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NUMERICAL COMPARISON OF THE EFFECT OF SOIL MOISTURE PERCENTAGE ON PERFORMANCE OF IMPACT AND VIBRATORY ROLLERS

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ABSTRACT

The use of impact rollers was developed at global level due to their suitable influence depth. These rollers have been designed and built in 3, 4, 5, 6 and octagonal forms that each has advantages and limitations not fully understood yet. Due to high costs of understanding the behavior of these rollers on various soils through field experiments, using verified numerical models can be helpful in such recognition with low cost. Therefore, in this study, the effect of moisture content on the improved depth by roller was evaluated. The results showed that with a larger increase in soil moisture content, the descending changes of the improved depth would also reduce and tend to a constant value.

Keywords: Cost, Experiment, Soil Moisture, Roller

INTRODUCTION

Having a numerical model can help understanding the behavior of a trihedral impact roller through providing the distribution of stress, cavity pressure, and thus the effective stress in the soil. Considering the benefits of improving problematic soils in the earthen dams, stopping leakage and piping of the dam body as well as and compressing thick layers of the dike masses, using the Trihedral Impact Roller is of great importance. Given that the subsidence caused by the impact roller is higher compared to other compression tools such as vibratory rollers, thus, this roller is considered a perfect tool to improve the roads infrastructure. An example of a subsidence caused by the impact roller in modifying the road is shown in Figure 1. A relatively small industrial property in Banksmeadow, on Sydney's Botany Sands, has been subjected to ground improvement using the "square" impact roller, avoiding any conventional compaction other than for the under-slab finishing layer. Impact rolling, providing deep in situ compaction achieved by a non-circular module, has been in use for more than 20 years [1]. Some of the earliest uses of impact to densify the ground include ramming foundations in Roman times to achieve a settlement target and a Chinese swinging weight dating from the Middle Ages or earlier [2]. Dowling, 1994 reports anecdotal evidence of the successful application of the impact roller to reduce leakage from water storages in the early 1990s [3]. Pinard and Ookeditse, 1990 and Pinard, 1999 discuss the principles of impact rollers and their use in semi-arid areas to achieve a stiffer more uniform subgrade using less water during compaction and with little control on subgrade moisture content [4,5].

Figure 1: Subsidence caused by a trihedral impact roller in the road infrastructure modification project

Following on from the early work on collapsing sands and coal stockpiles, impact roller applications have broadened over the last two decades. The common principle is the reduction in the volume of air voids in the impact rolled mass, and the impact roller is now used for the in situ densification of existing fill, such as on former industrial land or brown field sites, raised or reclaimed land and landfills, mine haul roads and bulk earthworks. In addition, apart from improving the relative density of the material, impact rolling reduces the material's permeability, a factor that has been utilized in the agricultural sector [6]. A method specification often proves effective for a proof-rolling exercise. Where there is a requirement to locate soft spots or unsuitable material, it can simply be sufficient to carry out a certain number of impact roller passes under observation, for example, as was successfully undertaken on the Port River

Expressway [7]. Considering the importance of using rollers in soil improvement projects, the effects of soil moisture content on functioning of impact and vibratory rollers were examined in this study.

MATERIALS AND METHODS

In the finite element method, the components should be superposed on each other to complete the making of stiffness matrix for problem solving. This is done ABAQUS through the superposition module. The ABAQUS provides two approaches for superposition of parts: The dependent sample method and independent sample method. The feature of the first method is preparation of the main part for meshing. The fragments copied from the original part are exactly meshed similar and dependent on the main part. This leads to less occupied memory and greatly reduces the computation time. In the independent sample method, each copy of the original piece is meshed quite independently from other samples. This technique, despite occupying a large amount of memory, provides the needed requirements to the user to change the meshing in necessary cases. In this study, due to lack copy part of the original piece, there was no difference in using these two methods, and both occupy the same amount of memory. Therefore, the independent method was used for the superposition of the components. Figure 2 shows the superposition of soil and the roller. To apply interactions, constraints and assigning the dampers and springs to the set-pieces, the interaction module is used in ABAQUS. Due to the semi-infinite real model, the energy applied to the model must be removed through the borders (geometric attenuation). Given the scale of the soil model with respect to the roller, this problem was resolved. Regarding the interaction, to apply interaction between the roller and soil levels, the classical theory of Mohr - Coulomb friction model was used to link the maximum permissible frictional shear stress along the contact face to the contact pressure between the contact surfaces.

In original form of Mohr - Coulomb friction model, the two surfaces in contact can transfer the contact stresses up to a certain level along their contact face before beginning slipping on each other surfaces. The Coulomb friction model considers the critical shear stress in which the slip between the surfaces should begin as a fraction of the contact pressure between the P surfaces ($\tau cr = \mu P$ that μ is the coefficient of friction). The contact behavior between soil and roller of by bearing in mind the tangential behavior in which it acts with friction coefficient of $\mu = 0.3$. Figure 3 shows the defining process and applying surface- to- surface interaction between the roller body and the soil surface.

