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THE PERFORMANCE OF AN AVELING-BARFORD VP 7.7 Mg. SELF-PROPELLED
VIBRATING ROLLER IN THE COMPACTION OF SOIL

by

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CONTENTS

	Page
Abstract	1
1. Introduction	1
2. The Aveling-Barford VP 7.7 Mg vibrating roller	2
3. Experimental procedure	4
4. Discussion of results	4
4.1 Relations between dry density and number of passes	4
4.2 Relations between dry density and moisture content	6
5. Output of the vibrating roller	6
6. Acknowledgements	7
7. References	7

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THE PERFORMANCE OF AN AVELING-BARFORD VP 7.7 Mg SELF-PROPELLED VIBRATING ROLLER IN THE COMPACTION OF SOIL

ABSTRACT

This Report describes an investigation into the performance of an Aveling-Barford VP 7.7Mg self-propelled vibrating roller in the compaction of a heavy clay, a sandy clay, a well-graded sand, a gravel-sand-clay, and a uniformly graded fine sand.

The results show that, in general, a satisfactory state of compaction would be achieved after 4 to 8 passes on 150-mm thick compacted layers of cohesive and well-graded granular soils. The machine is likely, therefore, when operated at a speed of travel of 2.4 km/h, to be capable of compacting, to a state satisfactory for earthwork construction, 70 to 140 m³/h of these types of soil. Tests with the heavy clay and well-graded sand indicated that higher outputs might be expected when using higher compacting speeds (140 to 220 m³/h at a speed of 5 km/h).

With uniformly graded fine sand, as often occurs with self-propelled machines, it was found that the roller would not operate on loose material and it was necessary to pre-compact the soil with a track-laying tractor to provide sufficient stability for the vibrating roller to be used. Following pre-compaction, 3 passes of the roller on 230 mm thick compacted layers were required to achieve a satisfactory state of compaction. Because of the necessity to pre-compact, application of the self-propelled vibrating roller to the compaction of uniformly graded materials must be somewhat limited.

1. INTRODUCTION

This Report describes an investigation into the performance of a 7.7 Mg self-propelled vibrating roller (Aveling-Barford VP), in the compaction of five types of natural soil. The soils were a heavy clay, a sandy clay, a well-graded sand, a gravel-sand-clay, and a uniformly graded fine sand. The particle-size distributions of these soils and the results of plasticity and specific-gravity tests, determined according to B.S.1377¹, are shown in Fig. 1.

The investigation was concerned primarily with determining the effect of the number of passes of the machine on the state of compaction produced in each soil. This information is important for the economical operation of the machine, in assessing the likely output figures, and in the preparation of method-type specifications. From the results it was also possible

to deduce the likely relations between the dry density and the moisture content of each soil for various numbers of passes of the vibrating roller.

The moisture content of the soil will affect the relation between the number of passes of the machine and the state of compaction produced but, to limit the duration of the investigation to reasonable proportions, the tests were, in general, carried out at one moisture content only for each soil. This moisture content was slightly lower than the average at which each soil is normally found in the British Isles, and it represents, therefore, a condition in which the soil is slightly more difficult than average to compact.

Similarly, only one depth of compacted layer was used with each of the soils, the selection of this depth being based upon that specified for the particular type of machine in Table 3 (Compaction Requirements, Earth-works) of the Ministry of Transport's Specification for Road and Bridge Works². In this specification the speed of travel of vibrating rollers is normally limited to a maximum of 2.4 km/h (1.5 mile/h) and this speed was used, therefore, for tests on each of the soils. In addition, however, with heavy clay and well-graded sand, other speeds of travel in the range 1.3 - 7.2 km/h were used.

2. THE AVELING-BARFORD VP 7.7 Mg VIBRATING ROLLER

The Aveling-Barford VP vibrating roller is shown in Plate 1, and details of the machine are given in Table 1. The machine is self-propelled, driven by two pneumatic-tyred steerable wheels at the rear. The freely-rotating vibrating roll is mounted at the front of the machine using rubber suspension units to isolate the vibrations from the chassis. The vibrational forces are produced by an eccentrically - weighted shaft rotating within the roll.

The power unit, a 64 kW four-cylinder diesel engine, is mounted over the rear axle, and drives the wheels through a hydrostatic transmission unit, propeller shaft, and differential axle. Thus a continuously variable forward or reverse travelling speed, up to the maximum value of 18.9 km/h can be achieved, largely independently of the engine speed.

The eccentrically-weighted shaft producing the vibration is driven by vee belts from a hydraulic motor, the oil supply to which is provided by a fixed-delivery pump mounted on the engine. At the governed maximum engine speed, the frequency of vibration is about 2300 cycles per minute.

The majority of the controls are centrally mounted in the operator's compartment and the machine can be controlled from either of the two seats (see Plate 1). A tachometer on the control panel indicates the frequency of vibration to the operator. Power steering is provided, and scraper bars are fitted to both the front and rear of the roll.

TABLE 1

Details of the 7.7 Mg ($7\frac{1}{2}$ ton) self-propelled vibrating roller as used in the investigation

Manufacturer	Aveling-Barford Ltd.
Machine designation	VP
Power Unit	6-cylinder, 4-stroke, diesel engine.
Engine number	2703 E 6015
Rated engine power	64 kW (86 hp)
Maximum governed engine speed	1800 rev/min
Maximum vibrator-shaft speed (nominal)	2300 rev/min
Vibrator-shaft speed (measured)	2400 rev/min
Centrifugal force (nominal)	142 kN (32000 lbf)
Normal speed of travel in tests	2.4 km/h ($1\frac{1}{2}$ mile/h)
Maximum speed of travel in tests	7.2 km/h ($4\frac{1}{2}$ mile/h)
Maximum speed of travel on road without vibration (measured)	18.9 km/h ($11\frac{3}{4}$ mile/h)
<u>Dimensions</u>	
Overall length	4.88m (1.92 in)
Overall width	2.08m (82 in)
Overall height	2.06m (81 in)
Width of roll	1.83m (72 in)
Diameter of roll	1.37m (54 in)
Rear wheel track	1.70m (67 in)
Roll-wheel base i.e. distance between front and rear axles	2.74m (108 in)
Tyre size on driving wheels	356 mm x 610 mm (14.00 in x 24 in)
Tyre inflation pressure during tests	138 kN/m ² (20 lbf/in ²)
<u>Masses</u>	
Total mass (including driver and fuel)	7.67 Mg (7 ton 11 cwt)
Distribution of mass:-	
Front roll	4.14 Mg (4 ton $1\frac{1}{2}$ cwt)
Rear axle	3.53 Mg (3 ton $9\frac{1}{2}$ cwt)
Mass per unit width of roll	2.27 Mg/m (127 lb/in)

3. EXPERIMENTAL PROCEDURE

To determine the effect of the number of passes of the vibrating roller on the state of compaction produced for each soil, loose layers of soil were prepared at the required moisture content by means of a rotary cultivator. The loose depths used were those estimated to produce about 165 mm thick compacted layers of cohesive and well-graded granular soils, and 240 mm of uniformly graded material, i.e. a compacted layer about 15 mm thicker than the layer in which it was intended to make measurements of the state of compaction.

