Effective Applications of Poker Vibrator for Compacting Quarry Dust as a Ground Improvement Technique

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ABSTRACT: Recently, quarry dust has been widely used as a ground improvement technique to replace the weak, incompetent soil under shallow foundations when there is a high groundwater table or weak soil. Practical approaches suggest that a poker vibrator can be used easily, to achieve a higher Degree of Compaction (DOC) in quarry dust, under saturated condition. However, as this technique is still novel to the industry, the expected results cannot be guaranteed. It is therefore essential to eliminate inappropriate practice by carrying out laboratory experiments on optimum poker vibration application techniques. The aim of this study was to optimize the effectiveness of poker vibrator in shallow foundation design by studying the variation of factors affecting it, including time of application, shape of the foundation, preferable layer thicknesses and application patterns of vibrators. According to the test results, the optimum period of compaction for poker vibration is around 35s/point. DOC increases with increasing application points and reduces with increasing initial layer thickness, regardless of pattern.

1 INTRODUCTION

Improvement of the underlying ground conditions plays a critical role in the construction process of a foundation, when the existing condition is unsatisfactory. Several techniques are adopted for the improvement of ground conditions which can vary due to ground condition and foundation type. Some of the ground improvement techniques adopted in construction field are consolidation and preloading, chemical treatment, static and dynamic compaction, etc. (Indraratna and Chu, 2005)

One of the major problems that can be aroused in the process is the presence of soil layers which have low strength parameters. In that case the weak soil layer should be removed up to the required depth and should be filled with a suitable cohesion-less granular soil and compacted well. Then the other major problem is the presence of a higher level of ground water table.

Currently there is a method adopted to overcome those problems in the construction industry, where quarry dust is used as the filling material. Quarry dust with appropriate moisture content and a proper compaction, can achieve a higher degree of compaction as it has rough, sharp and angular particles which lead to a higher DOC due to better interlocking between particles (Onyelowe et al., 2012).

A vibrating technique is the best method to achieve higher degree of compaction in granular soils and quarry dust, rather than a traditional compaction method (Drnevichetal., 2007). In this case, a poker vibrator is a better solution which can be used with an appropriate water content to achieve a higher degree of compaction in quarry dust (Whitman and Ortigosa, 1981).

However the problem is currently there is neither valid guideline nor procedure to follow this particular process. Also from a literature review, it was revealed that there is limited research done regarding this method of compaction.

In most practical situations, this process was done with the experience of the officer in-charge present at the site. As a result of that, it would not be able to achieve the expected degree of compaction in most cases, due to improper guidance or the practice, and the lack of knowledge and experience. Therefore, it is essential to carry out a research on this method and eliminate the improper practices by introducing a proper guideline.

According to research done by Aziz et al., (2009), this method is more suitable for ground improvements under shallow foundations with circular or rectangular individual footings where the largest dimension is less than around 1.5 m. Thus it is proposed to carry out the experiments in similar containers where the diameter and width are around 1 m.

Also it is proposed to do the experiments under saturated condition as it is impossible to control the moisture content and also it is noticed that in most practical situations, quarry dust is used as filling material when there is a high water table (Kumar and Biradar, 2014). All these conditions have been taken into consideration when carrying out experiments and always tried to idealize the experiments with the practical situations as much as possible.

Finally, under this research project, it is expected to study the application of poker vibrator for compacting quarry dust by varying different parameters such as layer thickness, application time, different patterns, shape of the container, etc., and find out what the most advisable applications

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of poker vibrator are, in order to achieve an optimum compaction.

2 RESEARCH OBJECTIVE

The main objective of this study was to propose new guidelines and methods to optimize the current construction practices in the application of poker vibrators for the compaction of quarry dust. In order to achieve this objective, the degree of compaction in quarry dust under various conditions was examined by changing different parameters, such as the shape of the container, layer thickness, time of application of poker vibrator and the pattern of use.

3 EXPERIMENTAL PROGRAMME

3.1 *Standard Proctor Compaction Test*

Maximum dry unit weight of the quarry dust sample was determined by carrying out a Standard Proctor Compaction Test according to ASTM D698.

