Sigma J Eng & Nat Sci 35 (4), 2017, 585-592

Sigma Journal of Engineering and Natural Sciences
Sigma Mühendislik ve Fen Bilimleri Dergisi

Research Article

THE EFFECT OF SHAPE PROPERTIES IN GRANULAR SOILS ON SETTLEMENT OF STRIP FOOTING OVERLYING ON SAND

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Received: 06.03.2017 Accepted: 25.05.2017

ABSTRACT

The main objective of this study is to research the effects of roundness, size and relative density of granular soil on the settlement of strip footing placed on soil. For doing this study soil samples has been obtained from calcareous soils with three roundness classes (Angular, Rounded and Well-rounded). Also, the samples have been prepared at 6 different sizes and two relative densities of 50% and 70%. Prepared granular samples with different properties have been subjected to the load by means of a strip footing at this experimental research. The load-Settlement graphs yielded from experimental research showed that the factors of roundness, size and relative density have effects on the ultimate bearing capacity and the value of settlement at failure moment in the granular soils. Research results showed that increasing roundness effected negatively the settlement of footing and caused the soil failure at smaller settlements and ultimate bearing capacity decreased by increasing roundness of particles. Whereas, increasing angularity, grain size and relative density of granular soil samples increased the bearing capacity and decreased the settlement.
Keywords: Roundness of particles, settlement, size of particles, relative density, strip footing.

1. INTRODUCTION

Engineering behavior of granular materials as one the most used geo-materials are studied for many years. Ultimate bearing capacity of granular materials and settlement of footing are classic issues at the field of geotechnical engineering [32]. Lots of studies have been done on different materials at different conditions [24]. Different methods such as reinforcement methods have been used for improving bearing capacity of soil or settlement of footings [2, 11, 12, 19, 23, 14, 16]. There are different factors can influenced soil behavior and affect its engineering properties such as particles size, relative density, grain size distribution and void ratios. Shape of particles is another factor that has effect on soil behavior [21, 27, 31].

Shape of particles is one of the factors that has effect on soil behavior. Sphericity, texture, roughness and roundness are some terms describing particle shapes [30, 15]. Studies have been showed that changing on shape of particles will change some mechanical properties of soil such as void ratio of aggregate [15, 18, 20, 6]. Yanrong (2013) studied on particle size and grain size distribution effect on shear strength of a composite soil. He has worked on clay, silt, river sand

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and crushed gravels. Direct shear box test has been used at his study for estimating shear strength of different materials [33].

Other studies have been done on relationships between mechanical properties of soil and particle shapes or grain size distributions [1, 3, 5]. At the study of Arasan et al. (2011), they have been studied on different materials of Calcareous, Ballast, and bearing balls. By calculating roundness value and considering shape of particles, samples have been classified to 6 different groups and effect of particle shapes on some geotechnical properties of soil has been studied [4].

Other studies have been done on soil bearing capacity of strip footings. At the same time lots of studies have been done on columns and footings [26, 28, 22, 13, 34]. At the study of Cicek et al. (2015) effect of reinforcement length on behavior of strip footing was investigated. Geogrid was used as reinforcing material and tests were done at laboratory conditions on reinforced and unreinforced soils. Different numbers of reinforcement layers with different length were used at this study. Results showed that length of reinforcement was necessary for achieving optimum reinforcing [17]. Soils such as granular materials, clay and silt were tested at different conditions. Load-settlement behavior of a shallow foundation lay on iron ore tailing was studied by Kuranchie et al. (2016) [25].

Although there are lots of studies done on strip footing and particle shapes, but effect of roundness and size on load-settlement behavior of strip footing were not found on literature. At this study effect of particles shape and size on settlement of a model strip footing were studied. Calcareous soil was used and tested at three roundness classes, 6 different size groups and two relative densities.

