EVALUATION CRITERIA FOR HAND-GUIDED VIBRATORY ROLLERS IN COMPACTION OF LATERITES FOR ROAD MAINTENANCE WORKS'

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ABSTRACT

This paper reports the results of an investigation aimed at evolving criteria for the use of Hand-guided vibratory rollers in the compaction of laterite for road maintenance works such as shoulder repairs and re-instatement of base course materials in failed sections. Samples of lateritic soil were collected from existing borrow pits in Tsamiya Babba and Chalawa areas of Kano State, Nigeria and classified using American Association of State Highway Officials (AASTHO) method as A-6, A-2-4 (sub-base) and A-2-6 (base) materials. Rolling tests were carried out with hand guided vibratory roller in six number bays prepared with 100 mm and 150 mm thick lateritic soil. This was to determine the economic number of passes required to achieve the maximum dry density (MDD) of the samples. It was found that for a base course, the number of passes required in compacting 100 mm and 150 mm thick layers of lateritic soil with a hand-guided rollers of weight 1015 kg were 14 and 16 respectively, while that of sub-base were 16 and 18 passes. In comparison with the rolling tests on similar materials in active earth works construction site using 10,000 kg self propelled roller, the number of passes is reduced to 4-6 and 5-8 passes for 100 mm and 150 mm base and sub base materials respectively. The number of passes required to achieve maximum dry density (MDD) depends on weight or size of compaction plant, layer thickness and material type. The hand-guided vibratory roller with 16-18 passes is recommended for maintenance work for economic base and sub-base lateritic soil material compaction.

Significance: Though the use of heavy duty self-propelled rollers has been widely recommended, it has been observed that the use of such big rollers is cumbersome in the compaction of small areas such as pot holes and smaller failed sections of roads. This is also compounded by operational cost in transporting the big sized rollers to site. This calls for the use of hand-guided rollers and hence the criteria for their optimum application.

Keywords: Hand-guided Roller, Lateritic soil, Sub-base, Base, Road maintenance Compaction.

1.0 INTRODUCTION

Soil compaction has been defined as a process whereby the soil particles are made to pack more closely together by reducing the air voids, generally by mechanical means. By compacting soil under controlled conditions, the air voids can be almost eliminated such that there will be fewer tendencies for subsequent changes in moisture content to take place (TRRL, 1975). Several factors influence the compaction of soil, such as soil moisture content, the amount of compaction, and the soil type. The increase in the dry density of the soil by compaction depends mainly on the moisture content of the soil and on the amount of compaction effort applied. Compaction of soil in the field can be achieved in the field by applying energy through pressure, impact or vibration, depending on the types of compaction plant used. The performance of compaction plants depends, largely on the soil type, the particle size distribution and the soil moisture content. These factors are taken into account in the selection of compaction plant for a particular job. Usually, a rolling test is carried out to establish the optimum moisture content and maximum dry density of the proposed plant for a particular type of soil material. It is also used to determine the economic number of passes of the plant that may be required to achieve the maximum dry density at known moisture content. Previous studies on soil compaction methods, conducted by the Transport and Road Research Laboratory in 1952, emphasized more on the use of big size rollers, usually greater than 2500kg, in the construction of embankments and road pavements. However, it has been observed that the use of such big rollers is cumbersome in the compaction of small areas such as potholes and smaller failed sections of the roads. The size of the rollers and the cost of haulage, when moving from one place to another, are some factors that make the use of hand rollers more convenient in road maintenance works. The hand-guided rollers are now being used in the compaction of laterite in road maintenance works. The most commonly used hand-guided rollers are smooth wheeled, double barreled, with an average weight of about 1000kg. They are usually used in the reinstatement of base materials in deep potholes and smaller failed sections, during the maintenance works. Hand rollers are now commonly used by Road Maintenance Agencies as well as the road maintenance contractors during patching of potholes, repairs of small failed sections and even reinstatement of narrow road shoulders, without any specification on the compaction technique that will be suitable for the proposed materials and the plant. The General Specification for Road and Bridges by the Federal Ministry of works, Vol.2, Clause 1052(1997) recommended the compaction trial by rolling test, to determine the most efficient compaction technique that will be suitable for the proposed materials and the plant in road construction. However, the specification does not include the case where compaction is required in the reinstatement base materials in potholes or small failed sections during maintenance work. Also for such smaller works of higher frequency, it may be difficult for the maintenance authorities to enforce the use of in-situ density tests for compaction control. The constraint in space, when dealing with smaller areas, coupled with the cost of haulage when moving a compaction plant from one place to another, makes the use of big rollers more cumbersome in road maintenance works. In view of that, it is imperative for the geotechnical engineers to provide a sound basis of allowing the use of hand rollers in the compaction of lateritic soil used in road maintenance works. The aim of the study is to evolve evaluation criteria for the use of hand-guided rollers in the compaction of laterite for road maintenance works.

