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A Simplified Procedure to Estimate Effects of Soil Lumps on Some Properties of Compacted Soil

[1] N Sangtian, [2] T. Thaveevouthti, [3] W.Puatatsananon, [4] C. Viratjandr
[1] [2] [3] [4] Ubonratchathani University, Thailand
Corresponding Author Email: [1] noth.s@ubu.ac.th, [2] Thanabhorn.t@ubu.ac.th, [3] wiwat.p@ubu.ac.th, [4] Chardbhoom.v@ubu.ac.th

***Abstract*— The present research attempt to propose a testing methodology, some preliminarily test results and data interpretation method to estimate effects of soil lumps on properties of compacted soil. Lumps of soil with various dimensions, from smaller than 1.18 mm to 37.5mm, are prepared and each dimension of soil lump is compacted with OMC to a cylindrical soil sample which is then compared with the sample obtained from conventional standard compaction test in which all soil lumps are thoroughly broken up before mixing with OMC (ASTM D698 – 12). Therefore effects of the soil lumps with several dimensions on moisture content distribution, dry density and strength of the compacted soil can be investigated. Eventually, data interpretation to estimate effects of lumps on properties of compacted soil is introduced for further application of soil compaction quality control.**

***Index Terms*— Soil lump, soil compaction, maximum dry density.**

I. INTRODUCTION

Compaction is one of the most common techniques used in ground improvement. The water content, so called optimum moisture content (OMC), providing maximum dry density in compaction can be determined by compaction test performed in laboratory. The obtained OMC is then used to control amount of water added into the soil compacted in the construction sites in which several types of work, such as road, landfill, dike or dam, is carried. A major difference between laboratory and real construction site is soil preparation for the compaction stage. Due to the amount of the soil, preparation in the laboratory can be neatly performed especially in term of uniformity of the water, OMC, mixed in the soil before compaction. In laboratory, the existing large soil lumps can be easily break up to a certain dimension providing good distribution of water mixed into the sample. However, in the construction site, even the same value of OMC is used in the mixing but, due to some existing large soil lumps, uniformity of water in the soil after mixing is certainly different from that of the sample in laboratory. Several studies, e.g. Robinson et al. (2005), Najser et al. (2010) and Shi & Herle (2017) have been carried concerning compressibility and shear strength of "Lumpy" soil in landfill.

The present research attempt to propose a testing methodology, some preliminarily test results and data interpretation method to estimated effects of soil lumps on properties of compacted soil especially in terms of water content distribution, dry density and strength.Highlight a section that you want to designate with a certain style, and then select the appropriate name on the style menu. The style will adjust your fonts and line spacing. **Do not change the font sizes or line spacing to squeeze more text into a limited number of pages.** Use italics for emphasis; do not underline.

II. MATERIALS AND BASIC PROPERTIES

The materials used in the research are composed of base soil and base soil mixed with additional clay or sand and could be divided into two groups. First group, so called SM group, is silty sand (SM), SM with 10% sand and SM with 20% clay. Second group, so called SC group, is clayey sand (SC), SC with 10% clay and SC with 20% clay. For the first group, SM, the base soil, has liquid limit (L.L.)=16.5% and plastic limit (P.L.)=13.29% for particle passing sieve no.40 and the additional clay has L.L.=55.54% and P.L.=19.25%. For the second group, SC, the base soil, has L.L.=31.1% and P.L.=13.30% for particle passing sieve no.40 and the additional clay has L.L.= 37% and P.L.=17.87%. A total number of six soil types, base soils and base soils with additional soils are then subjected to standard compaction tests and sample preparation procedures as described in the following session.

III. METHODOLOGY

As mentioned before, for each group of material, base soil, base soil with 10% clay or sand and base soil with 20% clay, are studied in the research. Firstly, the soils are subjected to standard compaction tests to determine OMC (ASTM D698 – 12). The obtained OMC values are mixed into the soils which are then compacted to a maximum dry density of each soil type. The compacted soil is then extruded and oven-dried for 24 hours and, eventually, broken up to pieces or lumps, with several dimensions as shown in Figure 1. It should be noted that the additional sand or clay is add in the mixture in order to observe effect of sand or clay content on difficulty of sample preparation. The soil lumps are graded by standard

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sieves, both US standard and BS standard, providing a dimension of, for SM group, smaller than 1.18mm, 1.18-2.36mm, 2.36-4.75mm, 4.75-9.5mm, 9.5-12.5mm, 20-25mm, 25-28mm and 28-37.5mm, and, for SC group, smaller than 4.75mm, 4.75-9.5mm, 9.5-12.5mm, 12.5-25mm and 25-37.5mm. The opening sizes of the sieve of each group are then averaged to be used as the lump size so called "Dimension" of the soil lumps.