2. MATERIAL AND METHOD

Calcareous soil was used for this study. Calcareous soil was sampled from the Ergunler Company, Erzurum,Turkey. Specific gravity of soil was determined 2.7 according to ASTM D 854-14. After washing and drying soil in laboratory temperature, it was sieved and classified to 6 different size groups from 0.30mm to 4.75mm. Roundness value of soil calculated by use of Cox (1927) equation and Power (1953) chart and it was classified as angular calcareous (AC) [18, 29]. Angular calcareous (AC) was changed to rounded calcareous (RC) and well-rounded calcareous (WRC) and tests were done at these three kinds of particles shapes. Soil grain size distributions (ASTM D 6913-04) are shown in Figure.1.

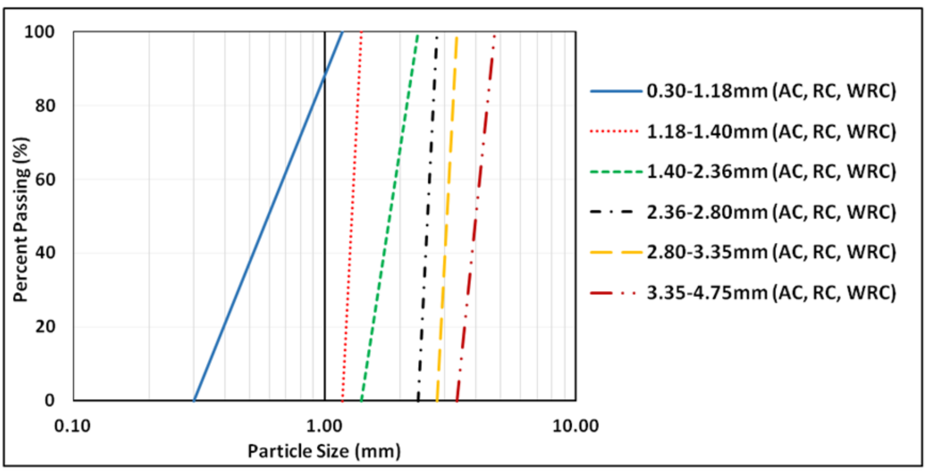

Figure 1. Grain Size Distribution of Soil

According to Arasan et al. (2010c), Los Angeles Rattler machine without balls was used to change AC to RC and WRC [6]. For doing this, angular soil was rounded for 50000 revolutions for preparing rounded soil. On the next step this soil was rounded for another 50000 revolutions to make well-rounded soil. After each step soil was washed, dried and sieved at 6 size groups. Roundness values of particles are shown in Table.1.

Table 1. Roundness Value and Classification of Materials [4].

Sample	Roundness Value	Roundness Group
Angular Calcareous (AC)	0.693-0.744	Angular-Sub Angular
Rounded Calcareous (RC)	0.786-0.803	Rounded-Well Rounded
Well-Rounded Calcareous (WRC)	0.834-0.854	Well Rounded

Soil samples prepared at three different roundness classes, sieved and divided to 6 size groups. On next step minimum and maximum void ratio of each group was determined according to ASTM D4253-16 and ASTM D4254-16.

A model tank with dimension of 1m*1m*0.1m was used at this study. Front part of tank was made by Plexiglas to see the soil and footing. A rigid polyamide strip footing with dimension of 9.8 cm of length, 5 cm of width and 4 cm of high was used as model footing. There was 1mm gap between footing and tank at each side footing for preventing any contact between tank and footing. At the same time two sides of footing and tank were coated with petroleum jelly for reducing and minimize probable friction between walls of tank and footing. Two linear variable displacement transducers (LVDT) were placed at two cross corner of footing. Average of these two LVDT values was considered as settlement of footing. A hydraulic jack was used for loading the footing. A load-cell with capacity of 50kN was used for measuring the load and transferred load to the footing by use of a steel shaft. Displacement speed of jack was <2mm/min and applied single point load to footing. This setup has transferred the data from tests set up to computer by help of a data logger.

By considering engineering properties of soil such as e_{min}, e_{max} and volume of model tank, weight of soil was calculated at each roundness classes, sizes and relative densities. Picture of model tank was shown in Figure.2.