2.0 MATERIALS AND METHODS

2.1 Materials

The soil samples were obtained from existing borrow pits at Tsamiya Babba, along eastern bye-pass, and Challawa in Tarauni and Kumbotso local Government Areas respectively. Both sample sites are in Kano State, Nigeria.

2.2 Methods

The two soil samples were classified using the American Association of State Highway Officials (AASHTO) soil classification system and the geotechnical properties of the natural soil determined in accordance with BS 1377(1990). The field compaction by rolling tests were carried out with hand-guided vibratory of 1000 kg weight. The two lateritic soil samples identified as base and sub-base material were prepared in six bays at 100 mm and 150 mm thick layers and the vibratory rollers were applied on each bay to determine the economic number of passes required to achieve the maximum dry density. The density of the compacted layer was determined using Core-cutter method and the moisture content was determined using Speedy moisture tester.

3.0 RESULTS AND DISCUSSION

The result of soil classification using the AASHTO system presented in Table 1 shows that Tsamiya Babba and Challawa soil samples are of A-2-4 and A-2.6 respectively. The classification revealed that Tsamiya lateritic soil samples meet the requirement for sub-base course while Challawa soil is for base course. This is consistent with provision of the Nigeria General Specification for Roads and Bridges (1997). Also other properties of the samples as shown in Table 1 confirms the liquid limit for both samples range from 22.10 to 24.10 for sub-base and 30 to 30.5 for base materials. The plastic limit for both lateritic soil samples is within 12 – 13, while the plastic index ranges from 9.30 to 11.00. All the Atterberg limits are consistent with the requirements specified for base and sub-base materials according to specification for roads and bridges. Thus the materials are suitable for use as sub-base course in case of Tsamiya soil and base course for Challawa lateritic soil.

The result of the optimum moisture content (OMC) and Maximum dry density (MDD) shown in Table 1 depict the Challawa lateritic soil (base material) as having average OMC and MDD of 8.3 and 2.14Mg/m^3 respectively with CBR value of

80%. The OMC and MDD values for Tsamiya Lateritic soil (sub-base) are given as 8.8 and 2.1Mg/m^3 respectively with soaked and unsoaked CBR values of 30% and 60%. Again the indices confirmed the suitability of both lateritic soil samples for base and sub-base work in accordance with the Nigeria General Specification for Roads and Bridges (1997). The results for rolling tests as shown in Figures 1 and 2 reveal that the Maximum dry density of the lateritic soil samples for both base and sub-base materials increases with increase in the number of passes of the hand-guided vibratory rollers.

Table 1: Properties of Lateritic Soil Materials from Tsamiya and Challawa area

Property	Quantity		Standard Specification FMW (1997)
	Tsamiya (sub-base Material)	Challawa (base material)	
Liquid Limit (%)	22.10 - 24.10	30.4 – 30.5	/>25(base) />35(subbase)
Plastic Limit (%)	14.10	19.7	NA
Plastic Index	9.30 - 10.00	10.70 – 11.00	/>12(for both)
Percentage Passing BS No 200 sieve	31.95	7.47	/>35(base) />35(subbase)
AASHTO Classification	A-2-4	A-2-6	
MDD Mg/m^3	2.1	2.14	
OMC (%)	8.8	8.3	
CBR soaked (%)	30	NA	</30(subbase)
CBR Un-soaked (%)	60	80	</80 (base)
Colour	Reddish brown	Reddish brown	

