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An Experimental Study on Effect of Particle Size and Angularity on Void Ratio of Granular Soils

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ABSTRACT

Maximum and minimum void ratios are two parameters that have effect on mechanical behavior of soil. There are different parameters that have effect on value of void ratio such as size, angularity, roundness and shape of particles. Particles size and roundness were studied at this work. Angular calcareous sand was selected and tested at this study. For doing tests, soil was washed, dried and sieved at 6 different size groups from 0.3mm to 4.75mmm. The sieves dimensions were 0.30, 1.18, 1.40, 2.36, 2.80, 3.35 and 4.75mm. Minimum and maximum void ratios were founded at all of these 6 size groups. At the second step angular soil has been changed to rounded calcareous soil by placing and turning soil in Los-Angeles machine without balls for 50000 revolutions and after rewashing and sieving the soil, minimum and maximum void ratios calculated for these rounded calcareous samples too. Same procedure was repeated for preparing well-rounded soil and same tests were done on new samples. Results showed that minimum and maximum void ratio decreased by increasing the size of soil samples. Same behavior of decreasing void ratio was seen when roundness of particle increased. Another result that can be mentioned was that, bigger uniformity coefficient (Cu) and wider range of particle sizes caused smaller void ratio. Results cleared that on minimum void ratio, size of particles showed more effect on angular soil than well-rounded. For maximum void ratio, effect of particles size was more considerable at rounded and well-rounded soil.

Keywords: Roundness, Angularity, Particle Shapes, Void Ratio

INTRODUCTION

Soil is one of the most used geo-materials at engineering works. Having information about this material and its mechanical properties and behavior will help engineers to have a better judgment at engineering issues. Mechanical and engineering behavior of particles in aggregates strongly depend on physical properties of particles such grain size distribution, unit weight of soil, type of aggregate particles and other engineering properties. One of the factors that have effect on particles and aggregate behavior is particles shape. This factor can have influence on shear behavior of granular materials [1-3].

Mackie and Dunn were the first researchers start working on effect of shape properties [4-5]. After them other researches were continued on following years [6-11]. Terms that are used to describe particles shape can be listed as sphericity, texture, roundness and roughness [12-13]. Particles shape, size, surface texture and same morphologic properties depend on particles dimension [14-15]. The methods used to determine angularity are similarly limited [16-17]. This was showed at Fig. 1. In recent times new methods such as image analysis methods were used for understanding and characterizing morphology of aggregates too [18].

Recent studies show that changing in angularity of particles will lead to changes at minimum and maximum void ratio (e_{min} and e_{max}), or shear strength of aggregates [13, 19-20]. On the other hand, angularity of materials will lead to an increase on shear strength of materials [21]. By searching literature, it will found that even if there are some investigations on particle shapes, but studies on engineering behavior of aggregate affected by particle roundness and angularity are rare even if soil is most frequent material in civil and geo-engineering [22]. This study focused on effect of roundness and size of particles on void ratio of a sandy soil.

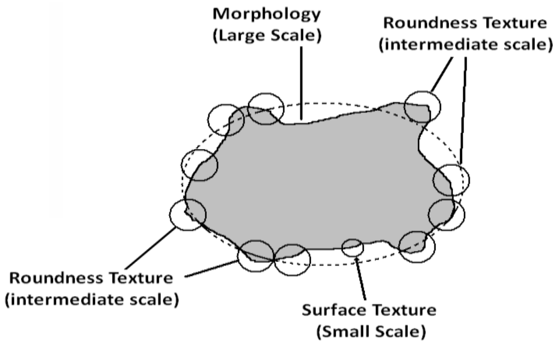

Fig. 1 Describing Particles Shape Depending on Particle Dimension [14-15]

MATERIAL AND METHODS

The soil that used for this study was gained from Ergunler Company in city of Erzurum, Turkey. It was angular calcareous soil (AC) and according to ASTM D 854-14 specific gravity of soil determined 2.7 [23]. The soil was washed and dried at laboratory temperature and sieved at 6 different size groups from 0.30mm to 4.75mm. The sieves dimensions were 0.30, 1.18, 1.40, 2.36, 2.80, 3.35 and 4.75mm. Minimum and maximum void ratios have been founded at all of these 6 size groups. Tests have been done on angular samples at laboratory and on next step soil was changed to rounded calcareous (RC). It was washed, dried, sieved and tests were repeated on new rounded samples. Same procedure happened for well-rounded calcareous (WRC) soil.