Figure 1. Sample of soil lumps with various dimensions

Each dimension of soil lump is then, again, mixed with the OMC of each soil type and compacted to a cylindrical soil sample which is then compared with the sample obtained from conventional standard compaction test in which all soil lumps are thoroughly broken up before mixing with OMC. Therefore effects of the soil lumps with several dimensions on moisture content distribution, dry density and shear strength of the compacted soil can be investigated. The flow chart, Figure 2, shows procedures of the studies.

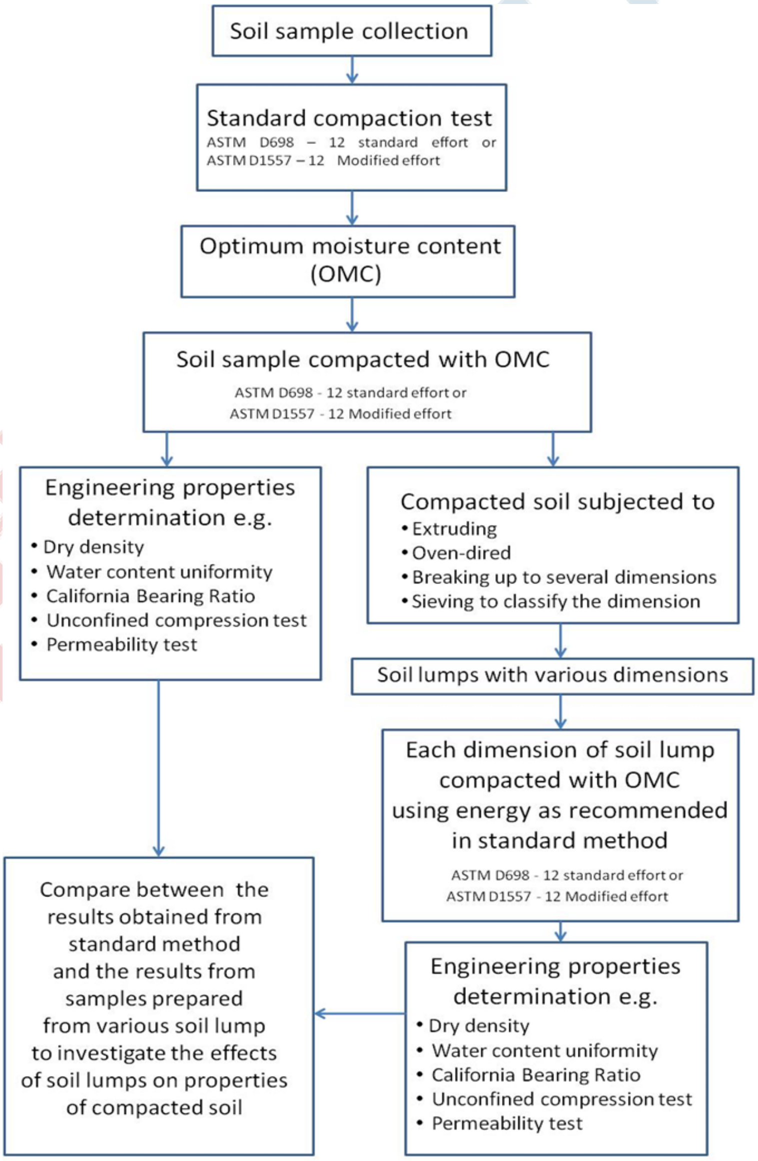

Figure 2. The proposed sample preparation procedure to study soil lump dimension effects on engineering properties of compacted soil