The prepared layer of loose soil was compacted with the required number of passes of the roller, the machine travelling alternately forwards and backwards, and remaining in the same track throughout, at the required speed of travel (see section 1).

With the uniformly graded fine sand, as is often the case with self-propelled machines, it was necessary to pre-compact the soil with a track-laying tractor and to carry out the first two passes without vibration. (This procedure was adopted after the failure of attempts to operate the roller on loose layers of the soil and with vibration for the first pass on the pre-compacted soil).

With the cohesive and well-graded granular soils, six dry-density determinations were made in the top 150 mm of compacted soil, using the sand-replacement method¹. With the uniformly graded fine sand, no over-stressing was observed in the upper part of the layer, as is frequently the case with this material, and it was not necessary to remove any material before measuring the state of compaction. Six dry-density measurements were thus made in the top 230 mm of the compacted layer. All the measurements were made in the area of compacted soil between the tracks of the rear wheels of the machine. The results are given in Figs 2 to 5.

A few tests were also carried out, with the heavy clay and well-graded sand, in which the machine was used without vibration. The results are included in Figs 2 and 4.

4. DISCUSSION OF RESULTS

4.1 Relations between dry density and number of passes

The relations obtained between dry density and number of passes of the vibrating roller (Figs 2 to 5) show that, apart from the tests with the heavy clay and uniformly graded fine sand, the state of compaction was increasing up to the maximum number of passes used in the tests (16). With the heavy clay (tests with vibration) and uniformly graded fine sand, little increase in the state of compaction occurred after about 8 passes.

An air content of 10 per cent or less is considered to be a satisfactory state of compaction with the cohesive and well-graded granular soils. At the moisture contents at which the tests were carried out, the roller produced air

contents of less than 10 per cent after 4 to 8 passes with these materials when travelling at a speed of about 2.4 km/h (Figs 2 to 4). The two sets of results for heavy clay (Fig. 2) illustrate the effect of variations in moisture content. Thus, at a speed of travel of 2.4 - 2.7 km/h the number of passes required to achieve a satisfactory state of compaction varied from 8 at a moisture content of 22.5 per cent to 6 at a moisture content of 24 per cent.

Figs 2 and 4 include relations, obtained with the heavy clay and the well-graded sand, between dry density and number of passes of the vibrating roller for different compacting speeds. The number of passes required to achieve air contents of 10 per cent or less increased as the speed of compaction increased (Table 2).

TABLE 2
Effect of speed of rolling on the compaction of heavy clay
and well-graded sand

Speed of rolling		Number of passes required to achieve a state of compaction equivalent to 10% air voids	
km/h	mile/h	Heavy clay	Well-graded sand
1.3	$\frac{3}{4}$	7	4
2.3	$1\frac{1}{2}$	8	4
4.7	3	8	5
7.2	$4\frac{1}{2}$	Approximately 16	6

With a vibrating compactor, it might be expected that the state of compaction achieved would be dependent upon the number of vibrational cycles applied to the soil. If this were the case, the number of passes required to achieve a state of compaction of 10 per cent air voids would be proportional to the speed of travel, i.e. the total number of vibrational cycles applied to a given area of soil would be the same for each speed of travel. This is clearly not the case with the results shown in Figs 2 and 4 and Table 2, where the effect of the speed of travel on the compaction performance is shown to be somewhat similar to that which is usually found with static weight rollers³. The contribution to the compaction process of the static weight of the machine is apparent from the results of tests without vibration which have been included in Figs 2 and 4.

With the uniformly graded fine sand, a dry density of 1.60 Mg/m³ or more is considered to be a satisfactory state of compaction. This was achieved in the tests (Fig 5) after about 3 passes of the vibrating roller.

However, as described in Section 3 above, for the machine to operate on the uniformly graded fine sand, it was necessary to pre-compact the soil with a track-laying tractor and then carry out the first two passes without vibration. Because of this requirement, the application of the machine to the compaction of uniformly graded materials must be somewhat limited. (To confirm this, the mobility of the machine was also tested on a pulverised fuel ash, another uniformly graded material, and again it could only be operated after the material had been pre-compacted using a track-laying tractor).

With the uniformly graded fine sand, it was observed that, unlike other vibrating rollers previously tested at the laboratory, no apparent overstressing of the surface of the layer occurred (i.e. the material did not remain in a loosened condition on the surface). It is thought that this was at least partly the result of the absence of horizontal shear planes produced, when using other vibrating machines, by large deformations of the material during early passes, or by the tractive effect of driven rolls. Thus, had the 7.7 Mg vibrating roller been capable of operating without pre-compaction of the soil, larger deformations would have occurred during early passes of the machine, and this would probably have caused the overstressing that normally would be expected.

4.2 Relations between dry density and moisture content

Relations between dry density and moisture content, for different numbers of passes of the vibrating roller on each of the soils tested, have been calculated (Figs 6 - 8). These relations were obtained by drawing curves through the points obtained in the study of the effect of the number of passes of the vibrating roller. These curves are approximately parallel to the average slope of similar relations established experimentally in the past with vibrating rollers⁴. Thus Figs 6 - 8 enable the performance of the machine to be assessed for moisture contents other than those used in the tests, and they also allow comparisons to be made with items of compaction plant previously tested^{4,5}.

5. OUTPUT OF THE VIBRATING ROLLER

The results of the investigation indicate that from 4 to 8 passes are required, at an average speed of travel of 2.4 km/h (the limitation normally imposed on this type of machine in the Ministry of Transport's Specification for Road and Bridge Works²), to compact cohesive and well-graded granular soils to a state satisfactory for earthwork construction. Thus, assuming that the machine is operated for 50 minutes in each hour, it would be possible to achieve outputs in the range 70 to 140 m³/h.

However, the relations between the output of heavy clay and well-graded sand, compacted to a satisfactory state, and the speed of travel of the vibrating roller shown in Fig. 9 indicate that for both cohesive and well-graded granular soils the output increased when speeds of travel in excess of 2.4 km/h were used. With the heavy clay maximum output occurred at an optimum speed of about 5 to 6 km/h, whereas with the well-graded sand

the output was increasing up to the maximum speed used, 7.2 km/h. The curves suggest that outputs in the range 140 to 230 m³/h might be expected when a speed of travel of about 5 km/h is used.

