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Determination of The Bearing Improvement Ratio For Clay Soil Improved With Stone Column Under Confined Condition

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Abstract - **The present work is focused towards the evaluation of bearing capacity improvement ratio q_r, determined trough the confined compression tests carried out on stone column penetrated in soft clay soil. The investigation was carried out using model tests of stone column performed inside cylindrical container of 300 mm in diameter and 350 mm in height. The undarined shear strength of the soil prepared in the containers ranged from 5.5 kPa to 13.5 kPa. The models ware tested immediately after preparation and some of the models were left to cure 10 days after preparation. It can be noticed from results that the treated soil loaded after 10 days shows an increase in bearing improvement ratio mare than that of treated soil loaded immediately.**

***Index Terms*: Bearing Improvement, Stone column, Clay, Confined Condition**

I. INTRODUCTION

Soft soils require improvement of their properties if they have to be utilized as foundation .For this purpose, different soil improvement techniques such as preloading ,sand drains ,dynamic compaction and stone column have been used as economical alternative to deep foundations.

The most attractive appears to be the stabilization of soft soil by installation of stone column that have been widely used in many countries during the last three decades. This is related to feasibility and the suitability of stone column technique. Stone column were known in France in the 1830s they have recently been rediscovered and the mechanism of their behaviour under load is not well understood. This method consists in forming vertical holes in the ground that are filled with crushed rock to form columns or "piles" confined by the soil. They are ideally suited for improving soft clays and silts and also for loss sand. Stone columns have been used in the support of basic foundation types, such as small isolated footing, strip footing and very common for large raft foundation,, wide spread loads and embankments. Aboshi et al (1979) investigated the stress distribution in a loaded composite foundation. Juran & Guermazi (1986) conducted a series of triaxial compression tests by using a specially modified triaxial cell on a composite soil specimens. These test showed the significant influence of the group effect, the replacement factor, and the partial consolidation of the soft soil on the stress concentration factor (n) and the settlement reduction of the foundation .Terashi et al (1991) investigated the bearing capacity of the clay ground improved by sand compaction pile method (SCP). The influence of various factors specially of load inclination and intensity of preload are revealed by a series of centrifuge model tests. Stewart & Fahey (1994) discussed the stress -time and stress concentration ratio (n) relationships resulted from a confined compression test of a single stone column. Al-Khafagi(1996) used the centrifuge modeling technique in the examination of the use of the sand compacted pile (SCP) for reinforcing soft clay ground. Juran & Riccobono (1991) presented the main results of an experimental study of the feasibility of using artificially cemented ,compacted -sand columns in the reinforcements of soft cohesive soil. Rasheed (1992) used the finite element method in a parametric study on the behavior of soft soils reinforced by 5 columns .Both linear and nonlinear hyperbolic models for soil stone column were adopted. Different parameters were studied and presented . The most effective parameter was found to be the ratio of spacing to the diameter of the column. Goughnour & Bayuk (1979) studied the observation results of a long term field test on vertically loaded stone column in soft soil. Aboshi et al (1979) studied the distribution of stress between sand pile and ground in sites. Bergado et al (l987) conducted full scale plate load tests and full scale embankment load test on fully penetrating granular piles on the soft Bangkok clay. The variation of the stress concentration ratio (n) was measured by means of earth pressure cells .It found that the stress concentration ratio (n) increased with increasing the area replacement ratio a_s. The present paper investigate the behavior of stone columns under confined compression state oriented mainly towards the determination the bearing capacity improvement ratio q_r.

II. TESTING EQUIPMENT AND PROCEDURE

Fig. (1) shows details of the complete set up which consist mainly of steel container, loading frame and accessories . The ratio of container height to the diameter was chosen equal to one to avoid the side friction of walls (Garnier, 2001). These accessories include three dial gages (with accuracy of 0.0lmm) above of model to measure the settlement of composite material, (stone column and surrounding soil), and two proving rings at the top of the model to measure simultaneously the applied total stress and the stress supported by stone column .The model tests were carried out in a cylindrical steel container, 300mm in diameter and 300 mm in height made of steel plate (6 mm in thickness). The soil used brought from the vicinity of Al-

Musaib technical college in Babylon. The soil consists of 32% sand, 4l% silt, and 27% clay, with liquid limit equal to 33% plastic limit of 17%. The soil was classified as (CL) Symbol according to unified soil classification system. The tests were carried on a single stone column of 100 mm in diameter and 300mm in height. The natural calcium carbonate crushed stone was used as a backfill material. These sizes were chosen in accordance with the guidelines suggested by Nayak (1983),where the particle size (1/6 to 1/7) of the diameter of columns.

