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Physıcal Modelıng Of The Effect Of The Rock Column Posıtıon On The Behavıor Of The Adjusted Soft Ground Tape

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Abstract

Building foundations on soft soils has been one of the problems faced by geotechnical engineers due to the low bearing capacity and the increase in the amount of settlement in these soils. One of the current solutions to this problem is to add a reinforcement element to the soil and one of the elements that can be added to the soil is a stone pole. In this method, 91 to 31% of the weak soil volume is replaced with suitable soil. In this research, we investigated the effect of the presence of single and group stone pillars, the position and length of the stone pillar on the bearing capacity of the strip foundation around a soft clay roof. In addition, the stone columns were strengthened using vertical bumpers and the effect of strengthening the stone columns in different modes on the behavior of the strip foundation adjacent to the slope was investigated. The results showed that in all cases reinforcing the clay slope with a stone pillar increased the bearing capacity of the strip foundation located near the slope. Also, equipping the stone column with remote control improves the performance of the stone column and increases the bearing capacity of the foundation according to the similar condition of the non-reinforced stone column. The optimum length of an unreinforced stone column under the foundation is 4 times the column diameter. The biggest effect of the stone column on the bearing capacity of the strip foundation occurred when the stone column was placed under the foundation and the bearing capacity of the foundation decreased as the distance between the column center and the foundation center increased. In addition, when the efficiency of the stone column group was examined, it was observed that the performance of double group stone columns in both reinforced and non-reinforced conditions was better than the triple group.

Keywords: Stone pillar, load bearing capacity, strip foundation, cradle, clay

INTRODUCTION

Floor carrying capacity has always been one of the most important factors in foundation design. Considering the carrying capacity more than the real value may cause the structures to be damaged or completely rupture, and the bearing capacity is less than the real value, causing the foundation to increase in size and the design uneconomical. Building engineering structures on soft ground always causes problems such as excessive collapse, deformation and instability in the structure. One of the methods used to reduce or prevent these problems, especially in loose sediments and fine grained soils, is the addition of columnar elements called rock pillars to the soil. Among the most important applications of rock columns are increasing the stability of natural slopes and embankments, increasing the bearing capacity of surface foundations built on soft soils, reducing subsidence, and reducing the liquefaction potential of sandy soils [1].

Researchers' laboratory research on unfortified stone columns has shown an improvement in bearing capacity and reduced soil subsidence [2], [3], [4]. When stone columns are built in very soft soils, the lateral limitation created by the surrounding soil may not be sufficient to form the stone column and may cause the abutment in the stone column to condense. This denting causes more ground subsidence and a serious decrease in the efficiency of the stone pillars. One way to improve the performance of rock columns in such soils is to use the tubular screws of ordinary rock columns in the form of tubing with a suitable geosynthetic (geogrid or geotextile) [5]. Strengthening stone pillars with geosynthetics, with the help of laboratory research by many researchers, including Melrovizhi and Ilamparothi (2014) [6], Neil and Boaza (2009) [7], Deb et al. (2011) [8], Yu and Lee (2012) [9], Dash and Bora (2013) [10], Ali et al. (2014) [12], Miranda and Da Costa (2016) [13], Miranda and Others (2017) [14] and Fattah et al. (2015) [15]. Numerical studies on reinforced concrete columns were also conducted by Lou et al. (2010) [16], Ali et al. (2014) [12] and Castro (2017) [17]. All the laboratory and numerical studies mentioned above show an improvement in the behavior of the stone column reinforced remotely compared to the unreinforced stone column. Said laboratory and numerical show an improvement in the behavior of the reinforced stone column. It is without reinforcement compared to the stone column.