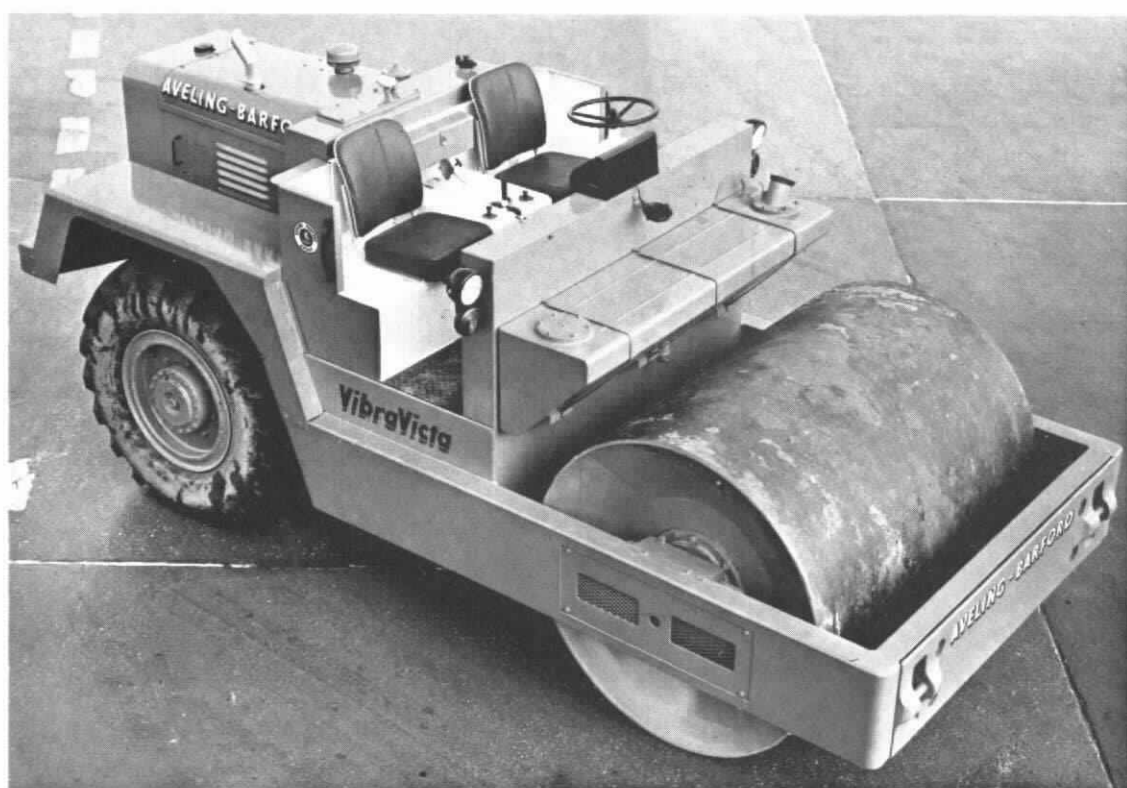
It should be remembered that the calculated outputs given above are only a guide to the likely performance of the vibrating roller, as they depend on the actual moisture content of the soil and on the site conditions.

6. ACKNOWLEDGEMENTS

Thanks are due to Aveling-Barford Ltd., for the loan of the vibrating roller. The work was carried out in the Earthworks and Foundations Section of the Construction Division, under the direction of W.A. Lewis and A.W. Parsons. The author was assisted in the experimental work by T.O. Odubanjo, together with F. Hughes, T. Newcombe, J. Rudd and P. Shepherd, of Aveling-Barford Ltd.

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4. LEWIS, W.A. Recent research into the compaction of soil by vibratory compaction equipment. Proc. 5th Internat. Conf. Soil Mech. 1961, 2,261-8.
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PLATE 1 The Aveling-Barford VP 7.7 Mg (7½ ton) self-propelled vibrating roller

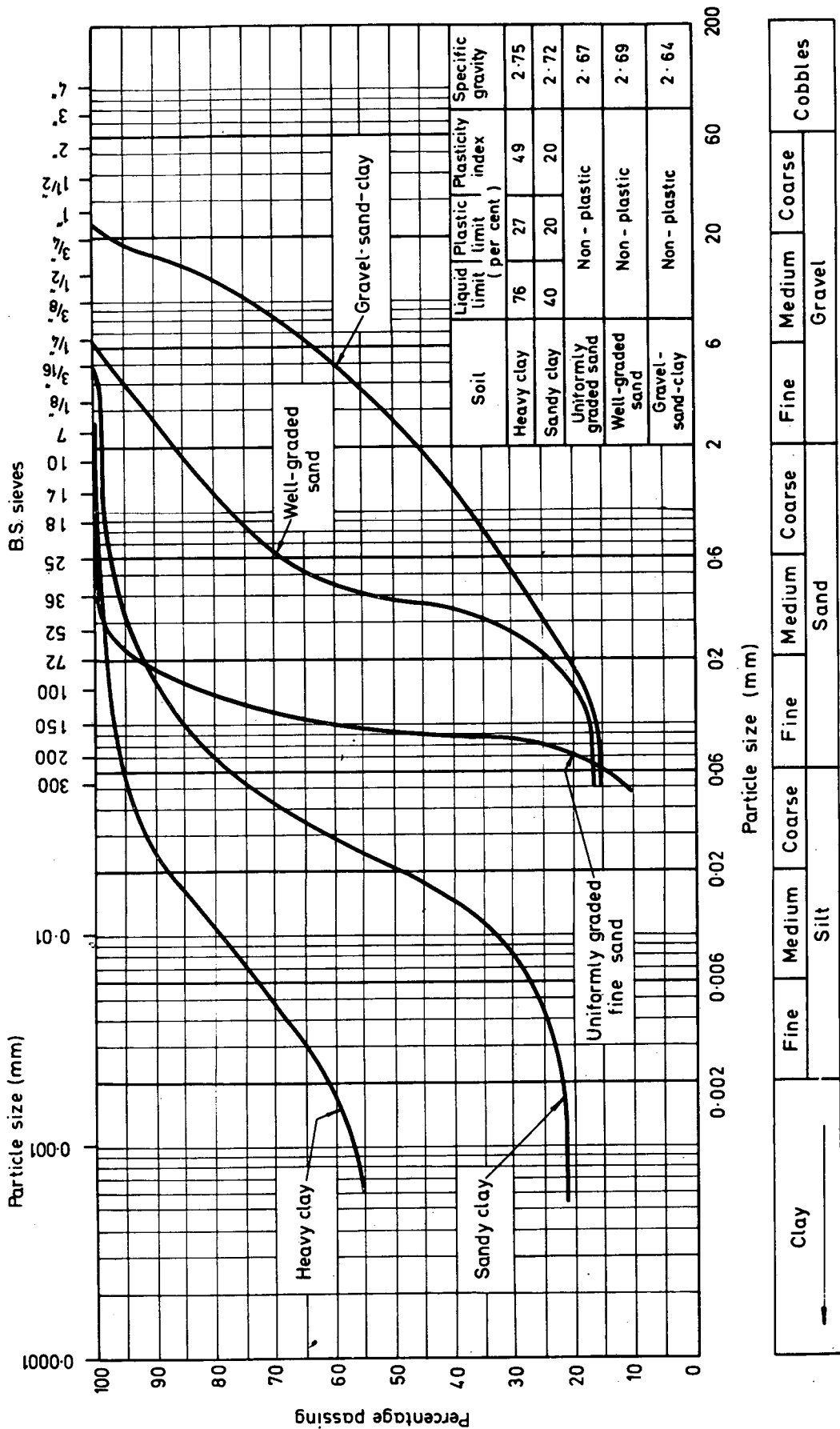


Fig. 1. PARTICLE - SIZE DISTRIBUTIONS AND RESULTS OF PLASTICITY AND SPECIFIC - GRAVITY TESTS FOR THE SOILS USED IN THE INVESTIGATION

