, had little if any effect on the compaction obtained and the governing factor was the 250-psi contact pressure which was the same for all three rollers.

The field California bearing ratio data, however, showed that values developed by compaction with the 14- and 21-sq.in. feet were approximately the same for equal values of moisture content and density and were significantly higher than values developed by compaction using the 7-sq.in. foot. In addition, it was noted from the field moisture content and density data that even though no higher densities were obtained, more uniform compaction was obtained with the 14- and 21-sq.in. feet than with the 7-sq.in. foot. Finally, the increased weight of roller with increasing foot size (necessary to obtain the same unit contact pressures) also increased the drawbar pull of the tractor towing the roller. No difficulty was experienced in towing the rollers with the 7- and 14-sq.in. feet, but for the 21-sq.in. foot the tractor was laboring, especially in the higher moisture content soil. All of the foregoing considerations indicate that the best compaction results were obtained with the 14- and 21-sq.in. feet. Inasmuch as there was no apparent advantage of the



LEGEND -- LÉGENDE

—— Field compaction by rubber-tired roller, 16 coverages
Compaction sur le terrain par rouleau sur pneumatiques, 16 "coverages"

--- Laboratory compaction in 6 in. diam. cylinder, 10-lb hammer, 18-in. drop, 5 layers, number of blows per layer as shown on curves
Compaction au laboratoire, dans un cylindre à un diamètre de 6 pouces; marteau de 10 livres, chute de 18 pouces; 5 couches, nombre de coups par couche indiqué dans le diagramme pour chaque courbe.

Fig. 6 Comparison of Laboratory Compaction with Field Compaction by Rubber-Tired Rollers
Comparaison entre la compaction au laboratoire et la compaction sur le terrain par rouleau sur pneumatiques

21-sq.in. foot over the 14-sq.in. foot, the 14-sq.in. area appears to be about the optimum foot size for these tests.

It should also be noted on Fig. 5 that the field optimum water contents for sheepsfoot roller compaction are to the left, or dry side, of the line of laboratory optimum water contents. Previous studies on the same soil type (*Turnbull* and *McFadden*, 1948) indicated that the field optimum water contents were on the wet side of the line of laboratory optimum values. The reason for this discrepancy is not clear.

Discussion of Results—Rubber-tired Roller

The rubber-tired roller at the three inflation pressures tested showed some increase in maximum density as the number of coverages was increased from 4 to 16 (Fig. 4). This increase was in the order of only 1 lb. per cu.ft. for the 50- and 90-psi pressures and slightly greater than 3 lbs. per cu.ft. for the 150-psi pressure. The optimum water contents showed a slight decrease with increase in density, amounting to less than 1 per cent for all three tire pressures. In comparison to the sheepsfoot rollers, it may be said that the effect of additional coverages on increasing density was less pronounced for the rubber-tired rollers, particularly at the two lower tire pressures.

Fig. 6 shows a comparison of the field compaction curves obtained by 16 coverages of the rubber-tired roller at the three inflation pressures with laboratory compaction curves at three different compactive efforts. It is quite evident that increasing the tire pressure on the roller resulted in substantial increase in the compacted densities obtained in the field. Sixteen coverages of the roller at a tire pressure of 50 psi gave a maximum density slightly greater than the laboratory standard AASHO value. When the tire pressure was increased to 90 psi a density nearly equivalent to the intermediate laboratory compactive effort was reached, and at 150-psi tire pressure a density of 1.5 lbs. per cu.ft. less than laboratory modified AASHO maximum was obtained.

The field optimum moisture contents for the rubber-tired roller are slightly on the wet side of the laboratory line of optimum values as shown on Fig. 6. These data are in agreement with previous tests referenced in the discussion on sheepsfoot rollers in a preceding paragraph. The implication of these data is that the compaction of this soil by rubber-tired rollers at moisture contents wet of optimum results in moisture-density relationships approaching saturation. This condition could result in pore water pressures in the soils under load with concurrent loss of strength.

Conclusions

On the basis of the tests reported in this paper and for the soil type studied in the investigation, the following conclusions are believed warranted.

(1) The 14-sq.in. foot appears to be the optimum foot size for the 250-psi sheepsfoot roller.

(2) Increasing the sheepsfoot roller foot size from 7 to 21 sq.in. while maintaining a constant contact pressure (250 psi) had no significant effect on the maximum density developed for a given number of passes.

(3) Increasing the tire inflation pressure of the rubber-tired roller from 50 to 150 psi resulted in substantial increases in maximum density and related decreases in optimum moisture content within the range between standard and modified AASHO laboratory compaction tests.

(4) Increasing the number of passes of the sheepsfoot roller from 6 to 24 and the number of coverages of the rubber-tired roller from 4 to 16 resulted in slight increases in the maximum density of the compacted soil; the effect was more pronounced for the sheepsfoot roller than for the rubber-tired roller.

(5) The behavior of the sheepsfoot roller during compaction is believed related to the bearing capactiy of the soil in that the rollers walked out on soils at or dry of the field optimum moisture content but did not walk out on soils wet of optimum.

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