Geotechnical engineers have always had a particular concern for slope stabilization. For this purpose, various methods such as retaining walls, piles and geosynthetics have been used to increase the reliability of slope stability. Using stone columns to stabilize slopes or prevent landslides can be considered as an alternative solution [1], [2], [18], [19], [20]. Gazavi and Şahmandi (2008) [21] used the limit equilibrium method to analyze the stability of a slope reinforced with a stone column. Also, in this study, analytical analysis results were compared with numerical modeling results with GEO-OFFICE software. The results showed that the highest reliability coefficient of triangular stability occurred when the position of the rock column was at the top of the slope. Sari et al. (2011) [22] investigated the stability of the filling on soft clay reinforced with stone columns using the finite difference method of plate strain and investigated the effective parameters in the reliability coefficient. Vakili et al. (2012) [23] investigated the behavior of clay roofs reinforced with stone columns using the laboratory model and verification with PLAXIS software. They investigated the effect of the distance between the columns on the slope stability coefficient, the effect on the load bearing capacity and the strip foundation placed on the canopy by placing unreinforced stone columns in the foot, middle and canopy. Both numerical and laboratory results show that the smaller the distance between the stone columns, the higher the load carrying capacity and the lower the settlement. Zhang et al. (2014) [24] numerically investigated the overall stability of the embankments on soft clay reinforced with rock columns and the critical shear slope level of the embankment. Using the column wall method and the equivalent surface method, they transformed the three-dimensional problem into a two-dimensional model with equivalent dimensions and features and verified the results with three-dimensional numerical analysis results. Chen et al. (2115) [25] used numerical and physical modeling to investigate the mechanism of fracture of reinforced rock columns in soft soil beneath the embankment. Numerical modeling was carried out in two dimensions and three dimensions using the finite element method. Al-Shakur 2015 [26] investigated slope stabilization using the slope balance method and the SLIDE program, using several rows of stone pillars and supports. The results showed that adding a stone column to the slope increased the reliability of the slope stability and also that the best position of the stone column was at the top and near the edge of the slope to achieve maximum reliability. Rai et al. 2018 [27] investigated numerically and experimentally the effect of stone columns on the bearing capacity of the strip foundation adjacent to the sand slope and the effect of parameters such as distance between columns and rock column stiffness. The findings of this study show that the bearing capacity of the strip foundation increases as the stiffness increases and the distance between the stone columns decreases. Although it is possible to place the foundations near a slope made of soft soil, so far not much attention has been paid to improving the bearing capacity and subsidence properties of foundations found under these conditions. In this research, an attempt was made to correct and improve the behavior of the strip foundation located upstream of the slope by adding stone pillars to the inclined body of soft clay. Correction of the behavior of the strip adjacent to the clay slope using a stone column is only performed by Vakili et al. It was researched in the laboratory by 2012 [23]. In this study, the effects of factors such as the position of the stone column, the length of the stone column and the strengthening of the stone column were not investigated. Therefore, in this study, stone columns were added to the slope body in different places and the best position was determined in terms of the maximum effect on the bearing capacity of the strip foundation. In addition, by measuring the effect of double and triple stone column groups on the behavior of the strip foundation adjacent to the slope, it was determined which arrangement is more cost effective in terms of performance. It should be noted that the influence of the position and group of stone pillars on both non-reinforced and reinforced stone pillars has been studied. In addition, a series of experiments were carried out to measure the effect of the length of the rock column under the foundation on the behavior of the strip foundation adjacent to the slope, and the optimal length of the rock column was determined. Optimizing the position of the rock column in the soft ground sloping body, optimizing the length of the rock column below the foundation, as well as optimizing the effect of the reinforced and non-reinforced stone column group on the strip near the soft soil slope was not one of the innovative aspects of this study using laboratory modeling, and other researchers It was examined by.

Physical Modeling

Material Properties

In order to obtain the mechanical parameters of the clay and stone column materials used in this study, first standard standard experiments were carried out. The angle, friction and adhesion of the clay were determined using the undrained triaxial test (CU) according to ASTM D 4767 [28]. In addition, the shear drainage shear strength of clay soil was determined using the unlimited compressive strength test (uniaxial) based on the ASTM D2166-06 [21] standard.