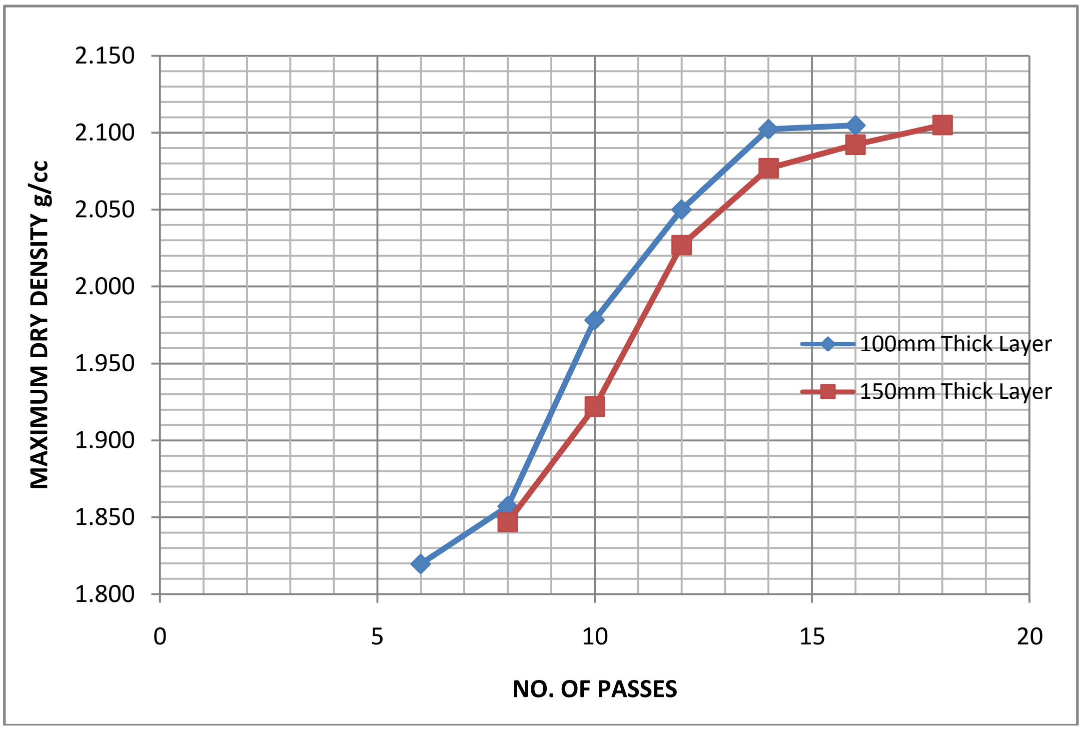

Figure 1: Maximum Dry Density (MDD) versus Number of Roller Passes for Base Material (Challawa) Lateritic soil

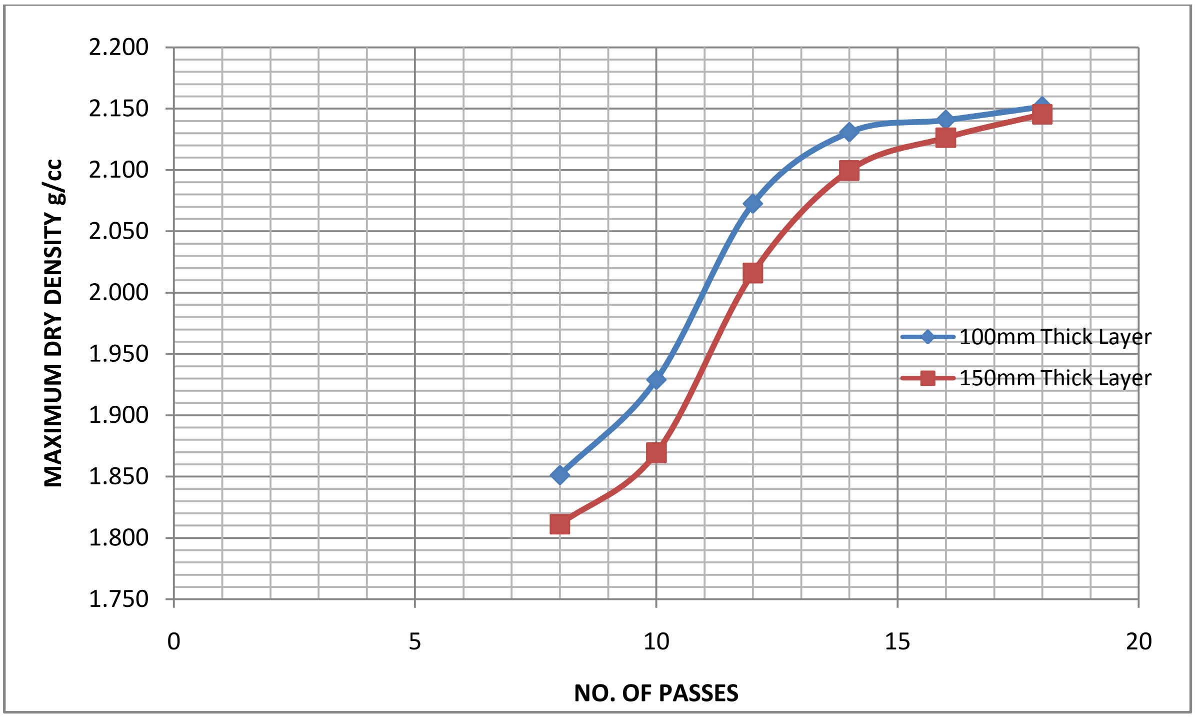

Figure 2: Maximum Dry Density (MDD) versus Number of Roller Passes for Sub-Base Material (Tsamiya) Lateritic soil