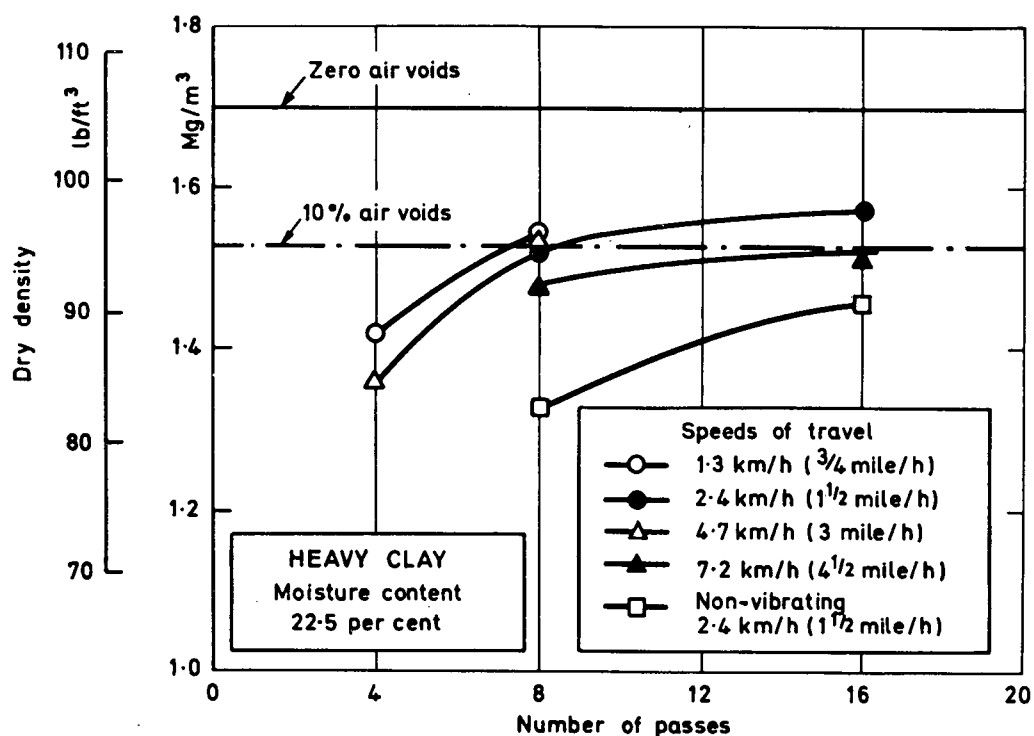
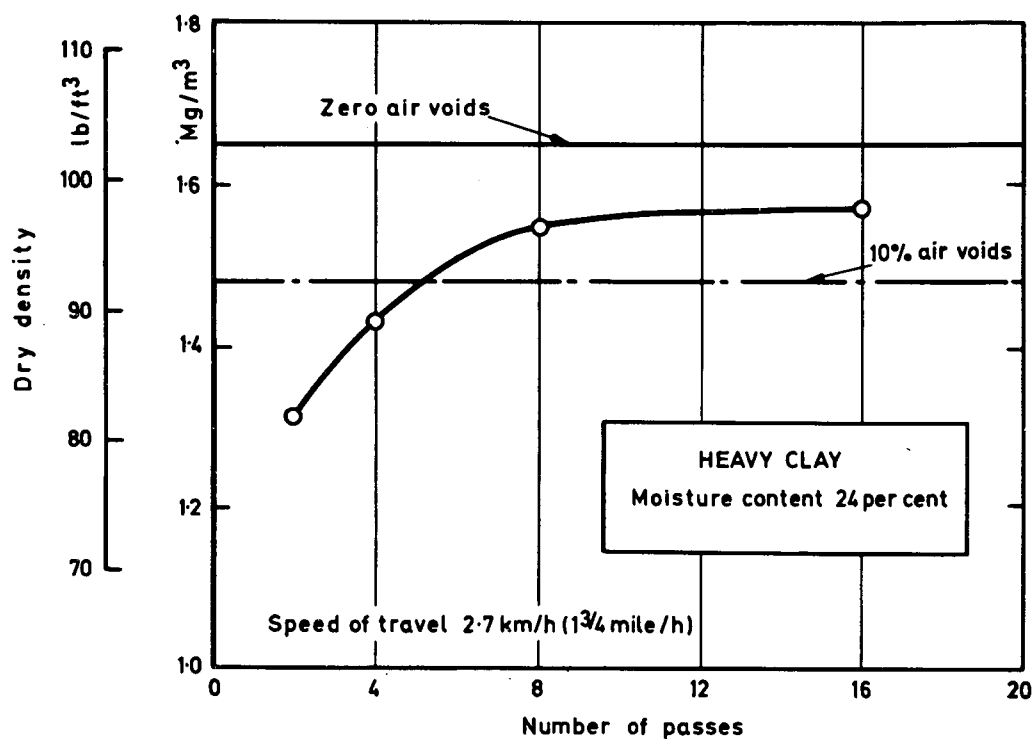


Fig. 2. RELATIONS BETWEEN DRY DENSITY OF 150 mm (6in) THICK COMPACTED LAYERS OF THE HEAVY CLAY AND NUMBER OF PASSES OF THE VIBRATING ROLLER

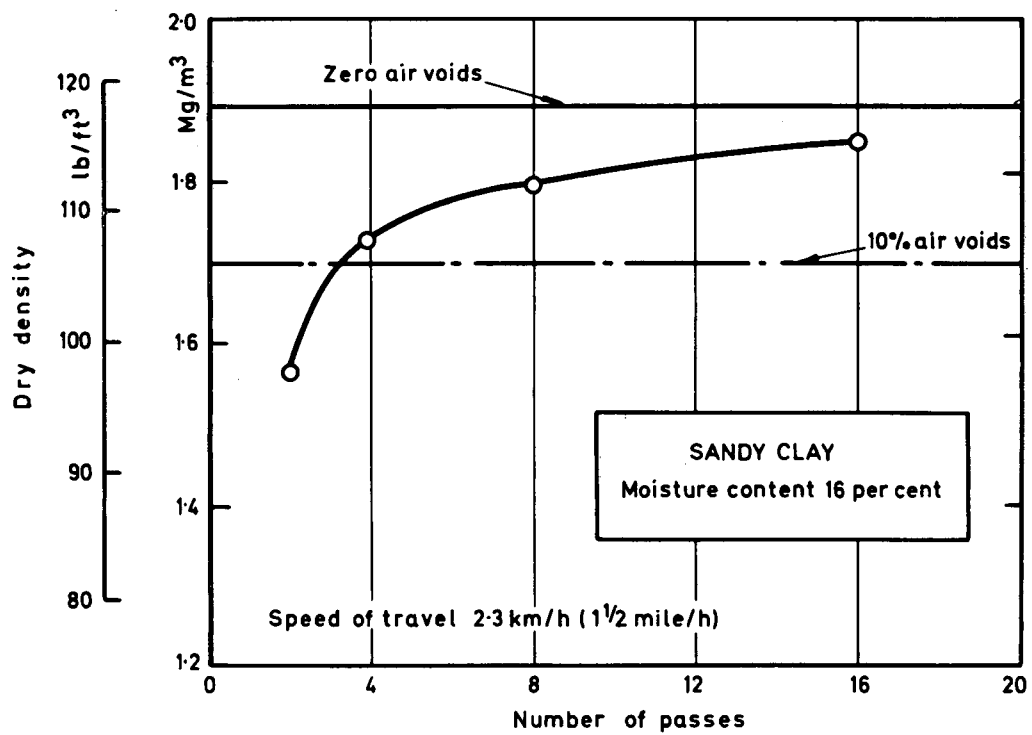


Fig. 3. RELATIONS BETWEEN DRY DENSITY OF 150mm (6in.) THICK COMPACTED LAYERS OF THE SANDY CLAY AND NUMBER OF PASSES OF THE VIBRATING ROLLER