The efficiency of rock columns mainly depends on the lateral limitation of the surrounding soil. In very soft soils (soils with a shear strength less than 15 kPa), the lateral limitation of the soil around the rock column is not sufficient, and the soil around the rock column cannot have the lateral resistance required for the rock column to function properly. And therefore, the stone column cannot provide the required load capacity [1], [2]. Therefore, in this study, a series of uniaxial tests were performed according to ASTM D2166-06 [21] to determine the percentage of moisture in clay in proportion to the undrained shear strength of 15 kPa. Soil with this type of moisture was used in all experiments. It should be noted that, in addition to moisture, the un-drained shear strength of the clay is a function of the percentage of density required. In order to simplify the sample preparation process, it has been tested that the impact energy of the samples prepared for the uniaxial tests is the same as the soil impact energy prepared in the slope modeling tests, so it can be concluded that the shear strength is only dependent. It shows the granulation diagram of soft clay and rock column materials. The friction angle of the column material was determined using the direct shear test according to ASTM D3080 [30]. The materials used in the experiments were chosen taking into account a range of scale effects. There should be a match between the largest grain size of the column material and the width of the foundation. For this reason, the grain size of the rock column material was chosen between 2 and 10 mm according to the 10 cm width selected for the strip foundation in all experiments. When loading reinforcements, stone columns must meet two conditions. First, the size of the holes should be such that even the smallest particles of the column material cannot pass through the hole, and second, in terms of strength, there should be an acceptable match between the small size physical modeling materials and their actual dimensions. Considering the scale rules proposed by Aya (1989) [1989], the ratio between the real dimensional (J p) of the reinforcement stiffness in the model and the reinforcement stiffness in the model with laboratory dimensions (J m) is calculated from the relation (Jp □ Jm □ □). In this relationship, 1 / is the model scale, and in this study, the model scale was accepted to be equal to 1.10. Therefore, the reinforcement stiffness in model tests should be considered to be much less than the reinforcement stiffness in terms of actual dimensions (J p □100Jm).

Test Machine

The device made to carry out the experiments consists of two general parts. The first part is the loading system on the foundation and the second part is the device tank. A 4-ton hydraulic jack system was designed and built to be loaded into the foundation clay in the laboratory room. This electric powered hydraulic system is designed to control the speed and density of loading. Also, a barometer gauge is installed on the hydraulic jack to check the oil pressure of the device in terms of load 1, which is used to measure the amount of load on the foundation after calibration. Oil was pumped from the engine of the machine to the piston of the hydraulic jack by high pressure hoses. Since the tests are carried out in the form of tension control, the hydraulic system should be designed in such a way that no change in the amount of load will be applied when the device is loaded on the foundation. Therefore, a double linear lock is built into the hose path to prevent any pressure drop even in the event of a power failure in the hoses. Stone columns are often used in groups and in projects in a regular grid. In fact, in this study, a longitudinal section of a hypothetical network of stone pillars located on a slope is investigated. This figure shows a 90 cm wide strip and a stone column underneath it. It is also shown in this figure that the rock column has changed its position and the parameter S represents the horizontal distance of the center of the rock column from the center of the foundation. It shows the different positions of the stone pillars at different stages of the experiments in two dimensions. The distance from the center of the strip to the edge of the slope was considered constant and equal to 10 cm in all experiments. Finally, the floor chamber was made according to the original design, measuring 30 cm × 120cm × 150cm. The dimensions of the reservoir are considered in such a way that the stresses caused by the load on the foundation and stone column will not reach the reservoir walls and the effects of the boundaries will not affect the results. This tank is made of steel and steel rings are used around it in order to have the required resistance and not deform during the loading process. In order to be able to see the changes in the pattern and shape of the soil, the tank was designed to be covered with two glasses on one side. These glasses are made of durable Securite type and can be inserted and removed from the tank made by rail. Due to the height of the soil tank, while the lower part of the slope was under construction, the upper glass was removed to gain access to the bottom of the room. An IPE16 beam support was installed in this tank along with a steel plate to accommodate the hydraulic jack piston. The beam was welded to the frame surrounding the tank. The dimensions of the model are 4cm × 10cm × 29cm and it is made of steel so that it does not change shape during loading. Glasses were also calibrated at 10 cm intervals to facilitate slope application and ground deformation.