This is not surprising as compaction increases the number of particles within a specific volume thereby increasing the shear strength (Mooney, 2007; Mooney and Rinehart, 2007). Consequently, any displacement due to external loading and surface settlement is thereby reduced because of denser structure. For 100 mm thick layer of base course material, the rolling test showed that MDD was surpassed marginally at about 14 passes with the hand-guided roller, while the 150 mm thick layer requires about 18 passes to attain an MDD of 2.15 Mg/m^3 which is about 0.5% more as shown in Figure 1. Figure 2 shows the result of 100 mm and 150 mm thick layers compaction for the sub-base materials, revealing that the MDD for both thicknesses were reached after 16 and 18 passes respectively. Considering the effect of material type on the compaction of the samples (Figure 3), the 100 mm thick layers of base and sub-base materials were compacted with 8 passes of hand-guided roller at relative compaction effort of 88.44% and 86.51% while at 16 passes, the relative compaction increased to 100.23% and 100.4% respectively. The result shows that higher compaction effort is required in the compaction of sub-base material. A similar scene is repeated in the 150 mm thick layer compaction (Figure 4) where 8 passes on base and sub-base materials reached 88% and 84.64% respectively whereas the 16 passes produced relative compaction of about 100.24% and 100.04% for base and sub-base materials.

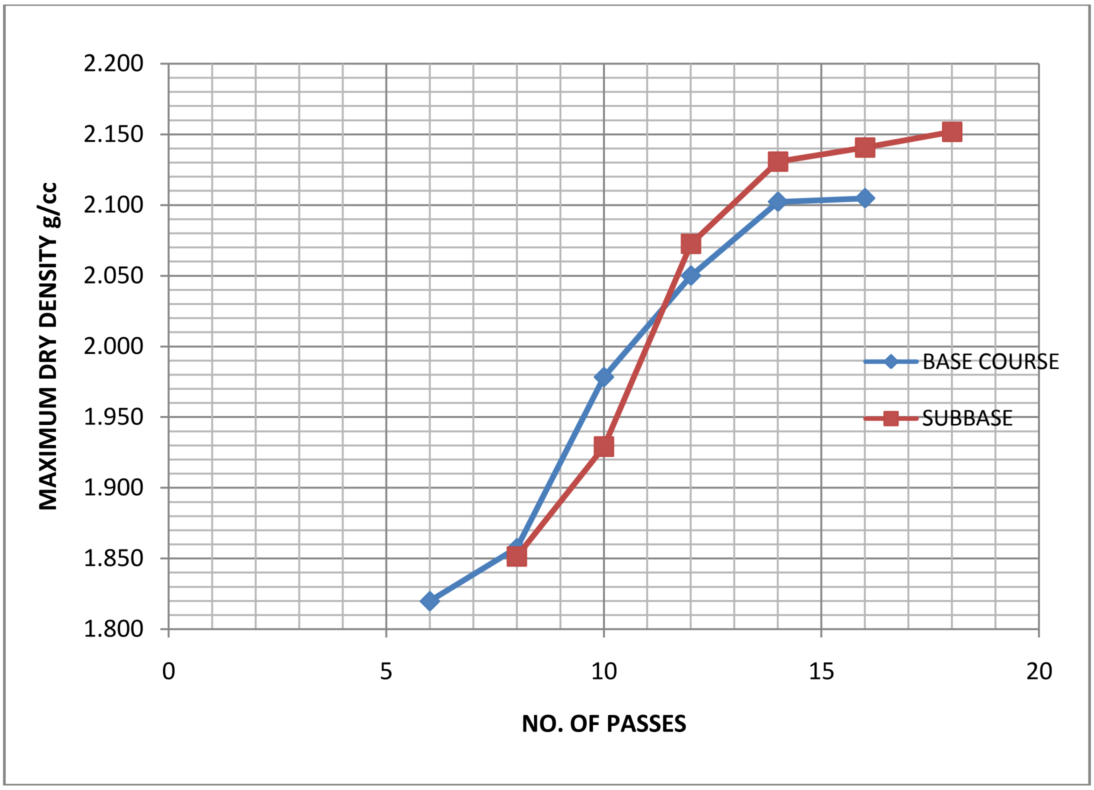

Figure 3: Maximum Dry Density (MDD) versus Number of Roller Passes for 100mm thick Lateritic soil Material