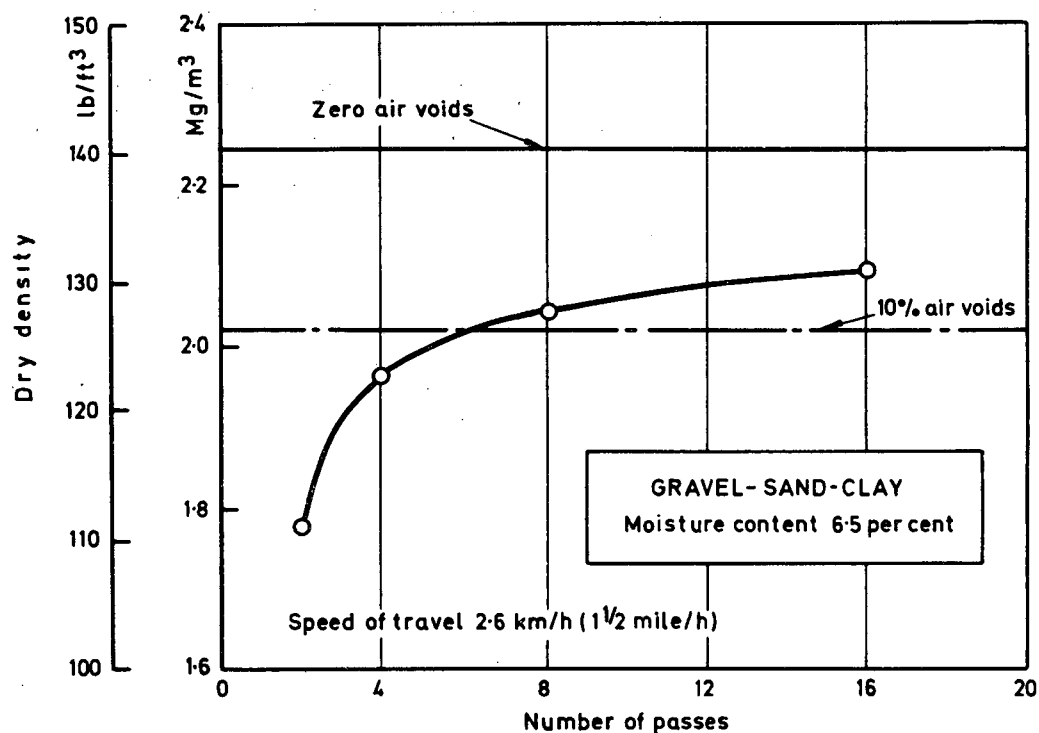
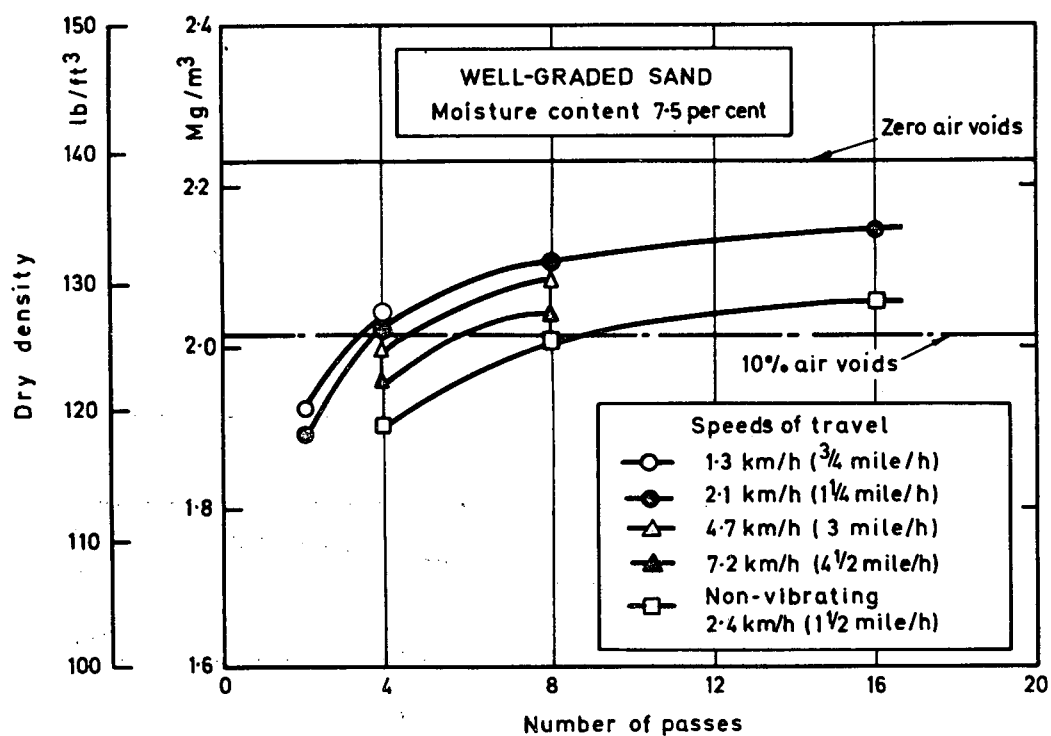


Fig. 4. RELATIONS BETWEEN DRY DENSITY OF 150 mm (6 in) THICK COMPACTED LAYERS OF THE WELL-GRADED GRANULAR SOILS AND NUMBER OF PASSES OF THE VIBRATING ROLLER