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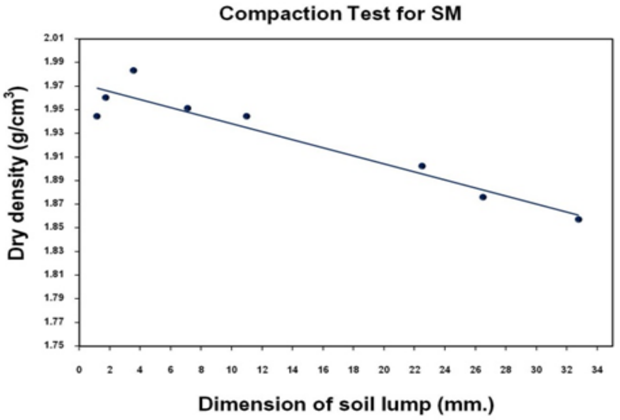
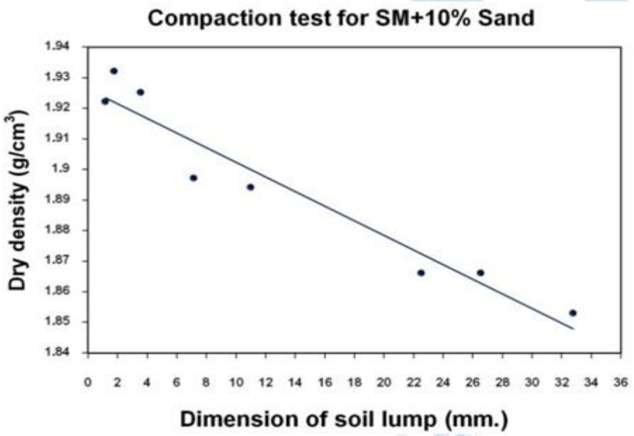
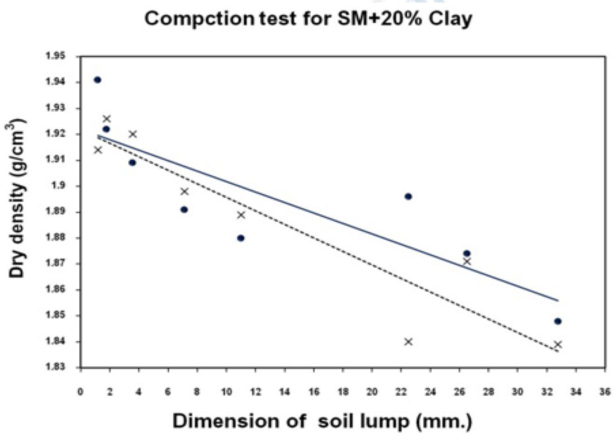
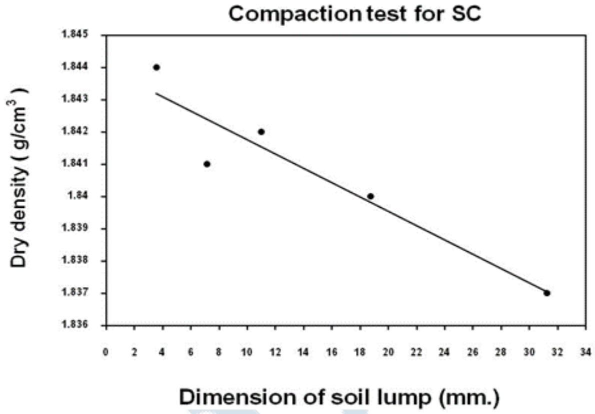
IV. RESULTS

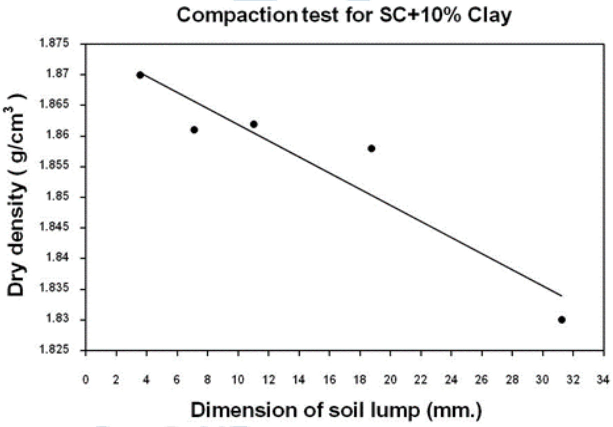
Six types of soil are subjected to standard compaction tests therefore the values of OMC are determined as following: SM=9%, SM+10%sand=8%, SM+20%clay=12%, SC=10%, SC+10%clay=12% and SC+20%clay=10%. The obtained OMC are then used to mix the soils which are then, as described earlier, compacted, extruded, oven-dried, broken up to lumps, graded to several lump dimensions, mixed again with OMC and re-compacted. After the final compaction, the cylindrical soil samples are extruded then dry density and distribution of water content across the sample section are observed and summarised in following figures.











