INFLUENCE OF MICA CONTENT ON DYNAMIC SHEAR MODULUS OF SANDY SOILS

Seda DURUKAN[1] , Ender BAŞARI[2]

[1] Manisa Celal Bayar University, Manisa Vocational School of Higher Education, Manisa-Turkey
[2] Manisa Celal Bayar University, Department of Civil Engineering, Manisa-Turkey

[1]seda.durukan@cbu.edu.tr, [2]ender.basari@cbu.edu.tr

Abstract: The Gediz River Delta soils contain abundant flatty (platy) mica grains. Mica grains can alter static and dynamic engineering characteristics of sandy soils due to their flatty shapes. In this study, influence of mica grains on dynamic shear modulus of sandy soils in Gediz River Delta was investigated. Maximum shear modulus (G_{max}), which is a major parameter in dynamic soil response analyses, can be obtained at small deformation amplitudes. Therefore, it is determined through measurement of shear wave velocity. Shear wave velocity provide valuable information about dynamic characteristics of soils. So it is very important to determine the shear wave velocity with high accuracy for dynamic soil response analysis. In this respect, firstly engineering boreholes were drilled and sandy soil samples were recovered along the borehole depth. The mica content of the samples was determined by means of X-RD analysis method. Then test sample contain 1.5%, 10% 20% mica grains were prepared to represent the Gediz River soils. Shear wave velocity of the sand samples were determined with bender element tests under 100 kPa cell pressures in triaxial test device. Followed by the bender element tests maximum shear modules were determined. End of the test program, shear wave velocity of the dense (Dr:55%) samples were determined as 249 m/sn, 214 m/sn and 187 m/sn for 1.5%, 10% and 20% mica content respectively. Mica was reduced the shear wave velocity in considerable percentage about 25% rate. Smiler effect was observed on the maximum shear modules and it is determined as 111.6 MPa, 82.4 MPa, and 62.9 MPa for 1.5%, 10%, 20% mica contents respectively for dense samples (Dr:55%). 20% mica content was reduced the shear wave velocity about 44% rate.

Keywords: Sand, mica content, shear wave velocity, maximum shear modulus

Introduction

Soil properties especially dynamic properties are determined by the empirical relations, although there are special tests for this purpose in the geotechnical engineering. The tests have high cost and perform of the tests requires long time. For this reasons, dynamic properties of the soil are determined by means of Standard Penetration Tests (SPT), Coni Penetration Tests (CPT), and Dynamic Penetration Tests (DPT) etc. Use of the empirical relations based on SPT, CPT, and DPT may lead to error in dynamic soil response analyses for the soils which contain abundant platy grains. In this respect, an experimental study was conducted on sandy soils which are deposited by Gediz River and contain abundant platy mica grains.

The shape of the soil grains are mainly depended on their geological origin and environmental conditions. Alluvial deposits formed by the Gediz River in the west Anatolia are good examples for the soils which contains abundant platy grains. The foundation of Gediz Basin contains rocks which consist of mica minerals (Tabban, 1980) so alluvial deposits in the Gediz Basin may contain about %20 platy mica grains (Başarı, 2012).

In the literature, there are many studies about influence of grain shape on soil behaviors (Santamarina & Cho, 2004). The studies mainly focused on angularity or roundness of grains (Thevanayagam, 2007). Grain shape effects on shear wave velocity were explored by some researchers. Cho et al. (2006) conducted a series bender element tests on rounded and crushed sands. The test results of the Cho et al. (2006) are given in Figure 1. According to Cho et al (2006), shear wave velocity increase with roundness as seen in Figure 1. Shear wave velocity of rounded sand samples is higher than shear wave velocity of angular sand samples. Angularity of the sand grains cause an increase voids between the grains this effect leads to decrease in density of media which shear waves propagate in its. Also, angularity of the grains causes a decrease contact surface area between sand grains. Decreases both of contact surface area and density of media leads to decrease shear wave velocity in soil. Stresses on contact surfaces between grains have a significant role on energy transmission between grains. High stress on the contact surface creates more stable structure in soil, so energy can transferred more easily between grains. In Figure 1 mean effective stress indicates stress on contact surfaces. High mean effective stress means high stress on contact surfaces. Therefore, increasing the mean effective stress cause an increase shear wave velocity as seen in Figure 1.