III. MODEL PREPARATION AND TESTING

A. Preparation of the Bed of Soil

Prior to the preparation of the bed of soil a relationship was obtained between the water content and the undrained shear strength of the soil, Fig. (2) illustrate this relationship. The undrained shear strength of the soil was measured by Swedish fall cone pentrometer. The conditional soil was mixed with enough quality of water to get the desired shear strength. The soil was placed in layers inside the steel container and each layer was tamped with a special tamping hammer of (50mmx50mm) in size. The final thickness of each layer was about 50 mm. The procedure continued until the final thickness of the bed of soil was 300 mm. After the completion of the preparation of the bed of soil, it was covered tightly with nylon sheets and left four days curing period.

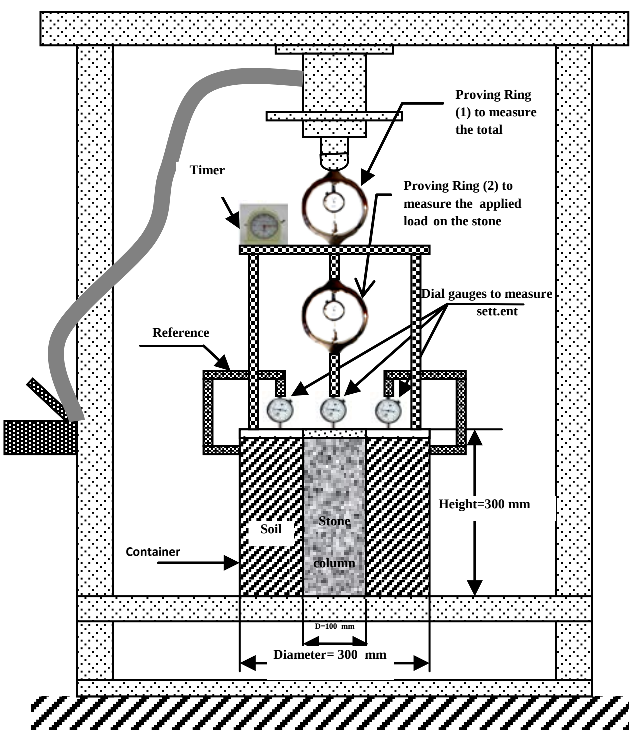

Fig. 1. Experimental set-up

B. Construction of Stone Columns

At the end of curing period, the top of the bed of soil was leveled. A hollow PVC tube, of external diameter (32 mm) and (2 mm) in thickness, coated with petroleum jelly was pushed vertically along the center of the soil to the required depth. The tube was then slowly withdrawn and twisted during the lifting process. The soil was removed from the tube and samples of the soil at different depths were taken for water content measurement. The crushed stone poured into the hole in layers and each layer was compacted gently using (30 mm) in diameter tamping rod. The unit weight of the compacted crushed stone was 16.3 kN/m^3 .The whole bed of clay was covered with a nylon sheet and protected from any lose of moisture and left for a period of 10 days .The temperature was measured daily along the period.

C. Model Testing Procedure

The surrounding soil was prepared at undrained shear strength of (cu=5.5 kPa, 8.5 kPa and 13.5 kPa) respectively. The models were tested immediately after preparation and some were left to cure for 10 days after preparation , the footing assembly was placed in position so that the center of the footing coincides with the center of the hydraulic jack. Loads were then applied through a loading disk in the form of load increments .Each load increment was left for (2.5 min). The dial gauge readings were recorded at the end of the period of each load. During each load increment, dial gauge of two proving rings measurements were recorded. The Load increments continued until total pressure reached 300 kPa. For comparison purposes. The loading tests were performed on container with untreated soil only.