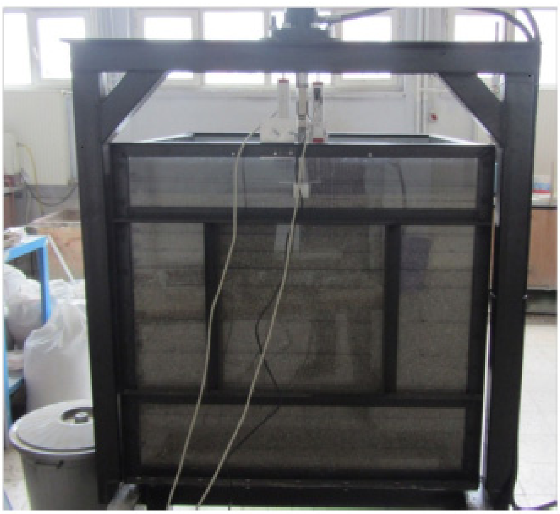

Figure 2. Picture of Text Box

3. RESULTS AND DISCUSSION

By considering soil properties at different conditions, dry unit weight of soil was calculated and shown for test samples at different roundness, sizes, and relative densities in Figure 3. As seen at this figure, dry unit weight of samples was increased by increasing roundness of materials. At the same time dry unit weight increased by increasing size of materials too. At groups of materials with size 0.30-1.18mm dry unit weight had an inconsequent behavior that is more than unit weight of 1.18-1.40mm. By looking to grain size distribution in Figure.1, it found that at size group of 0.30-1.18mm uniformity coefficient (Cu) is 2.13 but for other groups, Cu is near to 1. At the same time for size group of 0.30-1.18mm the boundary differences between smallest and biggest size are more than other groups. So, two factors of C_u and wider range of particle size boundary affected value of unit weight. Because of these reasons smallest size group showed different behavior.

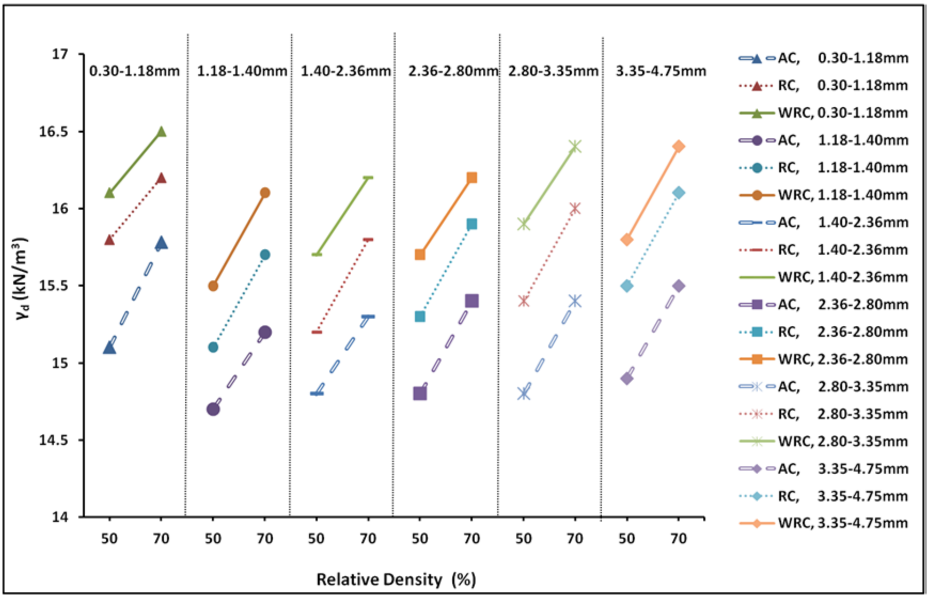

Figure 3. Dry Unit Weight of Tested Soils at Different Roundness Groups and Sizes (AC=Angular Calcareous, RC=Rounded Calcareous, WRC=Well-Rounded Calcareous)