Los-Angeles Rattler machine was used for changing angular soil to rounded and well-rounded soil. Angular soil was placed and turned in Los-Angeles machine without balls for 50000 revolutions to change angular soil to rounded soil. Same work was done on rounded soil for changing the shape of particles to well-rounded. This method has been explained at research of Arasan *et al* [24]. Roundness values of soil particles have been calculated and determined by Power chart and Cox equations [7, 25-26]. These values have been showed at Table -1.

Grain size distributions and type of all 6 groups of tested soils were gained according to ASTM D6913-04 and ASTM D 2487-11 [27-28] respectively and showed at Fig. 2. From grain size distribution graph it found that all types of samples were classified as poorly graded sand (SP).

By preparing samples at three different roundness classes and 6 different size groups, laboratory tests were done for finding some geotechnical properties of samples. Maximum and minimum void ratios for all samples were found according to ASTM D4253 – 16 and ASTM D4254 – 16 respectively [29-30].

Table - 1 Roundness Properties of Materials [26]

Sample	Roundness Value	Roundness Class
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

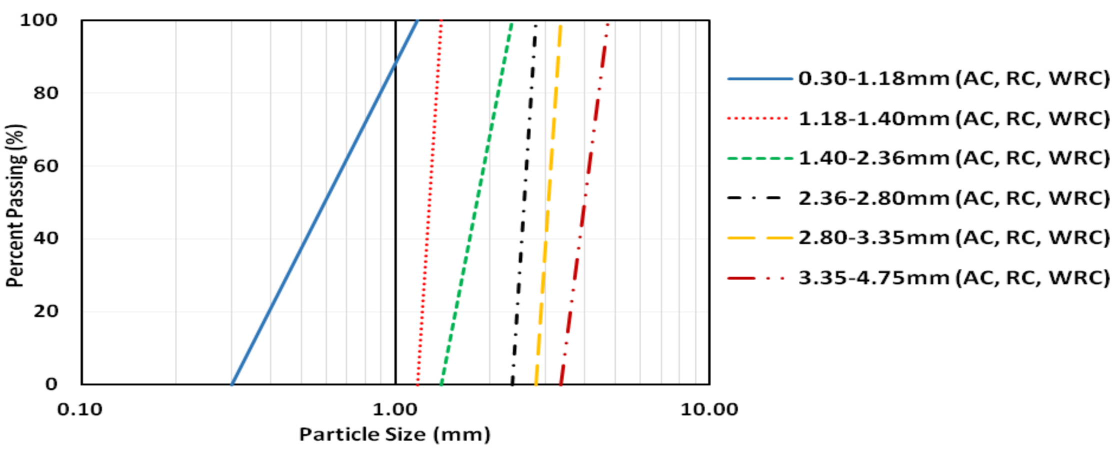

Fig. 2 Grain Size Distribution of Soil

RESULTS AND DISCUSSION

Tests were done at laboratory and each test was repeated at least 3 times for ensuring the results. Maximum and minimum void ratios of samples were found by knowing specific gravity of soil and calculating weight and volume of soil samples at loosest and densest condition. Values of minimum and maximum void ratio were shown at Fig. 3 and Fig. 4 respectively. At these figures e_{min} and e_{max} have been shown and compared at three different roundness classes and 6 different size groups. By looking to the results it found that particle size has effect on void ratio value and both minimum and maximum void ratios (e_{min} & e_{max}) were decreased by increasing the particle size from 1.18mm to 4.75mm. Only on groups of materials with size 0.30-1.18mm to 1.8-1.40mm void ratios had an inconsequent behavior and they increased with increasing the size.

Grain size distribution should be paid attention for explaining the reason of this illogical behavior of increasing of e_{max} and e_{min} at smallest size group. By looking to grain size distribution at Fig. 2 it found that uniformity coefficient **(**C_u) is 2.13 for size of 0.30-1.18mm that for other groups C_u is near to 1. At first group (0.30-1.18mm) the wide of smallest and biggest size is more than other groups. So value of C_u and wider range of particle size have effect on value of void ratio and because of these reason smallest group size showed different behavior.