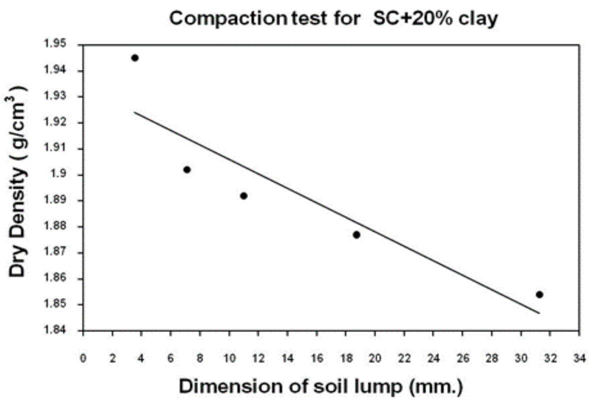


Figure 3. Effect of soil lumps on dry density of compacted soil

Figure 3 shows that dimension of soil lumps obviously affects on dry density of the compacted soil in every mixture. Larger dimension of lump will reduce the dry density obtained after compaction because larger soil lumps lead to less uniformity of water content on the sample horizontal section as shown in Figure4. Reduction of dry density after compaction varies from approximately 0.4% in SC to approximately 5.5% in SM. For SC group, with lager soil lumps, higher clay content apparently lead to higher reduction of dry density. Because, in the present article, the authors attempt to propose testing procedure and data interpretation for further application, intensive comparative

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study of the dry density variation between each type of soil has not been reported.

It should be noted that, due to its hardness, breaking up the oven-dried compacted cylindrical soil sample with higher clay content, e.g. SC+20% clay, might be time consuming and, therefore, should be taken account on test schedule time planning. Furthermore, due to scattering of the data, eight data points as used in SM group, is recommended. If more scattering of data point is found, e.g. SM+20%Clay, additional repeating test might be required. Linier variation is presumably fitted for test results in Figure3. However, nonlinear variation may occasionally be found in tests on some other soil types.

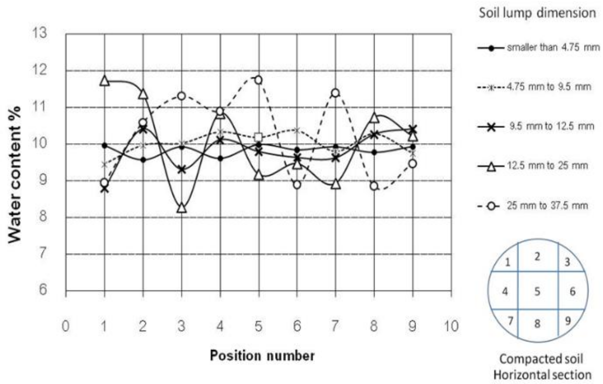

Figure 4. Variation of water content on horizontal section of compacted SC

V. FURTHER APPLICATIONS

The present research shows that, with the proposed procedure, effects of soil lump dimension on some engineering properties can be explored. Soil samples, prepared from a selected soil lump dimension, can be subjected to several laboratory soil testing e.g. unconfined compression test, triaxial test, permeability test or California Bearing Ratio (ASTM D1883 – 16) or CBR as presented in Figure 5. In Figure 5, it is also seen that increasing of compacted soil lump dimension obviously reduces CBR value of the compacted soil.