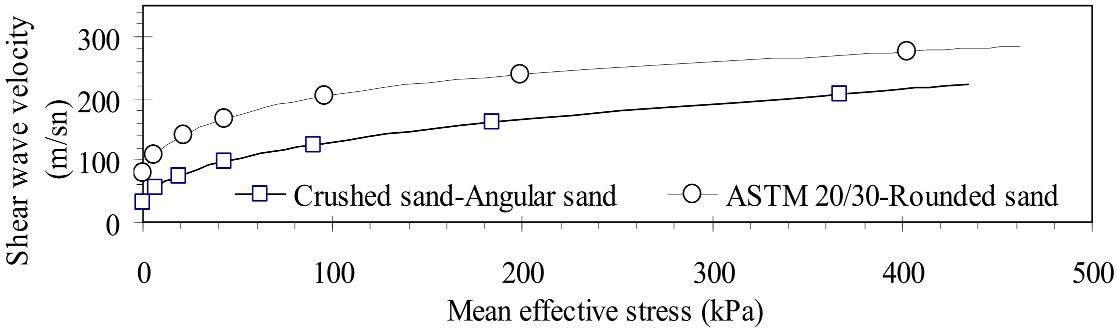

Figure 1. Roundness effect on the shear wave velocity (Cho et al. 2006).

Lee et al. (2007) explored effects of mica grain size ratio on shear wave velocity of sand. In the study, mica grains in different sizes were used. Bender element tests were conducted on samples, which were prepared in conventional oedometer cell as they were vertically loaded. Unfortunately, void ratios or densities of the samples cannot be inferred from the study. Nevertheless, mica effect on the sand samples is obvious in the study (Figure 2). As seen in Figure 2, shear wave velocity decreases with mica content for all mica grain sizes ratio.

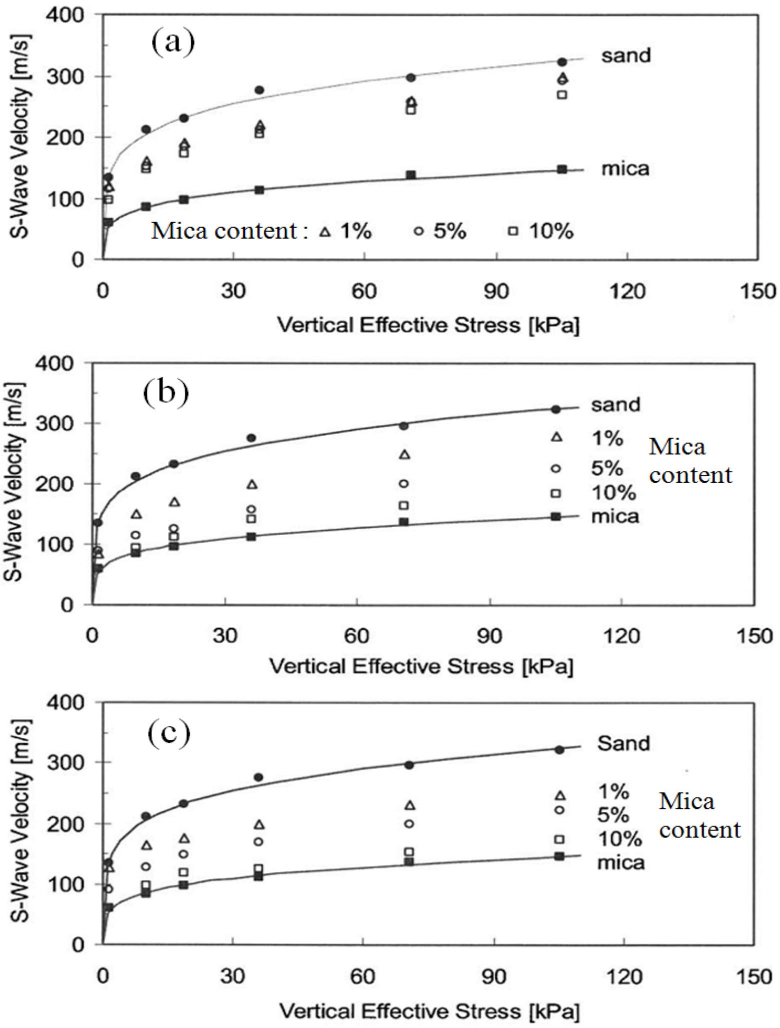

Figure 2. Mica grain size effect on shear wave velocity. (a), (b) and (c) are D_{mica}/D_{sand}=0.33, D_{mica}/D_{sand}=1.0 and D_{mica}/D_{sand}=3.0, respectively (Lee et al., 2007).

Lee et al. (2007) and Santamarina & Cho (2004) explain mica effect on the sand behavior with ordering and bridging concept (Figure 3 and Figure 4). In this concept, when size of the mica grains are equal to or larger than size of the sand grains (D_{50}-mica/D_{50}-sand 1.0), mica grains create bridges among sand grains, and increase the global void ratio. When the global void ratio increases, the strength of sand decreases while compressibility of the sand increases.