Clay Preparation

The clay required for the experiments was prepared from the brick kilns in Kavar province of Fars. The humidity in the field is 4% and it had to be increased to 25% by adding water to carry out the experiments. To bring the soil moisture to 21%, a certain weight of soil and water was first mixed and thoroughly kneaded to homogenize the moisture. The moist soil was then transferred to a plastic bag and stored as a seal for a week to distribute the moisture evenly throughout the soil. These steps were repeated for each experiment, and finally the soil in plastic bags was used to form the body of the soil slopes. Initially and before the soil was poured into the tank, the bottom of the tank was covered with plastic to prevent soil moisture from escaping. After each stage of the experiments, the clay surface was covered with plastic to prevent soil moisture change. During the soil transfer phase to the lower half of the tank, the glass at the top of the tank was removed to gain access to the lower half. Clay was placed in the tank in layers of 5 cm. To obtain equal density, the volume and weight of each 5 cm layer was calculated based on a specific gravity of 20 kN / m, and this amount of clay was weighed and placed in the tank. To check the correctness of the soil in the right place, a series of marking lines were drawn at a distance of 5 cm from the device body. Then, with special hammer blows, 5 cm clay layers were placed in the desired level between two consecutive marking lines. For this reason, the number of hammer blows was determined on a trial and error basis, and great care was taken to correctly place each 5 cm layer in the predetermined location. Each 5 cm layer was compressed with an average of 5 special hammer blows dropped from a height of 20 cm into the soil. The dimensions of this hammer's plate were 25cm × 25cm and its weight was equal to 6.8kg. This process continued until the entire slope was completed.

Construction Stages of Unreinforced and Reinforced Stone Pillars

Stone columns with a diameter of 90 cm and a length of 40 cm were made in all experiments in this section. These dimensions were selected according to the optimal length found in the present study and at least by the findings of Barksdahl and Bachus (1983) [1] to control abdominal rupture.

The column has a length-to-diameter ratio of 4, which is consistent. All stone pillars were built using the replacement method 1. Metal cylinders with a diameter of 10 cm and open at both ends are used to carry out this method. The inside and outside of these rollers were oiled to reduce friction, and the roller entered the soil up to a height of 40 cm, and then the clay was removed from inside the roller. Then, the weight of 1 cm column material layers according to the specific gravity of 16 kg / m3 for each layer was calculated and the same amount of column material was weighed. In the next step, the metal cylinder was pulled out a little more than 5 cm using auxiliary tools and poured into the hole approximately 5 cm from the previously separated column material. While the materials of the stone column were hammered with a light hammer and a small number of blows, it was ensured that there was not too much impact on the stone column and the soft clay around the stone column was not damaged. Therefore, a special hammer with a diameter of 9 cm and a weight of 2.7 kg was made to hammer these materials. Each 5 cm layer of column material was hammered with a 20 cm drop height and 10 strokes using this hammer. This whipping resulted in a relative density of about 66.55% in the materials. The metal roller was then removed an additional 5 cm and another 5 cm layer was squeezed applied. This process was repeated alternately to complete the entire column. The materials chosen for the stone column are strong enough not to break during testing. In addition, all the sand volume required for the stone column materials was obtained from a fixed source and the damaged column materials were discarded after each test.

Unreinforced stone column application steps: a) (placing a metal cylinder on the ground, b) pouring the column material and hammering the material in 3 cm layers, c) forging the column and tool column material applied in the last layer on the left, d) the completed stone column Reinforced concrete columns In order to be able to do it, the remote reinforcement mesh of the column should be prepared. In all experiments, this web was prepared as a cylinder 10 cm in diameter and 40 cm in height. The web was first cut and then placed overlapping the edges, with the beginning and end 20 mm overlapping, and the overlapping area was well glued with a special polyethylene adhesive. In all tests, after the test was completed and the gun was removed, the bonded area was inspected so that the adhesive did not open due to applied stresses. The pillar cavity was then created by dipping a metal cylinder into clay and draining the soil inside. The cylindrical reinforcing mesh was then placed inside the metal cylinder. Then carefully and without changing the position of the luminaire the metal cylinder around it was pulled a little more than 5 cm. Next, the pre-weighed column material was poured into the reinforcing mesh and hammered with a percussion tool, as in the non-reinforced case, with 10 strokes. Later, the metal cylinder was lifted 1 cm more, the materials were poured and pounded, and this process was repeated and the reinforced stone column was completed.