In both analyses, the CPS3 element, a linear triangular element, was used for meshing the roller, which is an element member of the three-node family. Figure 4 shows the roller meshing with this element. A total number of 760 elements and 500 elements were used in dynamic analysis and geostatic analysis, respectively. The exact same procedures were used for modeling of the trihedral roller. Figures 4 and 5 respectively show the meshing of the trihedral roller and the set of trihedral roller and soil together.

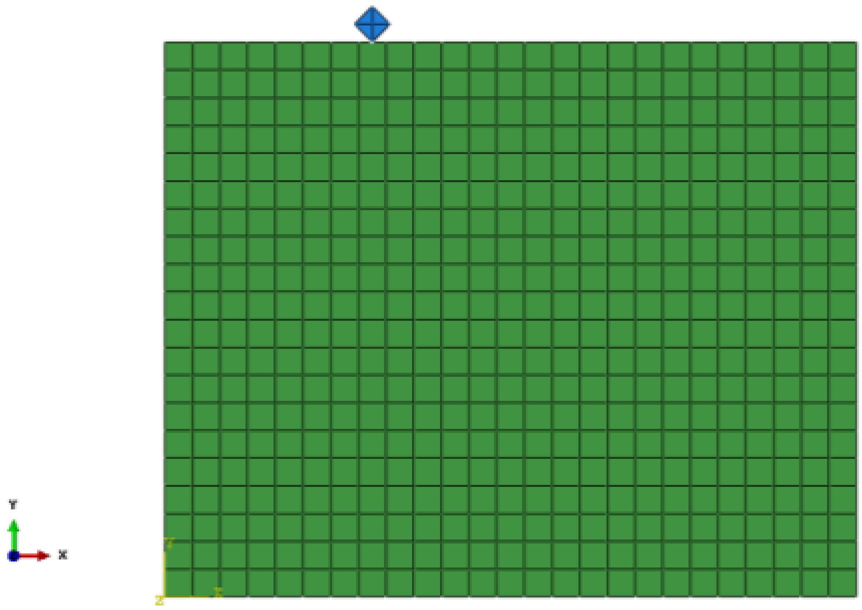

Figure 2: Soil and roller superposition

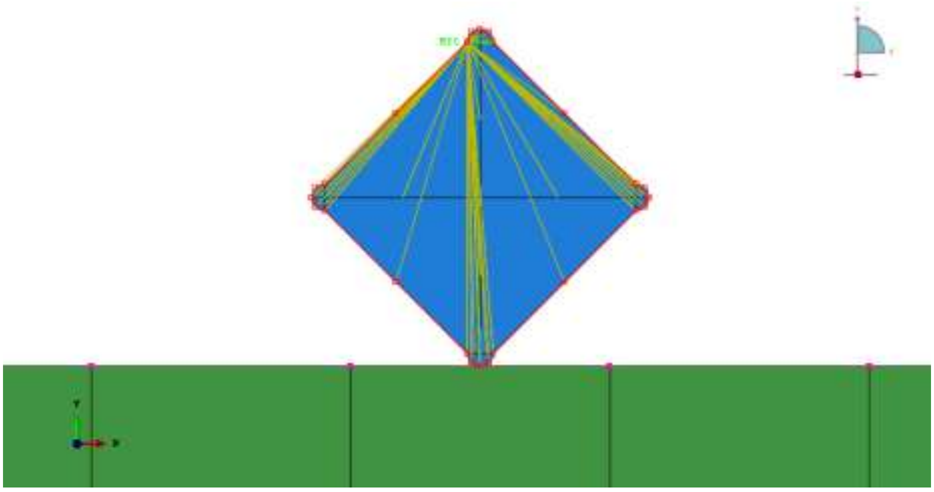

Figure 3: Defining the surface- to- surface interaction between the roller surface and the soil surface