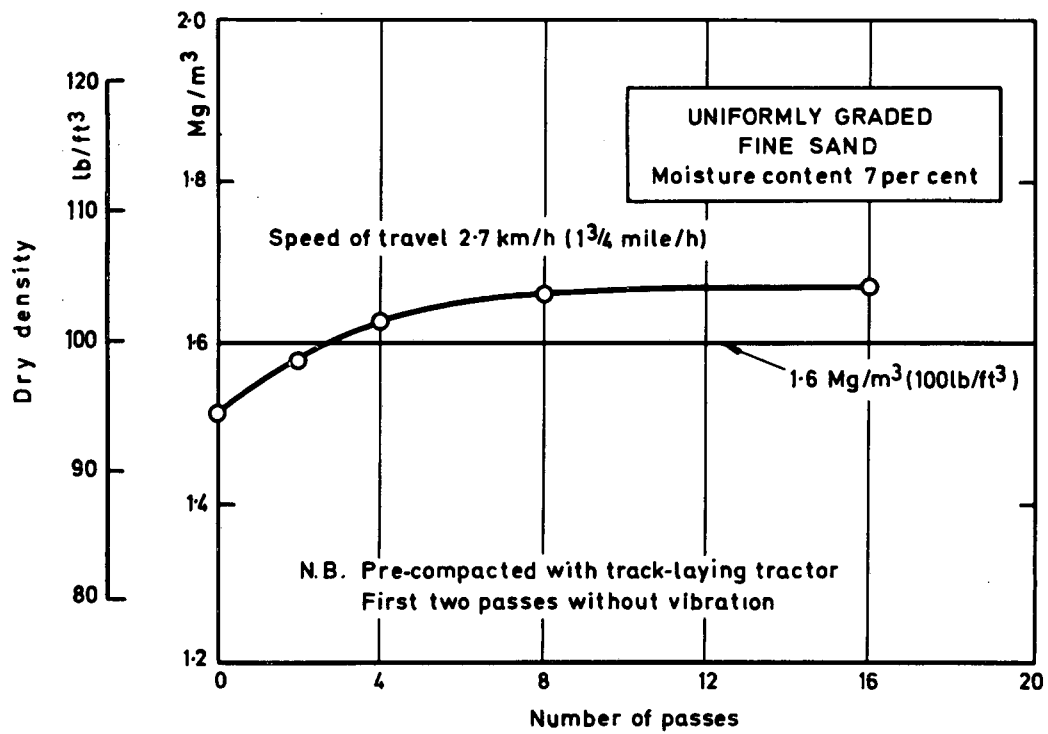


Fig. 5. RELATIONS BETWEEN DRY DENSITY OF 230mm (9in) THICK COMPACTED LAYERS OF THE UNIFORMLY GRADED FINE SAND AND NUMBER OF PASSES OF THE VIBRATING ROLLER

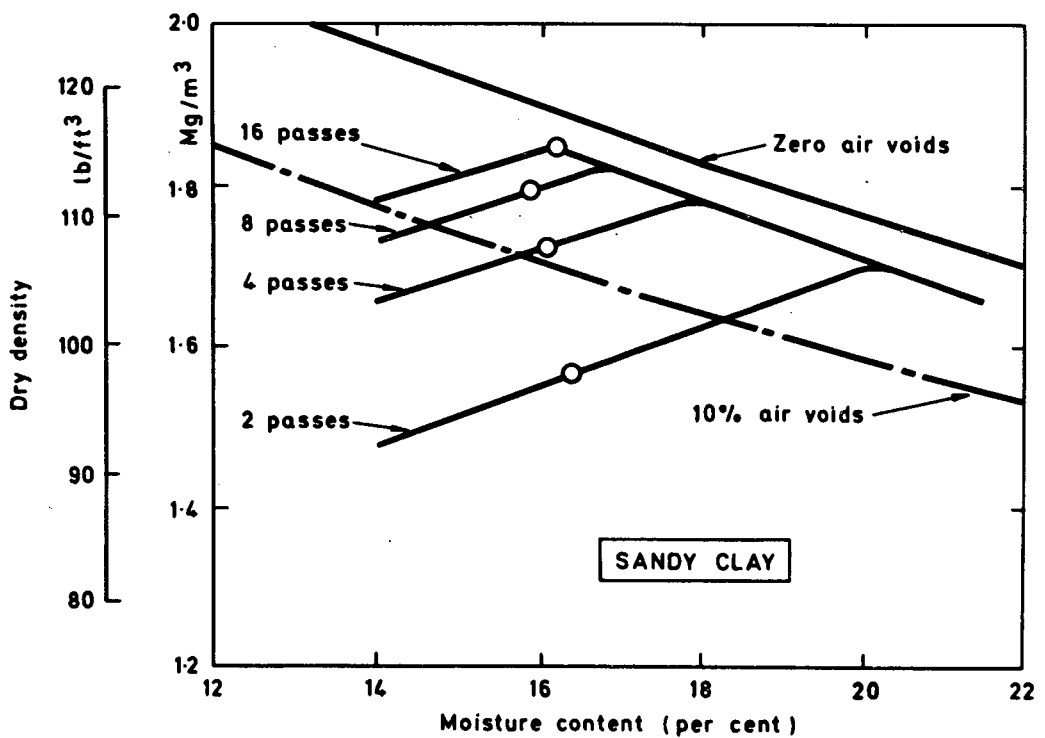
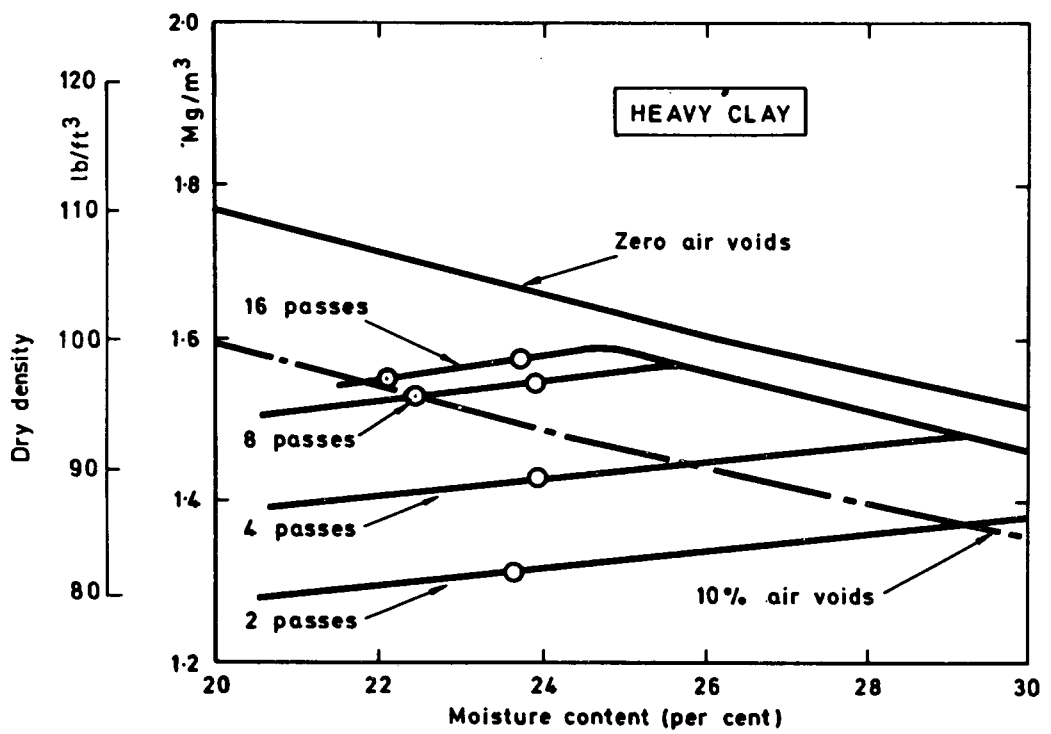


Fig. 6. CALCULATED RELATIONS BETWEEN DRY DENSITY AND MOISTURE CONTENT OF 150mm (6in.) THICK COMPACTED LAYERS OF THE COHESIVE SOILS WHEN USING THE VIBRATING ROLLER AT SPEEDS OF TRAVEL IN THE RANGE 2.1 TO 2.7 km/h (1¼ TO 1¾ mile/h)