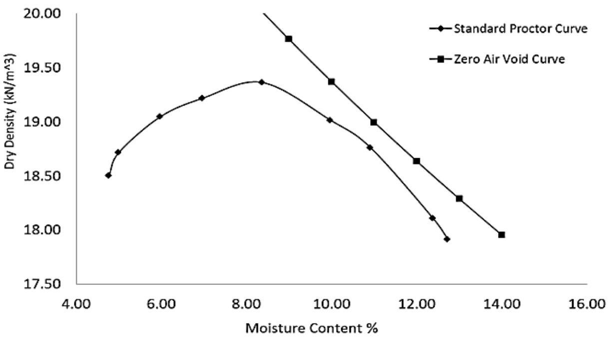

Fig. 1 Standard Proctor Curve of quarry dust

According to Fig. 1, the maximum dry unit weight of the quarry dust sample was 19.4 kN/m^3.

3.2 *Determination of field dry unit weight in each trial*

- The total wet weight (W_{wet}) of the quarry dust was measured before placing it into the container and the dry weight (W_{dry}) of the quarry dust was obtained by measuring the average moisture content (M_0).
- Since containers are rigid, the sectional areas are considered to be constants, so that the volume of compacted quarry dust is determined by measuring the average height of quarry dust after compaction (V_{avg}).
- Field dry unit weight can be obtained by knowing the dry weight of quarry dust and average volume of sample after the compaction.
- Finally after knowing the field dry unit weight in each trial and the maximum dry unit weight from Proctor Compaction Test, the degree of compaction can be determined in each trial.

3.3 *Idealization and special considerations*

- Typically, excavations for shallow foundations are circular or rectangular. Therefore, similar shaped containers were used in the experiments, and the diameter and width of the containers were approximately 1 m.
- Since the containers were made of rigid material, they can be considered as similar to the boundaries in footing excavations in the ground, where the excavated surface is relatively rigid compared with the filling material.
- Quarry dust was first placed on the containers in the loose state, and no effort was made initially to compact the dust, prior to the compaction provided by the poker vibrator.
- All the experiments were conducted under saturated conditions, as quarry dust is used as replacement material of weak, incompetent soil below the level of ground water table.

3.4 *Variation of parameters*

Parameters to be varied are selected after carefully reviewing the literature, where the highest priorities are given to the parameters which may highly affect the degree of compaction.

3.4.1 *Time of application of Poker Vibrator*

The first phase of the experiments focused on the evaluation of the optimum time for poker vibrator application to achieve the desired DOC. In order to do this, while keeping the other three parameters constant, the time of poker vibrator application was gradually increased by 5 s increments.

3.4.2 *Shape of the containers used*

The experiments were conducted in circular and rectangular shaped containers, where the dimensions of the containers are approximately equal to each other and similar to practical situations as well. The shapes and the average dimensions of the containers are illustrated in Fig. 2.

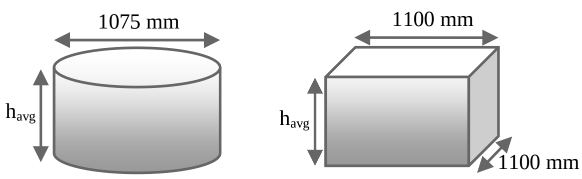

Fig. 2 Shape of the containers used

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3.4.3 *Distance between two points of application of Poker Vibrator (Pattern)*

The application patterns of the poker vibrator may play a critical role in each of these compaction processes and they may vary due to the shape of the footing. This was studied by changing the vibrator application pattern in containers of different shapes, and the plan views of several patterns adopted in the experiments are illustrated in Fig. 3 and Fig. 4.

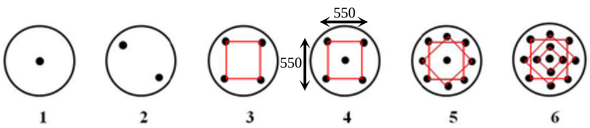

Fig. 3 Patterns used in circular container

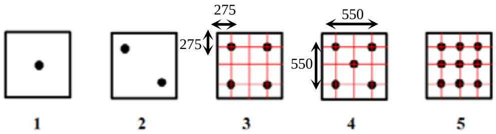

Fig. 4 Patterns used in rectangular container

**All dimensions are in millimeters.*

3.4.4 *Layer thickness of quarry dust*

In most practical situations, quarry dust has to be placed in several layers according to the excavation depth, level of ground water table, required bearing capacity, etc. This was the subject of the next stage of the study. Three layer thicknesses, 300 mm, 450 mm and 600 mm were used, and for each layer thickness, the poker vibrator was applied in several patterns.