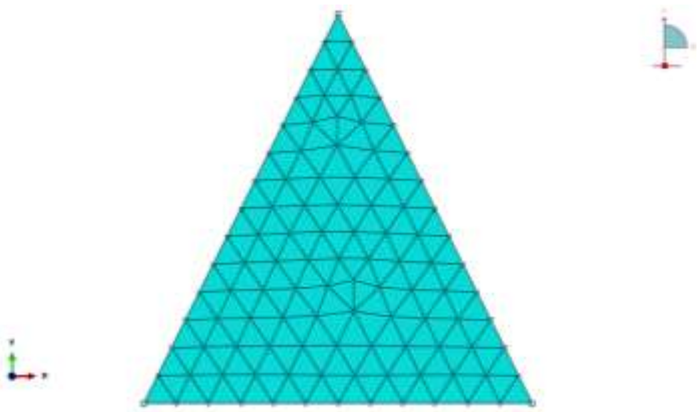

Figure 4: Meshing of Trihedral Impact Roller

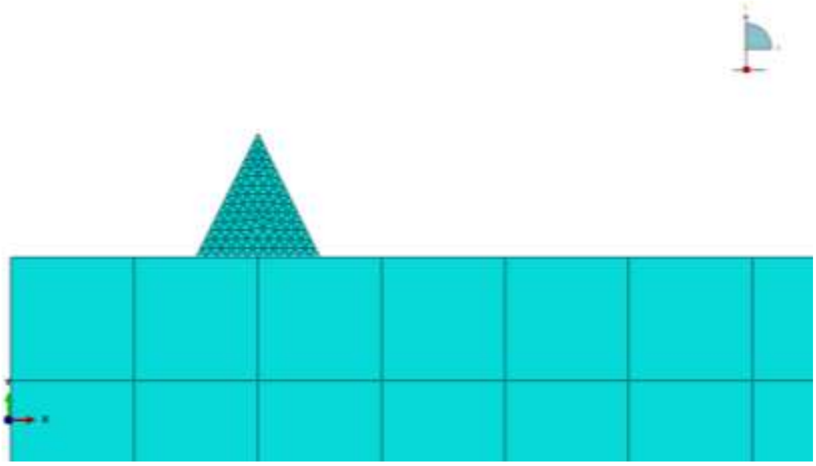

Figure 5: Meshing of the superposed set

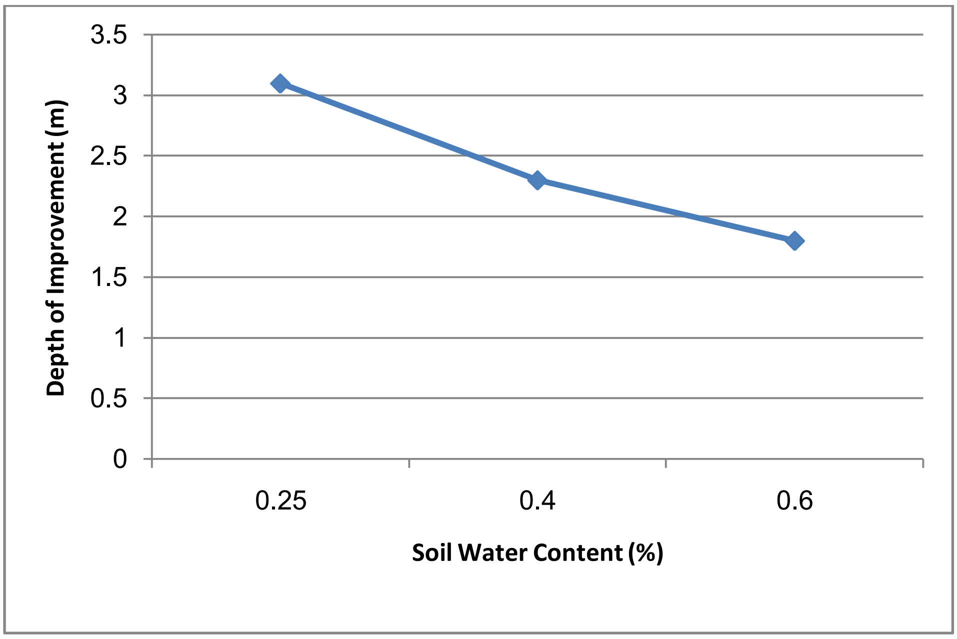

Figure 6: Effect of soil moisture content on the improved depth

DISCUSSION

To investigate the effect of soil moisture percentage on the improved depth, the soil moisture content was changed in three modes of 0.25, 0.4 and 0.6 moisture content, while other parameters were kept constant. The results of these changes are given in Figure 6 based on the improved depth.

Increased soil moisture content from 0.25 to 0.4 caused a 35% reduction in the improved depth, while increased soil moisture content from 0.4 to 0.6 caused a 0.28 reduction in the improved depth. This result suggests that with further increased soil moisture, the descending changes of the improved depth would reduce and tend to a constant value. As can be seen, since increased soil moisture results in decreased efficiency of the roller in the impact roller system, compared with the vibrating roller that always needs the increased soil moisture for the roller efficiency, one can conclude that much less water would be needed while using the impact roller compared to the vibratory roller, which in turn will reduce the cavity water pressure and increase the soil effective stress.

CONCLUSION

In order to investigate the influence of soil moisture on the impact and vibratory rollers' performance, simulation was performed by a numerical model. The results showed that the ABAQUS software has an acceptable ability to simulate the roller and soil. Also, the increase in soil moisture content can cause a 35% reduction in the improved depth, and with further increase in the moisture content of the soil, the descending changes of the improved depth would also reduce and tend to a constant value. Also, while using the Impact Roller, there would be much less need to water use than the vibratory roller, which in turn reduces the cavity water pressure and increases the soil effective stress.

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