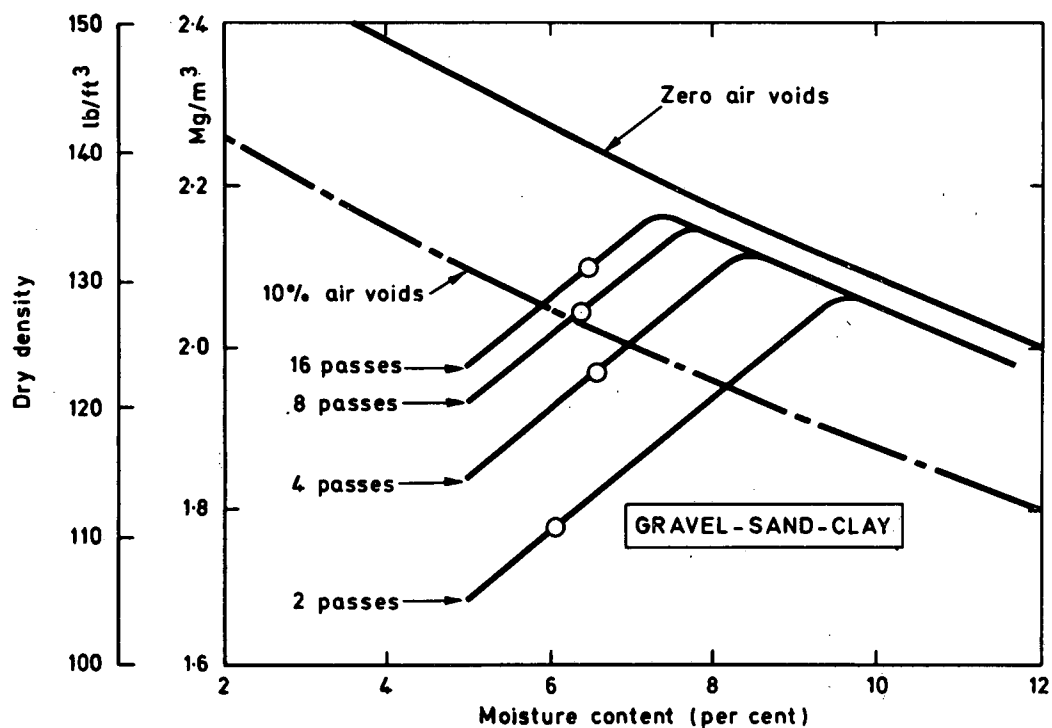
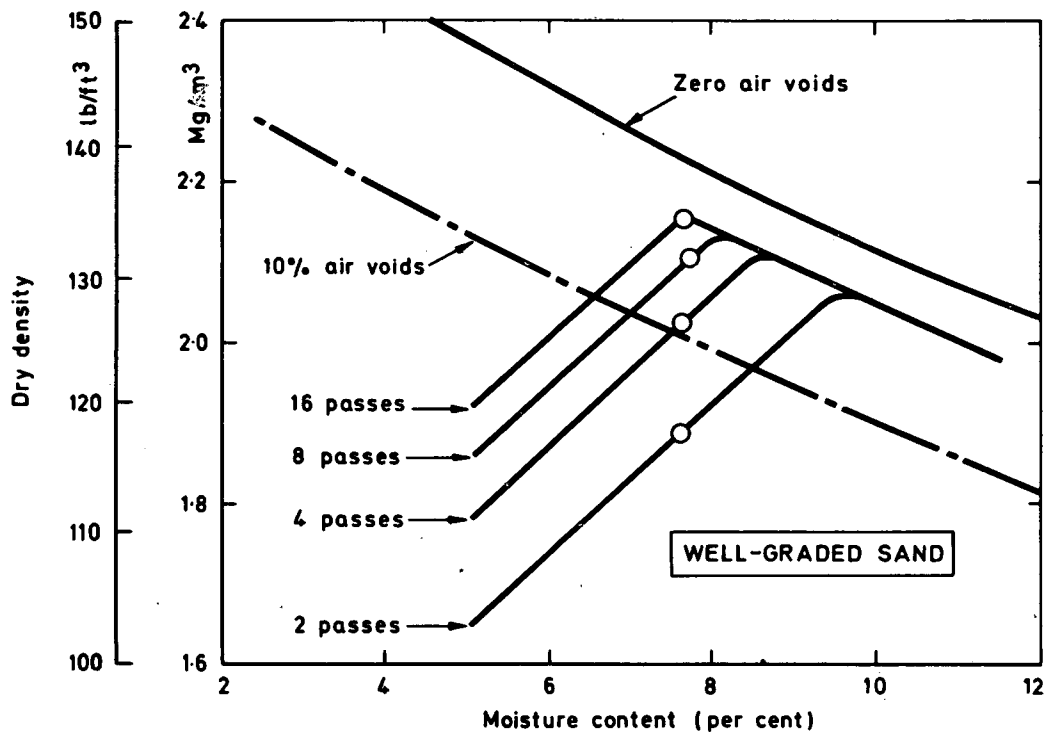


Fig. 7. CALCULATED RELATIONS BETWEEN DRY DENSITY AND MOISTURE CONTENT OF 150 mm (6 in) THICK COMPACTED LAYERS OF THE WELL-GRADED GRANULAR SOILS WHEN USING THE VIBRATING ROLLER AT SPEEDS OF TRAVEL IN THE RANGE 2.1 to 2.7 km/h ($1\frac{1}{4}$ to $1\frac{3}{4}$ mile/h)