Reinforced concrete column application stages: a) Preparation of the reinforced concrete column network, b) Placing the prepared mesh into the soil into the sold metal cylinder and pouring and pounding the stone column materials in 3 cm layers, c) The column executed in the last layer on the left, d) column diameter control

Test Results and Discussion

The purpose of this study is to evaluate the position of the reinforced and unreinforced Sang columns, as well as the effect of the length of the unreinforced stone columns on the behavior of the strip foundation adjacent to the soft clay slope. In addition, the effect of two and three reinforced and unreinforced stone columns on the bearing capacity of the strip foundation was investigated. In this context, L represents the length of the stone column. L′ Remote reinforcement height D is the diameter of the stone column and the diameter of the reinforcement, S is the distance between the center of the stone column and the center of the foundation. And S′ is the distance between the center and center of two adjacent columns in the stone column group. It should be noted that a series of repetitive tests have been carried out to ensure the accuracy of the results and that these tests show an acceptable agreement with the results.

As mentioned earlier, the basis of the model was created using the tension control method. Strain control transmission may better show the rupture and final load, but the experiments were carried out under tension control and the loading stages were considered as small as possible to determine the final load well. In fact, if the loading pitch is too large, the actual final load value may be between two load points and may not be read well. With the tension control method, the rate of increase in load is constant. Therefore, at each stage of the experiment, the load was constant and the straw change time of the sedimentation changes was less than 0.01 mm / min, the next step of the load was applied. It should also be noted that in all tests, due to the limitations of the test, the slope at which this slope actually occurred during loading was avoided. Finally, stress settlement diagrams were drawn and bearing capacity values were obtained from these diagrams using the tangential method. The tangential method is used by most engineers to determine the load corresponding to the high point of slope change in the stress-strain curve. In this method, the load

corresponding to the point at which there are significant changes in the meeting is selected as the load capacity [33]. Studies have shown that when the clay slope is strengthened with a stone pillar, the ultimate bearing capacity of the foundation increases. This increase is often defined as a dimensionless parameter called the Load Capacity Ratio (BCR).
(1)

$$BCR = \frac{Q_u(r)}{Q_u}$$

In this relationship, the ultimate load bearing capacity of the Qu (r) rock column and the strip foundation on the reinforced soil with Qu is the ultimate load-bearing capacity of the same foundation on the rock column-less soil under the same conditions.

The Effect of the Position of Non-Reinforced Stone Pillars

Stress-strain diagrams of strip foundations are shown for the ratios of different SD distances of unreinforced stone columns. Also, a slope diagram without the stone pillar is given in this figure for comparison with other cases. In all experiments in this section, the stone column was 40 cm in length and 10 cm in diameter. Laboratory results show that adding a stone column to the clay slope at all distances increases the bearing capacity of the strip foundation.
Also, the largest bearing capacity relates to when the stone column is placed just below the strip foundation. This is because in this case the vertical load of the foundation is directly and axially transferred to the rock column, which causes the snow rupture mechanism in the rock column. As soon as the rock column is placed under the foundation and placed next to the foundation (S / D = 1), a sharp decrease in the bearing capacity of the foundation occurs. The reason for this is that the stone column passes from the abdominal region to its lateral deformation in the rupture mechanism. When a stone column is not under the foundation, in fact the dominant force applied from the foundation to the column is the shear force and this force causes lateral deformation of the column. When a stone column is not under the foundation, in fact the dominant force applied from the foundation to the column is the shear force and this force causes lateral deformation of the column. Lateral deformation refers to the curvature and inclination of the upper part of the column relative to the lower part, which occurs whenever the stone column is not below the foundation.