4 RESULTS & DISCUSSION

4.1 *Variation of Degree of Compaction w.r.t. application time of poker vibrator*

Two experiments were conducted for pattern 01 and pattern 02 in circular container with an initial layer thickness of 300 mm, to assess the effect on application time of poker vibrator.

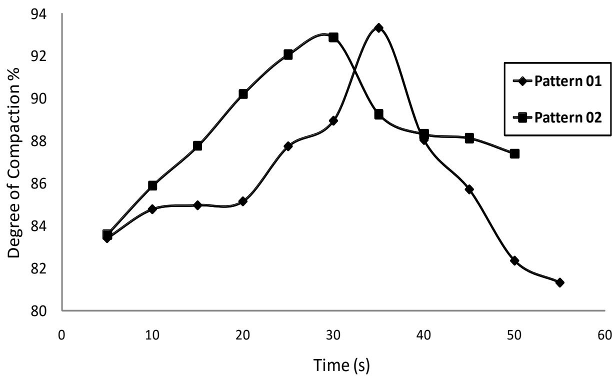

Fig. 5 Variation of DOC w.r.t time

- According to Fig.5, the DOC first increases with increasing time (up to 35 s) and then start to reduce with time (after reaching a peak value). This can be explained technically, as the application of poker vibration for a longer time period may loosen the soil again, due to excessive vibration, and it may diminish the degree of compaction. Therefore, it is considered that the optimum compaction occurred after around 35 s of vibration and that particular time was chosen as the optimum time of application of the poker vibrator per point. All the remaining experiments were conducted with this application time of 35 s/point.

4.2 *Variation of Degree of Compaction w.r.t. application pattern of poker vibrator*

The variation of DOC with application pattern was assessed for several layer thicknesses by conducting a series of experiments in both circular and rectangular containers. All the experiments were conducted with an application time of 35 s per application point, which was considered to be an optimum application time according to the above results (see Fig.5).

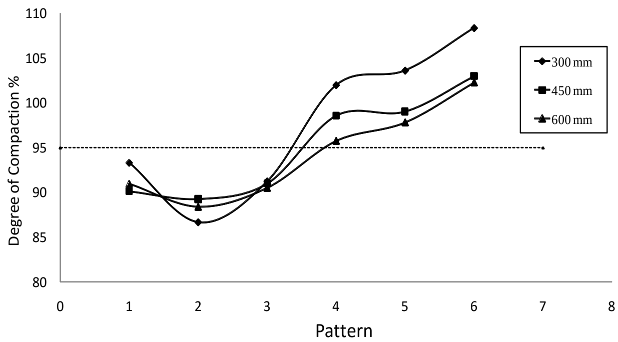

Fig. 6 Variation of DOC w.r.t. patterns for different layer thicknesses in **circular container**

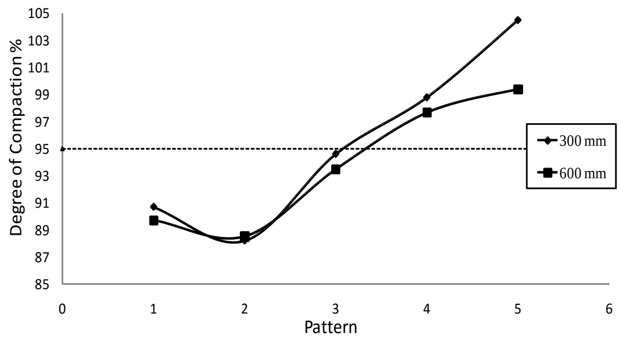

Fig. 7 Variation of DOC w.r.t. patterns for different layer thicknesses in **rectangular container**

- According to Fig. 6 and 7, the variation of DOC with vibrator application patterns exhibits a similar pattern for each layer thickness, and the DOC generally increases with increasing pattern number.

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- However, a careful examination of figures shows that the DOC in the first pattern (application of vibrator only at the centre) is relatively higher than that in patterns 2 and 3 (application near the circumference)
- In most cases pattern 4, 5, 6 give DOC s greater than 95% and in some cases (pattern 6) it is more than 100%.

4.3 *Variation of Degree of Compaction w.r.t. layer thicknesses*

The variation between initial layer thickness and DOC was then assessed, maintaining the application time at 35 s per point.