Figure 3. Possible mica-sand ordering patterns depending on orientation angle (Lee, et al. 2007).

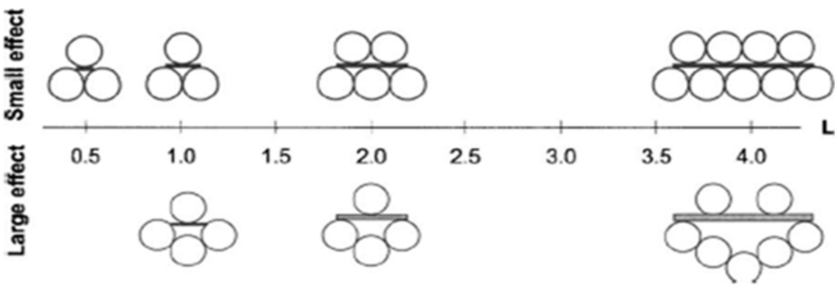

Figure 4. Bridging and ordering effects of mica plates (Lee, et al. 2007)

Materials and Methods

The test samples were taken from field (Figure 5). For this purpose boreholes were drilled in alluvial sandy soils of Gediz River Delta. Alluvial sandy materials which contain platy mica grains in test program were generally obtained from the Standard Penetration Test (SPT) spoon as seen in Figure 5. Amount of sample obtained from the SPT spoon is not enough to prepare the test sample for triaxial device. Because of this reason, the sandy samples of SPT spoons were combined then test program were conducted. The grain size distributions of the field (test samples) can be seen in Figure 5. The upper and lower bounds for the grain size of the alluvial sandy materials in Gediz River Delta are also shown in Figure 5. Diameter ratio of separated sand and platy mica grains (D_{mica}/D_{sand}) is 1.07. Coefficients of uniformity (c_u) for sand and mica grains are 1.67 and 1.64 respectively.

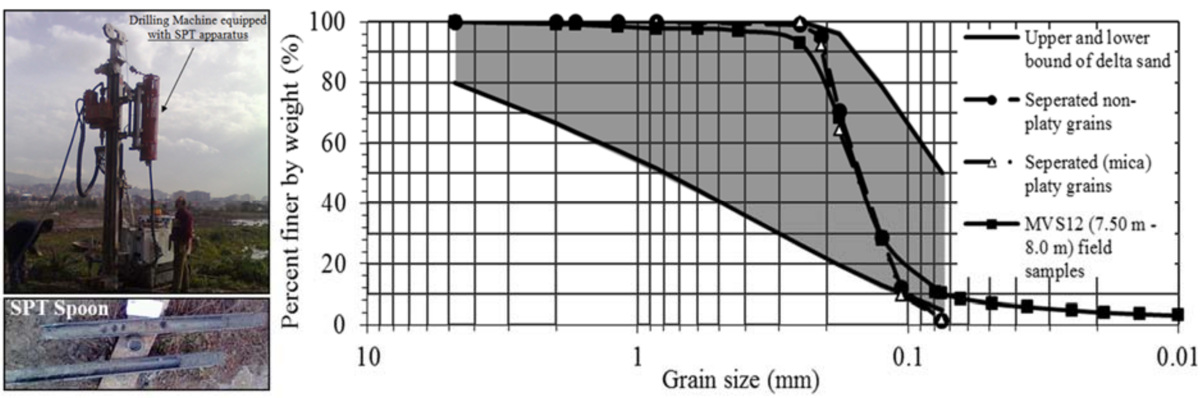

Figure 5. Field study and grain size distribution of field and test samples.

The percentage by weigh of mica minerals (platy grains) for field samples was determined by analyzing the X-Ray Diffraction (X-RD) test results (Başarı, 2012). Mica contents of field samples were determined as %5 - %20. Then mica flakes and rounded sand grains were separated from each other by flotation technique (Geredeli & Özbayoğlu 1995). Separated rounded sand grains and mica flakes were mixed in certain percentage for prepare test samples. Test samples were prepared at three different mica contents (1.5%, 10%, 20%) by weigh and three different relative densities (30%, 55%, 80%).

Maximum shear modules (G_{max}) of the test samples were determined helping with Equation 1. Shear wave velocity (V_s) of the samples were determined with bender element test. Bender element tests were conducted on triaxial test samples under 100 kPa confining pressure (cell pressure).Triaxial test samples were prepared with moist tamping method (Ishihara, 2003). Diameter and length of prepared samples are 70 mm and 140 mm respectively. Before the bender element test, test samples were saturated and isotopically consolidated under 100 kPa confining pressure. Saturation degree of the tests samples was determined with B value. B values of the all samples are equal or higher than 0.95.

$$G_{max}=\rho V_s^2 \quad (1)$$

Bender element test device consists two piezoelectric tips, signal generator and oscilloscope. One of piezoelectric tips is called transmitter and other tips is called receiver. Transmitter converts electric signals to waves, receiver converts waves motion to electric signals. Travelling time of shear waves in soil sample is determined as illustrated in Figure 6. Wave velocity within the soil is found by dividing the distance between bender element tips to the travelling time. In the bender element test program, amplitude of the used signal was 20 mV.