The Effect of the Position of Reinforced Concrete Columns

It is worth noting that in all experiments in this section, the stone column length and reinforcement length are equal to 40 cm, and the stone column diameter and remote reinforcement diameter to 10 cm. By adding a reinforced stone column under the foundation (S / D = 0), the bearing capacity of the strip foundation increased by about 11% compared to the bearing capacity of the strip-reinforced foundation, un-reinforced stone under similar conditions. In addition, the examination of the bearing capacity of the foundation in different parts of the reinforced stone column compared to the bearing capacity values of the foundation in the presence of the unreinforced stone column in the same place, the load capacity occurring at the bearing capacity S / D = 0 due to the remote strengthening of the stone pillar. The reason for the greater effect of the booster in S / D = 0 mode compared to other modes is the remote boost resistance against the abdomen of the column in this mode. In other cases, (S / D = 1,2,3,4) is the lateral deformation mechanism of the column and the increase in bearing capacity occurred solely due to the addition of a stabilizing shear due to the retaining material of the rock column.

The highest BCR value in both the reinforced rock column and the non-reinforced column is when the column is placed just below the foundation (S / D = 0). The reason is the working mechanism of the stone column in the form of an axial bearing. As the stone column moves away from the strip in both arm and non-reinforced columns, the column's mechanism deforms laterally and the rate of increase in the bearing capacity decreases compared to the slope without the stone column. The declining trend and slope in the bearing capacity are almost the same in both armed and non-reinforced state diagrams. Moving the BCR diagram to 9 shows that if the distance between the rock column and the foundation is more than four times the diameter, the column no longer has much influence on the behavior of the foundation.

Effect of the Length of Stone Pillars

The effect of the length of non-reinforced (L) stone columns on the behavior of the strip adjacent to the soft ground slope was investigated and tested for four different lengths L = 3D, 4D, 5D, 6D. In this part of the experiment, all stone columns of different lengths were built just below the strip. The results show that increasing the length of the rock column from 3D to 4D resulted in a significant increase in the bearing capacity of the strip foundation of about 25%. With the further increase in the length of the stone column to 5D, there was not much improvement in behavior and the carrying capacity increased by only about 2% compared to 4D. Also, with the increase in the length of the stone column to 6D, there was not much difference compared to 5D mode, and the bearing capacity of the foundation only increased by about 2%. Therefore, it can be concluded that for a strip reinforced with an unreinforced stone column around the slope, the optimal length of the stone column, which causes the greatest improvement in the behavior of the foundation, is 4 times the diameter of the stone.

Effect of Stone Column Group

In practice, stone pillars are always used in groups with a regular grid arrangement. As a matter of fact, in this study, a longitudinal section with the dimensions of 30 cm × 150 cm was examined in the plan of the column group on the slope with the surrounding soil. According to the research done by Dash and Bora [10], the optimum distance between the center and the center of the stone pillars in the group is 3 times the diameter of the column. The results of their research showed that the bearing capacity of the stone column decreases if the distance between the columns is more than 3 times the column diameter, and also that the distance decreases if the column is less than 3 times the diameter of the column. The distance has a significant effect on the bearing capacity of the stone column. For this reason, in this study, the transverse distance between the center and the center of the stone pillars in the row examined in the experiments conducted with the adjacent assumption row was accepted as 30 cm. In addition, it is thought that the dimensions of the reservoir are not too large and the longitudinal distance of the columns is 20 cm longer in order to prepare and fill the required volume of soil.