On minimum void ratio (e_{min}), peak value of e_{min} was 0.677 at angular soil with size of 1.18-1.40mm that reduced to 0.63 at size of 3.35-4.75mm. For rounded and well-rounded samples, the peak values of e_{min} were 0.57 and 0.54 respectively at size of 1.18-1.40mm that reduced to 0.58 and 0.55 at biggest size group. Changes and reducing on minimum void ratio (e_{min}) on angular samples were more that rounded samples. These changes and reducing were more at rounded samples in comparison with well-rounded.

On maximum void ratio (e_{max}), like minimum void ratio (e_{min}), peak value of e_{max} belongs to size group of 1.18-1.40 witch was 1. By increasing size up to 4.75mm, it reduced to 0.98. These values were 0.95 and 0.89 for rounded and 0.58 and 0.55 for well-rounded soils. Opposite of e_{min}, increasing roundness of samples caused more effect on maximum void ratio (e_{max}) of soil. On the other word, changes of void ratio were more considerable at well-rounded samples than angular samples.

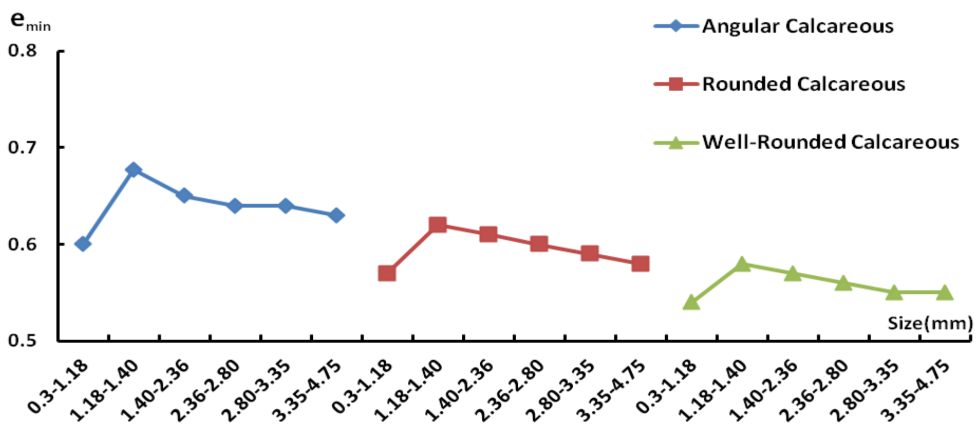

Fig. 3 Minimum Void Ratio for Three Roundness Classes of Soil

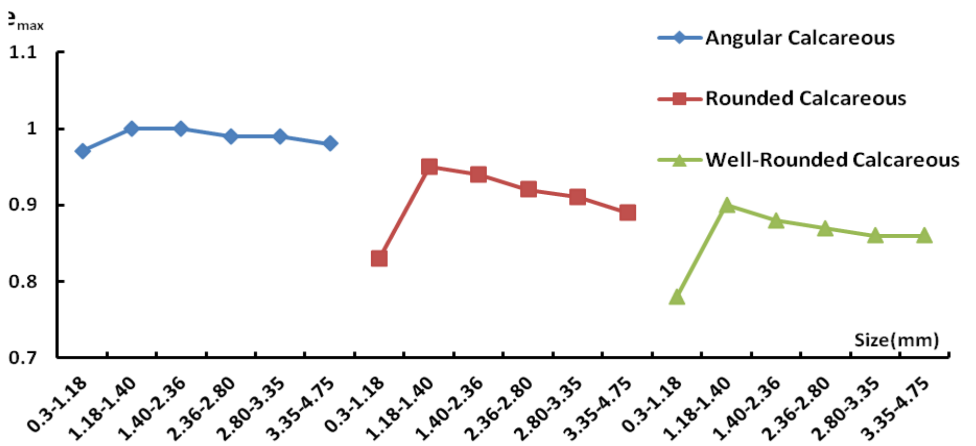

Fig. 4 Maximum Void Ratio for Three Roundness Classes of Soil

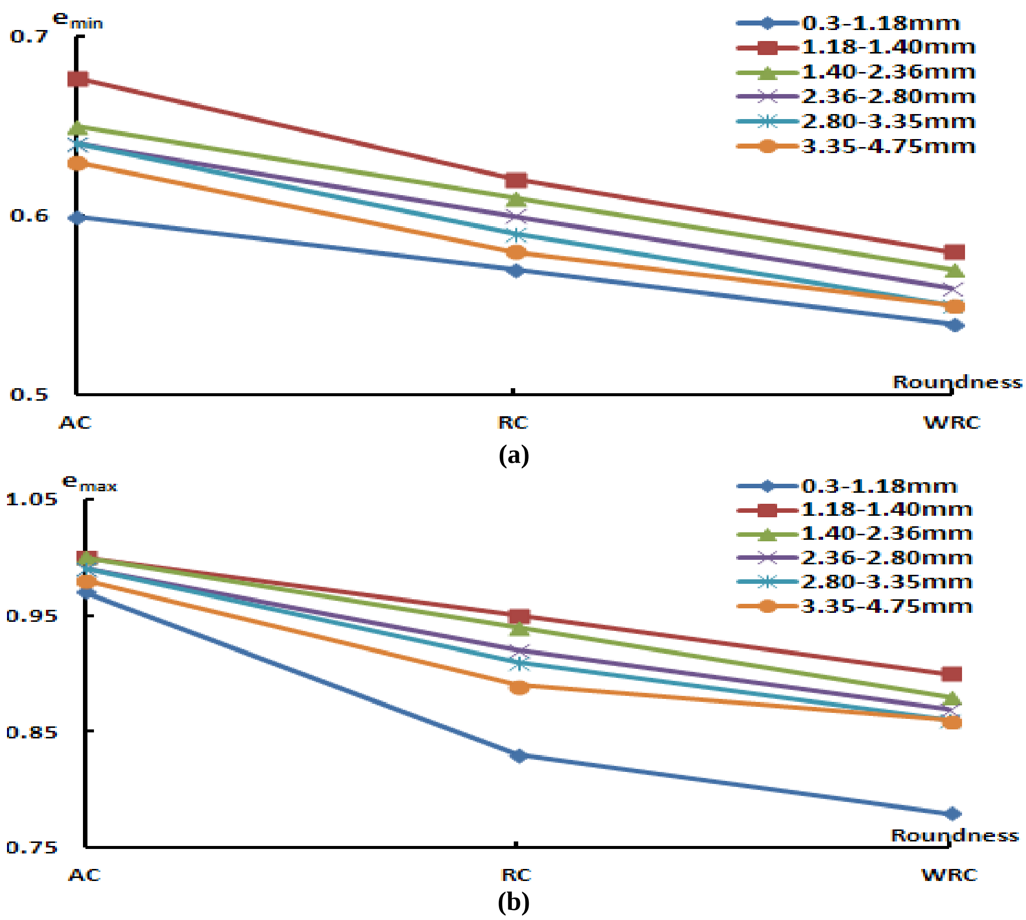

Fig. 5 Minimum and Maximum Void Ratios at Three Different Roundness Classes of Angular (AC), Rounded (RC) and Well-Rounded (WRC) Calcareous

Void ratios were compared at three different classes of angular calcareous (AC), rounded calcareous (RC) and well-rounded calcareous (WRC) at Fig. 5 By looking to this figure it found that void ratios were decreased by increasing roundness of particles and changing particles from angular to rounded and well-rounded shape. Graphs on Fig. 5 showed that on minimum void ratio, size of particles showed more effect on angular samples than well-rounded. For maximum void ratio effect of particle size are more considerable at rounded and well-rounded samples. As dry density of a soil sample depends on void ratio, roundness and size will affect maximum and minimum density of soil too. It means by increasing roundness of a soil we can get to bigger density at the same soil or by increasing size of aggregate at the same roundness class a bigger density will be achieved.

CONCLUSION

Particle size, roundness and uniformity coefficient are the parameters that have effect on void ratio value. Increasing each of them will cause both maximum and minimum void ratio decrease. On compacted materials that void ratio is going toward minimum, size of particles on angular soils show its effect more than rounded and well-rounded soils. It is completely opposite on loose materials that void ratio is going toward maximum. Beside soil size and roundness of particles, uniformity coefficient is another factor that has effect on void ratio of materials and can be studied in other works more completely to make a relation between these three factors.

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