By considering soil geotechnical properties, weight of angular samples were calculated and placed in the tank with relative densities of 50% and 70%. After filling tank with aggregate, strip footing was placed on the surface of soil. After placing and fixing LVDTs footing was loaded and load value and settlement of footing were transferred to computer. Settlement of footing gained from average of two LVDT values and q_u calculated by dividing force to area of footing placed on soil. Each test was done at least three times for insuring the results. After drawing Load-settlement graphs, q_u and settlement of footing were gained on failing moment. All these steps were done for all sizes and three roundness classes of soils at two different relative densities of 50% and 70%. Figure 4 shows the ultimate bearing capacity of soil samples at different roundness groups and sizes. Results showed that increasing roundness of particles caused decrease on ultimate bearing capacity of soil samples. The other result gained from this figure is that increasing size and relative density lead to an increase on ultimate bearing capacity of tested samples.

Increasing ultimate bearing capacity is more considerable on angular soil than rounded or well-rounded calcareous. Especially at bigger sizes or relative densities this increase shows itself more than smaller size or relative densities.

Another important factor on strip footings behavior is settlement. Settlement of footing was gained at failure moment from Load-Settlement graphs and compared together in Figure 5 and Figure.6 at three different roundness classes and two relative densities for all 6 size groups.

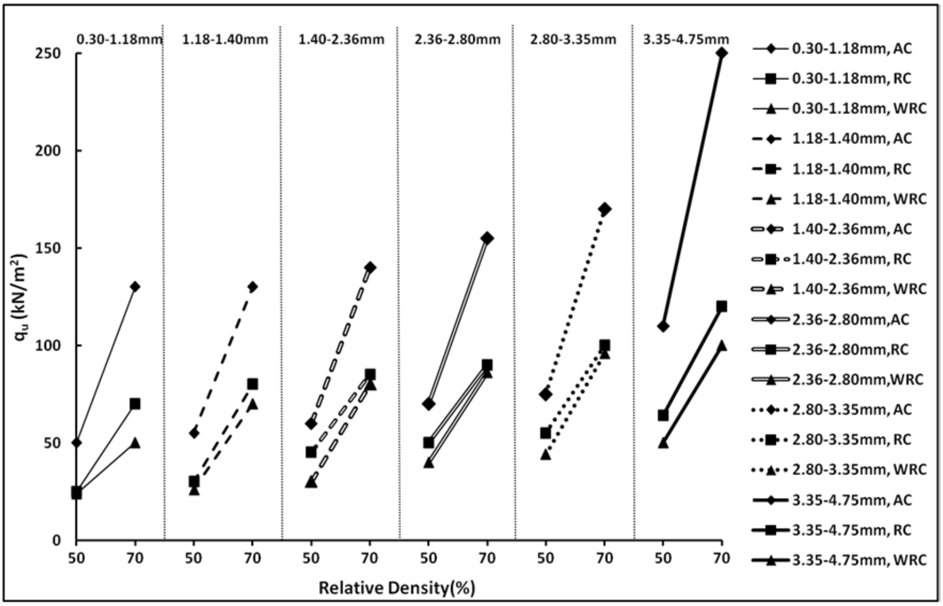

Figure 4. Ultimate Bearing Capacity of Soil at Different Roundness.

By looking to these figures it found that increasing roundness of particles and changing their shape from angular shape to rounded or well-rounded calcareous caused decrease on settlement of footing. It means the soil under footing has been failed sooner with less settlement. At the same time increasing size of soil samples caused improvement of settlement of footing and increased it. Settlement at relative density of 70% is something like 2 times more than settlement at Dr=50% at the same conditions of particles roundness and size. Increasing size from 0.30mm to 4.75mm caused an increase on settlement of footing near to 100% at both relative densities of 50% and 70% for both rounded and well rounded soil samples. On angular samples this increasing is about 60% to 70% when soil size increased from 0.30mm to 4.75mm.