A total of four experiments were carried out on double and triple group stone columns under reinforced and non-reinforced conditions. In these four experiments, the first stone pillar was placed under the foundation, and the other pillars were placed 20 cm from center to center (S D / D = 2). The arrangement of double and triple stone columns is shown schematically. In these four experiments, all stone columns and reinforcements are 40 cm in length and 10 cm in diameter. It shows stone columns realized in three groups of non-reinforced stone columns. It also shows the stress-strain diagrams related to the experiments of the unreinforced rock column group and its slope with and without the rock column under the foundation with the single column without reinforcement. The results show that the bearing capacity of the strip foundation adjacent to the slope increases with the increasing number of stone columns. To evaluate the performance of the stone column group, the efficiency parameter of the stone columns is defined as follows:

In this regard, ŋ is the yield of the stone column group, g (u) is the ultimate bearing capacity of the foundation strip in the presence of the stone column group and Qu, the ultimate bearing capacity of the foundation strip in the presence of each stone column without the effect of the group. Using this relationship, the efficiency of double group unreinforced stone columns was equal to 1/80%, and the efficiency of triple group unreinforced stone columns was equal to / 70.2%. For this reason, the performance of double group unreinforced stone columns is better and more economical than the triple group in increasing the bearing capacity of the foundation located near the clay slope.

The results of the reinforced concrete column group experiments are shown in comparison with the slope without rock columns and the position of the armed stone column under the foundation. In addition, when the ratio (2) was used, the efficiency of double group reinforced concrete columns was equal to 2.83%, and the efficiency of triple group reinforced concrete columns was equal to 6/72%. The results are compared with the efficiency of the unreinforced stone column group in the same situation, and it is seen that the efficiency of the reinforced concrete column group is slightly better than the unreinforced column group. Also in the armed mode, as in the non-reinforced mode, the efficiency of the double stone column group was better than the group of three. The results show an increase in the bearing capacity ratio with increasing number of stone columns. In the same case, it is seen that the effect of the reinforced concrete column on the bearing capacity of the foundation is more than the effect of the stone column without reinforcement. The greatest impact of reinforcement on the load-bearing capacity of the foundation occurred in the case of a three-column group of stones, and the reason is that the three resistance elements of the pillars resist slope, one against shrinkage and the other two against lateral deformation.

RESULT

In this study, a number of experiments have been carried out on the slope of clay reinforced with rock columns to investigate the effect of rock columns on the strip behavior adjacent to the slope. Stone columns were studied in both reinforced and non-reinforced experiments and the following results were obtained:

• The best location for installing a stone column on both unreinforced and non-reinforced stone pillars is to place the pillar just below the foundation (S / D = 0). The distance between the center of the column and the center of the foundation has reduced the bearing capacity of the foundation. Therefore, the closer the pillars to the end of the slope, the better their performance. When the rock column is under the foundation (S / D = 0), the breaking mechanism of the rock column is of abdominal type, and when the rock column is not below the foundation, the mechanism of column rupture is lateral deformation.

• The rate of influence of remote reinforcement on the bearing capacity of the strip foundation is maximum when the stone column is placed just below the foundation (S / D = 0) compared to other cases (S / D ≠ 0). Strengthening of stone columns that are not under foundation and located within the body of the slope has little effect on the behavior of the strip foundation adjacent to the slope.

• The optimum length of an unreinforced stone column under a strip foundation is 4 times the diameter of the column. Increasing the column length from 3D to 4D increases the bearing capacity of the foundation by 25%. Further increasing the column length to 5D and 6D results in a 2% and 4% increase in load capacity, respectively, compared to the column length equal to 4D. If the distance between the center of the rock column and the center of the foundation is more than four times the diameter of the foundation, the other stone has little effect on the behavior of the foundation and approaches BCR 1.

• In the non-reinforced stone column group study, the efficiency of double group stone columns is equal to 80/2, and the efficiency of triple stone column group is equal to 70/3%. And it can be concluded that the performance of double group stone columns is better and more economical than the triple group.

• The experimental results regarding the reinforced concrete stone group have shown that the efficiency of the double group reinforced concrete stone columns is higher than the efficiency of the triple group of these columns. In addition, the group efficiency of stone columns in the reinforced condition is slightly higher than the group efficiency of stone columns without reinforcement under similar conditions.

It should be noted that the results obtained in this study are based on 1/10 scale model experiments and are limited to the conditions examined. Therefore, in order to generalize the results, full-scale experiments are required for control and verification.

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