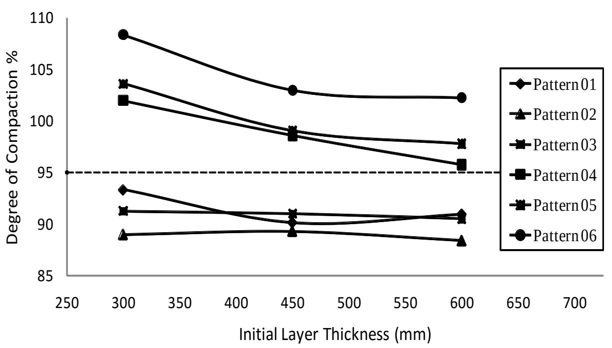

Fig. 8 Variation of DOC w.r.t. thickness for different patterns in **circular container**

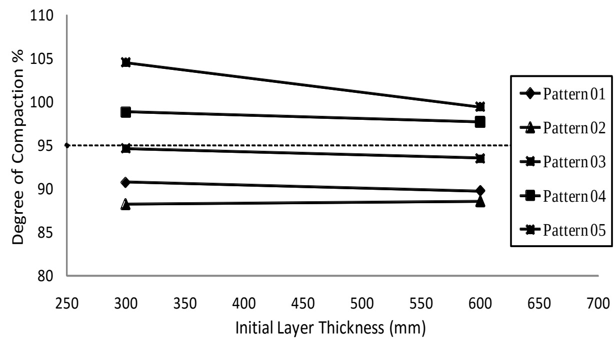

Fig. 9 Variation of DOC w.r.t. thickness for different patterns in **rectangular container**

- According to Fig. 8 and 9, DOC decreases with increasing initial layer thickness, regardless of pattern.
- Also in both cases DOC s are greater than 95% for pattern 4, 5 and 6.

5 CONCLUSIONS & RECOMMENDATIONS

- The most effective period of compaction for poker vibration is around 30 s after the compaction starts and lasts up to around 10 s. Application of poker vibration beyond this limit may loosen the soil due to excessive vibration and it may diminish the degree of compaction. Thus, an average application time of poker vibrator can be recommended as 35 s per point.
- Degree of Compaction (DOC) in both containers follow the same variation pattern with number of application points, and DOC generally increases with increasing application points. Thus, it can be expected that, the higher the application locations, the greater the vibration effect, which enhances the compaction process.
- In every case, application of the vibrator at the middle gives a relatively higher DOC than application at the corners, because vibration of middle area affects a greater area in the quarry fill compared to vibrating at the corners. This may happen due to availability of rigid boundary at corners, which will hinder the vibration effect. Therefore, vibration should be applied away from the edges as much as possible, in order to achieve effective vibration compaction.
- However, in the case of square or rectangular footings, the poker vibrator should also be applied at the corners, to achieve full and uniform compaction throughout the filling, including all the edges.
- Regarding the layer thickness effect, DOC reduces with increasing initial layer thickness, regardless of number of application points, because reducing the layer thickness causes the vibration applying dust thickness to be reduced. This provides more vibration to the dust in the entire layer.
- Since the DOC reduces with the initial layer thickness, the layer thickness should be carefully designed to achieve the desired DOC. If the excavation is too deep, it can be filled with several layers by applying the poker vibrator to each layer separately, to effectively compact the soil.

6 REFERENCE

Aziz Al-Mosawe Mosa J., Albusoda B.S. and Yaseen A.S. (2009). Bearing capacity of shallow footing on soft clay improved by compacted cement dust. Journal of Engineering. 15(04), 4417-4428.

Drnevich V., Evans A. and Prochaska A. (2007). Study of effective soil compaction control of granular soils. School of Civil Engineering, Purdue University. FHWA/IN/JTRP-2007/12.

Indraratna, B. and Chu, J. (2005) Ground Improvement – Case Histories, Elsevier, 1115p

Kumar U.A. and Biradar K.B., (2014). Soft sub grade stabilization with quarry dust-an industrial waste. International journal of research in engineering and technology. 03(08), 409-412.

Onyelowe ken C., Okafor F. O. and Nwachukwu D. G. (2012). Geophysical use of quarry dust (as admixture) as applied to soil stabilization and modification. ARPN journal of earth sciences. 1(1), 06-08.

Whitman R.V. and Ortigosa de P. (1981). Densification of sand by vertical vibration.

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