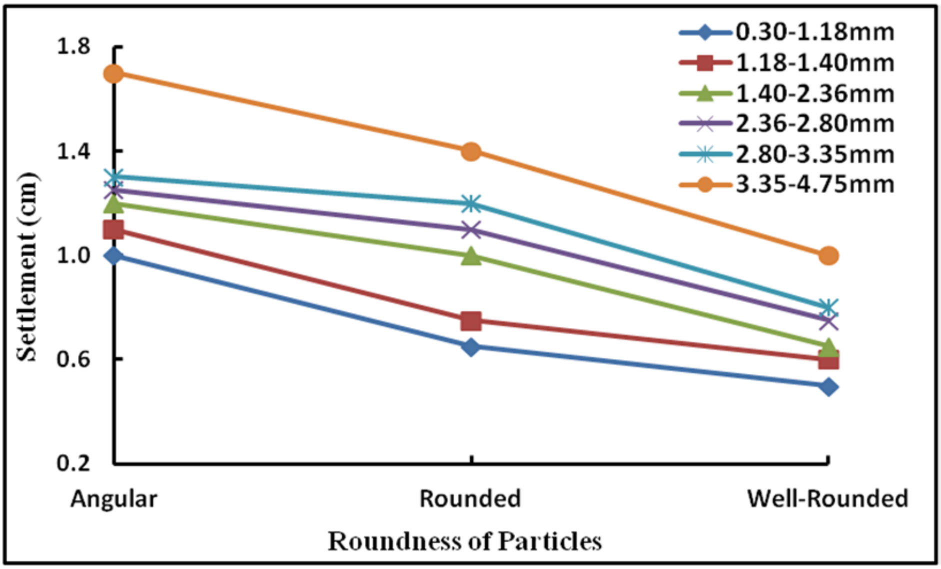

Figure 5. Settlement of Footing for Dr=50%

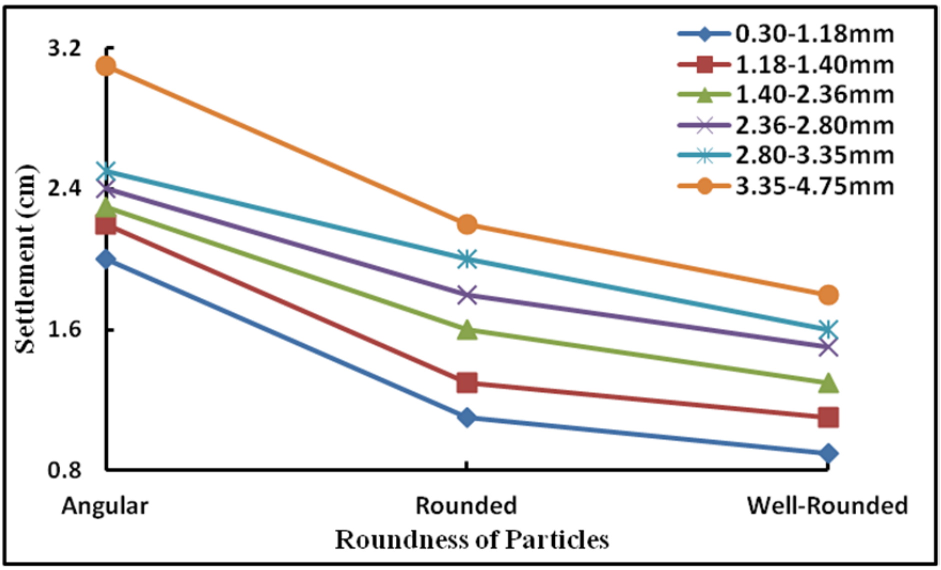

Figure 6. Settlement of Footing for Dr=70%

4. CONCLUSION

Roundness of particles had effect on ultimate bearing capacity of soil and settlement of footing laid on soil. Increasing roundness of particles caused decrease on ultimate bearing capacity of soil. At the same time soil samples reached to failure point with less settlement while roundness increases. The other factors that had effect on soil behavior were angularity, grain size and relative density of aggregate. Increasing these factors of aggregate leaded to improvement on both bearing capacity and settlement. These items can be considered on engineering issues for improving soil behavior.

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