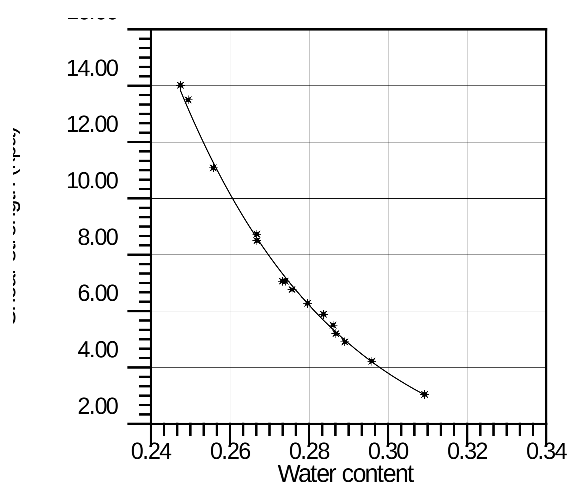

Fig. 2. Shear strength -water content relationship

IV. PRESENTATION AND DISCUSSION

Fig.(3)relates the bearing ratio (q/cu) versus deformation ratio(S/D) ratio for untreated soil and soil treated with stone only .The surrounding soil was prepared at undrained shear strength of (cu=5.5 kPa ,8.5 kap and 13.5 kPa)respectively. The models were tested immediately after preparation and some were left to cure for 10 days . This Fig. demonstrates that the stone column in all bearing ratio shows significant difference in the behavior corresponding to (S/D) ratio. This Fig. also indicates that when the shear strength of soil is decreased the effect of stone column became more visible and a clear increase in (q/cu) ratio is noticed . This behavior is attributed to the truth that the calculation of stresses is dependent on stress applied on replacement soil in zone of stone column only , disregarding stress applied on soil surrounding the column . Thus the affect of improvement seemed clearly in treated soil of low shear strength . It can be noticed also from Fig. (3) that the treated soil loaded after 10 days shows an increase in bearing capacity more than that of treated soil loaded immediately .This behavior is related to the drainage effect .

The bearing improvement ratio achieved by stone columns is presented by the ratio ($q_{treated}$ / $q_{untreated}$)versus (S/D) ratio (Fig. (4) ranges from 5.6 at S/D=5% to 6.3 at S/D=10% in an average of 6 and 2.9 at S/D=5% to 3.6 at S/D=10% in an average of 3.3 and 2 at S/D=5% to 2.6 in an average of 2.3 at shear strength of soil(cu=5.5 kPa ,cu=8.5 kPa and cu=13.5kPa) respectively for treated soil loaded after 10 days curing . Fig.(4) also shows the ($q_{treated}$ / $q_{untreated}$) ranges from 5 at S/D=5% to 5.3 at S/D=10% in an average of 5.2 and 2.8 at S/D=5% to 3.1 at S/D=10% in an average of 3 and 2 at S/D=5% to 2.6 at S/D=10% in an average of 2.3 at shear strength of soil(cu=5.3 kPa ,cu=8.5 kPa and cu=13.3kPa) respectively for treated soil loaded immediately .

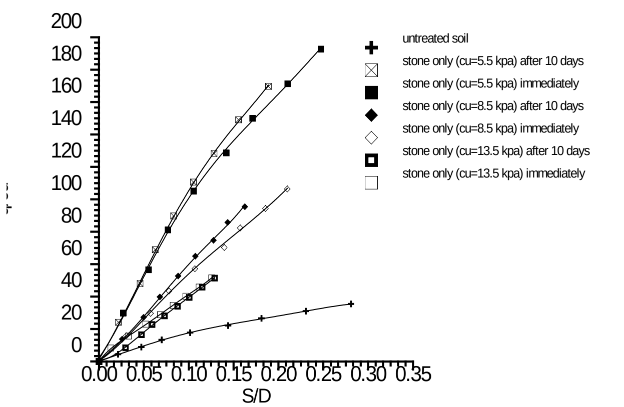

Fig. 3. Variation of (q/cu) ratio with (settlement/Dia.) (S/D) ratio

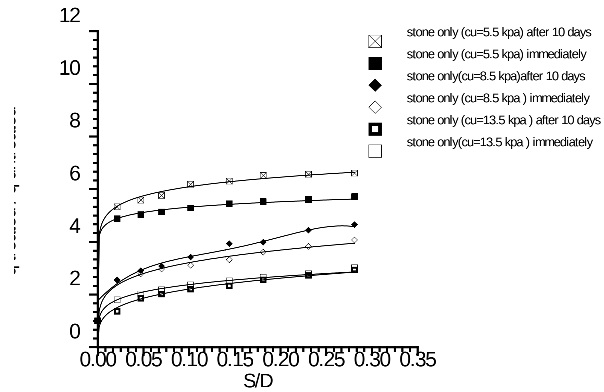

Fig. 4. Bearing improvement ratio with (settlement/Dia.) (S/D) ratio

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