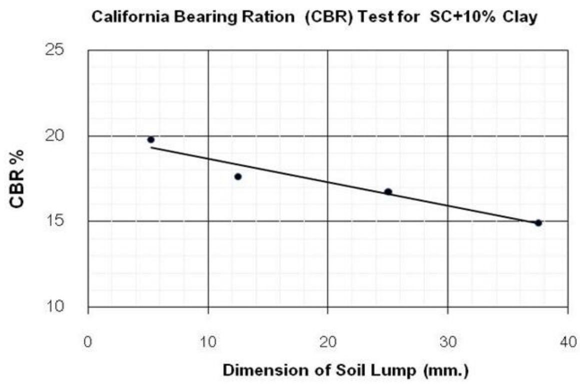

Figure 5. Effect of soil lump on California Bearing Ratio (CBR) of compacted soil

Furthermore, correlation between soil lump dimension and a corresponding engineering property can be used to estimate lump dimension at the boundary of the acceptable zone of the related work. For example, in subbase layer for road construction or general soil compaction work, the required soil density after field compaction may be 95% or 90% of that obtained in laboratory standard compaction in which OMC is applied into the soil. As described earlier, a factor leading to reduction of dry density after field compaction is remaining of large soil lumps. Therefore plotting of dry density after compaction versus soil lump dimension, e.g. Figure 6, can be used to estimate the acceptable dimension of soil lumps existing during field compaction. And, eventually, this could be used as an optional procedure in field compaction quality control prior to the field density test that may be performed in the last stage.

Figure 6 demonstrates application of the graph obtained from the proposed procedure. In the picture, dry density is plotted against soil lump dimension. The linear trend line is fitted to give a linear equation. The trend line can be extrapolated backward to a dry density value which should be obtained from "no lumps" condition and extrapolated forward to estimate a soil lump dimension giving lower dry density outside the testing range. For example, in Figure 6, to get a field dry density of 95% or 90% of laboratory maximum dry density, material in the field which has large amount of existing soil lumps with a dimension larger than approximately 30mm or 60mm respectively should be re-graded before adding water and compaction.

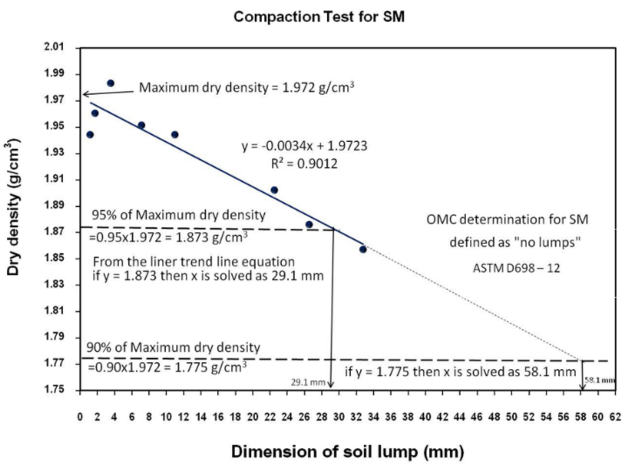

Figure 6. Application of compaction test result to estimate effects of soil lumps

It should be again noted that, in the proposed testing procedure, each particular dimension of soil lump should be chosen for a test to clearly investigate effects of the dimension on properties of compacted soil. For example, in compaction test, in a compaction mould should be filled with soil lumps of only one dimension e.g. 25-37.5mm. Then another dimension might be selected for the next test. Mixing of several dimensions in one test may be representing real field situation but effects of a particular dimension may be not clearly observed.

VI. CONCLUSION

1. The proposed testing procedure can explore and especially estimate effects of soil lumps with various dimensions on some engineering properties of compacted soil such as dry density and California Bearing Ratio value.
2. The proposed testing procedure should be applied to study effect of soil lump on a certain engineering property of compacted soil because between the dimension of approximately 4 mm to 40 mm, e.g. SC+10%clay, the dry density varies only 2-3% while the CBR value vary more than 20%. Applying result from testing on one engineering property to estimate behavior of another engineering property may produce significant error.
3. It is recommended that evaluating effects of the soil lumps on properties of compacted soil should be carried as a "routine" laboratory test for related works such as road construction, flood protection dike construction or earth dam construction because, comparing with the overall value of the project, the testing process does not highly cost and potentially provide essential information which is useful for the quality control of the related construction.

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