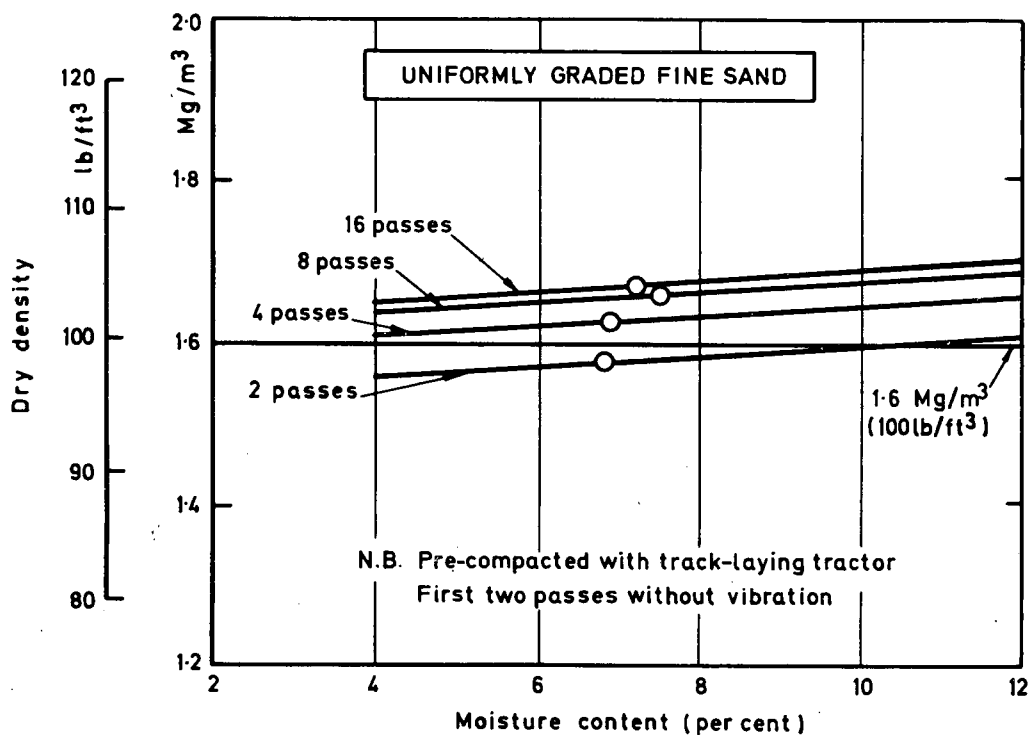


Fig. 8. CALCULATED RELATIONS BETWEEN DRY DENSITY AND MOISTURE CONTENT OF 230mm (9in) THICK COMPACTED LAYERS OF THE UNIFORMLY GRADED FINE SAND WHEN USING THE VIBRATING ROLLER AT SPEEDS OF TRAVEL IN THE RANGE 2.1 to 2.7 km/h (1¹/₄ to 1³/₄ mile/h)

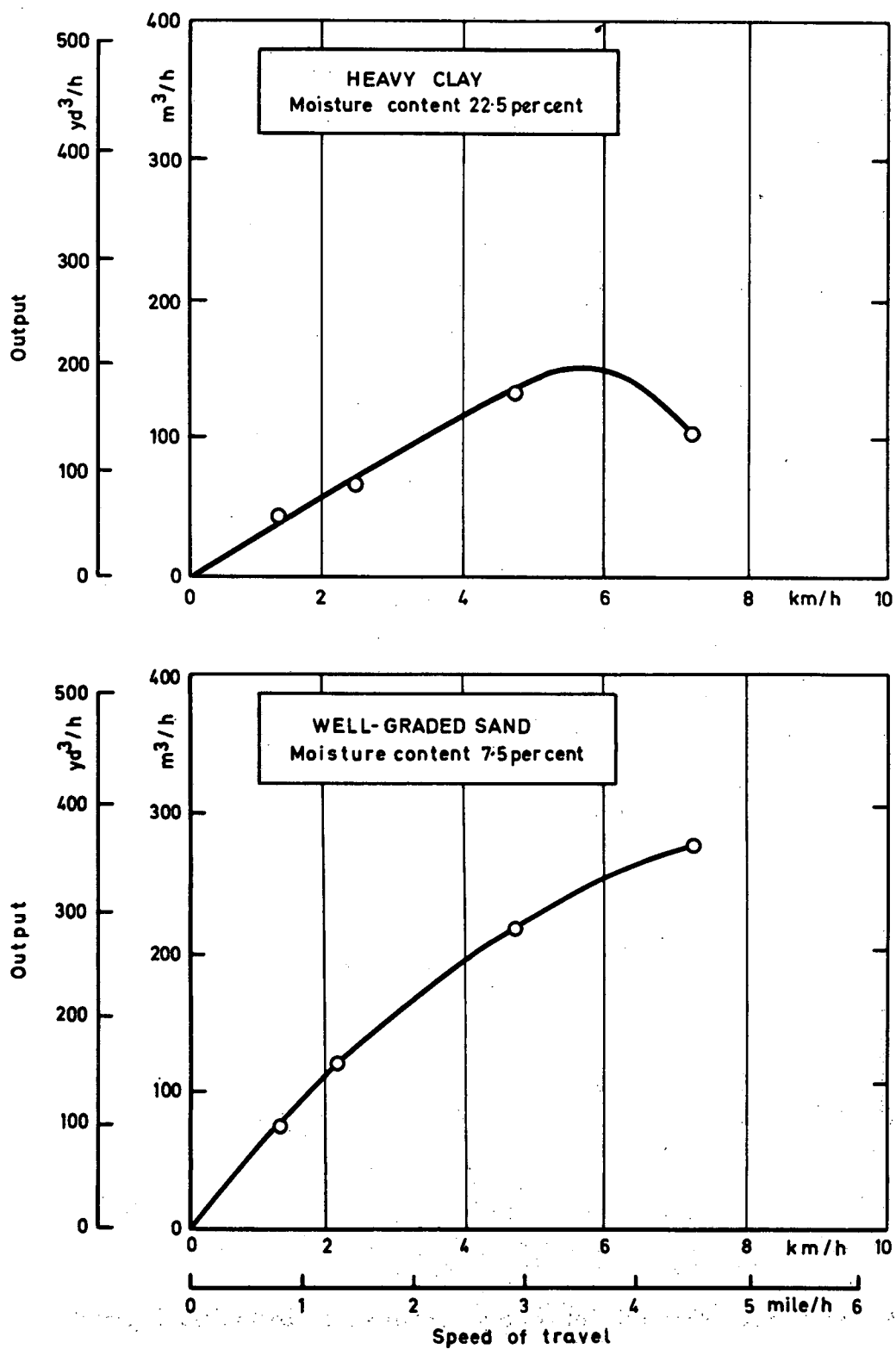


Fig. 9. RELATIONS BETWEEN OUTPUT OF THE HEAVY CLAY AND WELL-GRADED SAND, COMPACTED TO 10 per cent AIR VOIDS, AND SPEED OF TRAVEL OF THE VIBRATING ROLLER

Printed at Road Research Laboratory, Crowthorne, Berkshire, England.

ABSTRACT

The performance of an Aveling-Barford VP 7.7 Mg self-propelled vibrating roller in the compaction of soil: A,F, TOOMBS: Ministry of Transport, RRL Report LR 257: Crowthorne, 1969 (Road Research Laboratory). This Report describes an investigation into the performance of an Aveling-Barford VP 7.7 Mg self-propelled vibrating roller in the compaction of a heavy clay, a sandy clay, a well-graded sand, a gravel-sand-clay, and a uniformly graded fine sand.

The results show that, in general, a satisfactory state of compaction would be achieved after 4 to 8 passes on 150-mm thick compacted layers of cohesive and well-graded granular soils. The machine is likely, when operated at a speed of travel of 2.4 km/h, therefore, to be capable of compacting, to a state satisfactory for earthwork construction, 70 to 140 m³/h of these types of soil. Tests with the heavy clay and well-graded sand indicated that higher outputs might be expected when using higher compacting speeds (140 to 220 m³/h at a speed of 5 km/h).

With uniformly graded fine sand, as often occurs with self-propelled machines, it was found that the roller would not operate on loose material and it was necessary to precompact the soil with a track-laying tractor to provide sufficient stability for the vibrating roller to be used. Following pre-compaction, 3 passes of the roller on 230 mm thick compacted layers, were required to achieve a satisfactory state of compaction. Because of the necessity of precompact, application of the self-propelled vibrating roller to the compaction of uniformly graded materials must be somewhat limited.