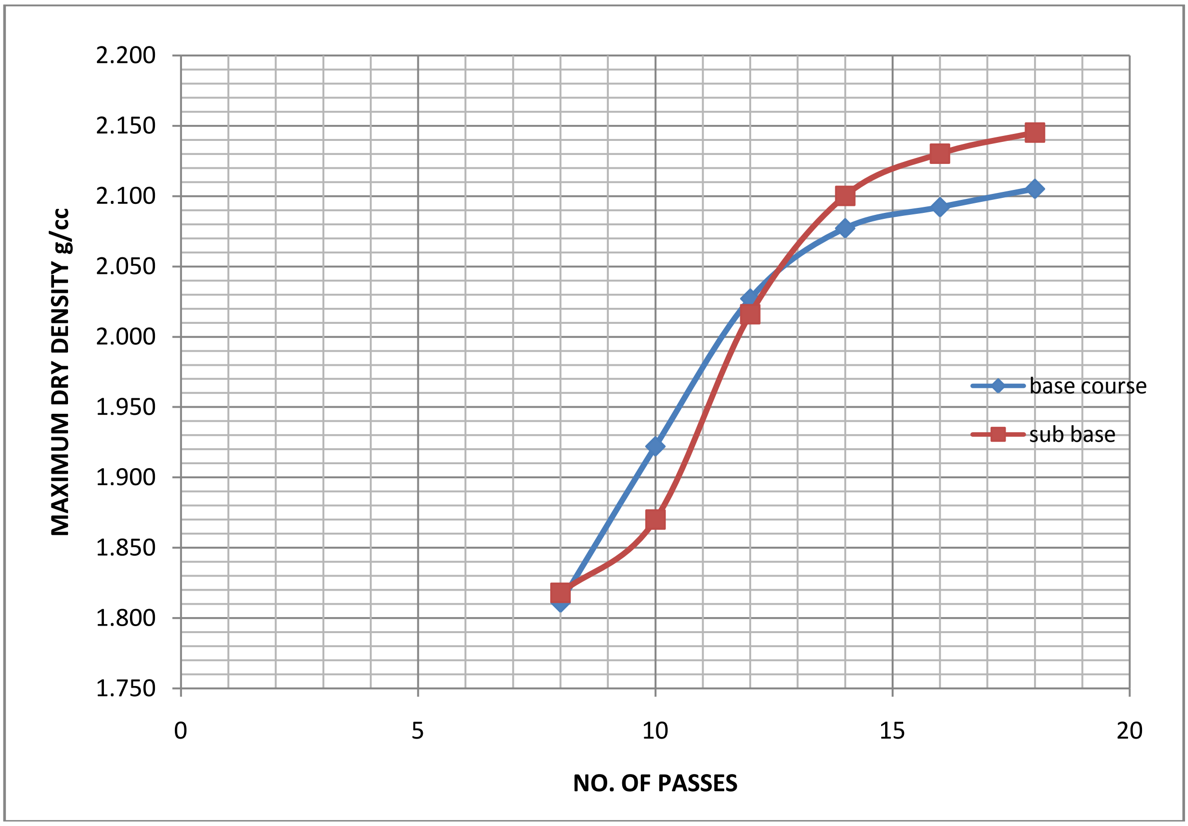

Figure 4: Maximum Dry Density (MDD) versus Number of Roller Passes for 150mm thick Lateritic soil Material.

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

Based on the laboratory and field experiments, analysis and findings, the following conclusion are made:

1. The dry densities of compacted layers of lateritic soil increased as the number of passes of the hand-guided roller increases for different thickness of base and sub-base layer materials;
2. The noticeable increase in dry densities become marginal when the Maximum Dry Density (MDD) is reached irrespective of increases in the number of passes;
3. The value of relative compaction decreased with increase in the layer thickness for the same number of passes;
4. The sub-base material requires more compaction effort than the base course materials when compacted at the same layer thickness and moisture content;
5. The number of passes of vibratory hand-guided roller required to compact 100mm and 150mm thick lateritic soil for base course to its MDD are 14 and 16 passes respectively. While 16 and 18 passes are required to compact 100mm and 150mm thick soil layer for sub-base course.

4.2 Recommendations

It is therefore recommended that the compaction of lateritic soil of 100mm and 150mm thick of A-2-6 and A-2-4 soil meant for base and sub-base materials should have a minimum number of 14 and 16 passes and 16 and 18 passes respectively. With this result the road maintenance agencies in Nigeria can have bases for setting criteria for lateritic soil compaction in road works.

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