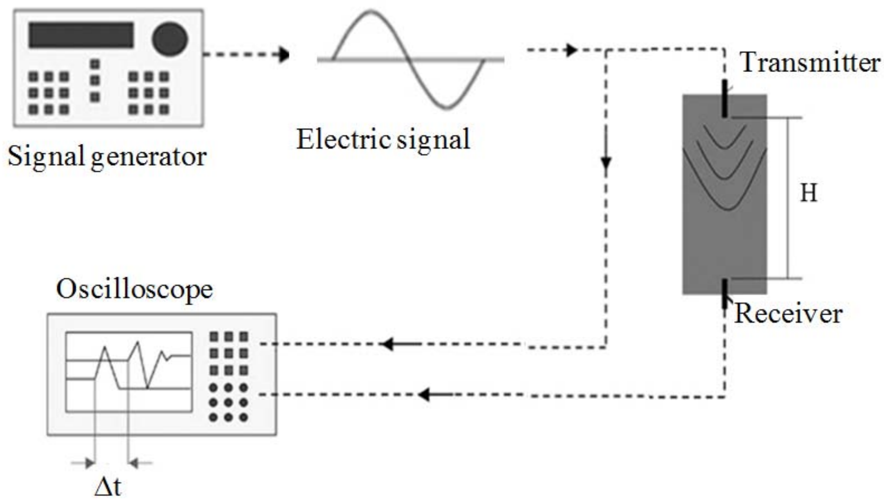

Figure 6. Illustration of bender element test.

Tests Results

Shear wave velocities of soil samples at different mica contents, prepared at relative density values between loose, dense and very dense states, were measured via bender element tests as described above. Samples were set up at 1.5, 10 and 20% mica content. Size ratio of mica and sand (D_{mica}/D_{sand}) grain is 1.07. One of the recorded signals from bender element tests and measured shear wave velocity (V_s) are presented in Figure 7.

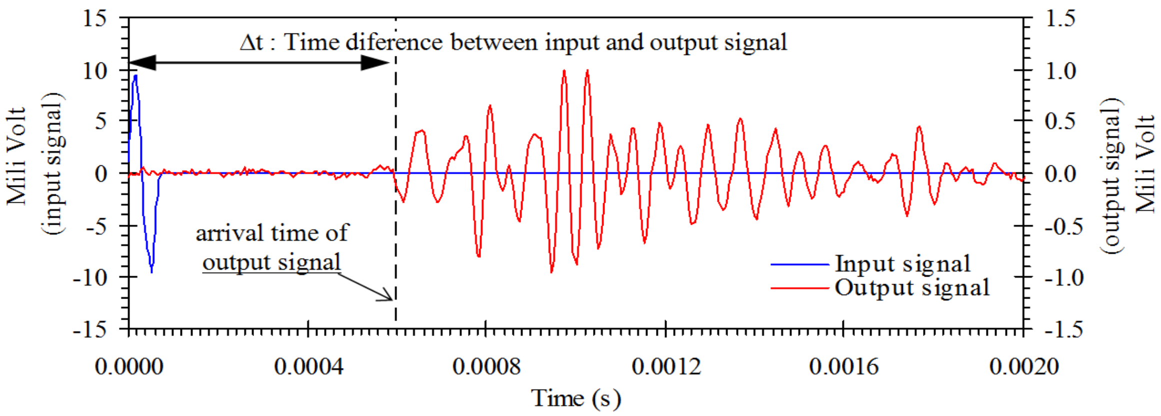

Figure 7. Recorded signals during bender element test.

Test results for shear waves (V_s) presented in Figure 8. Changes of shear wave velocity corresponds to the mica content given in Figure 8.a. Effects of the relative density on shear wave velocity is shown in Figure 8.b. Maximum shear modules (G_{max}) can be seen in Figure 9. Maximum shear modules calculated helping with Equation 1 as seen in Figure 9.a and Figure 9.b. As expected mica and relative density have similar effect on shear waves velocity and maximum shear modules. Both of shear wave velocity (V_s) and maximum shear modules (G_{max}) decrease with increasing of mica content. When the Figures 8 and Figure 9 are carefully examined, it can be seen that relative density can change influence of mica content on shear wave velocity and maximum shear modules.

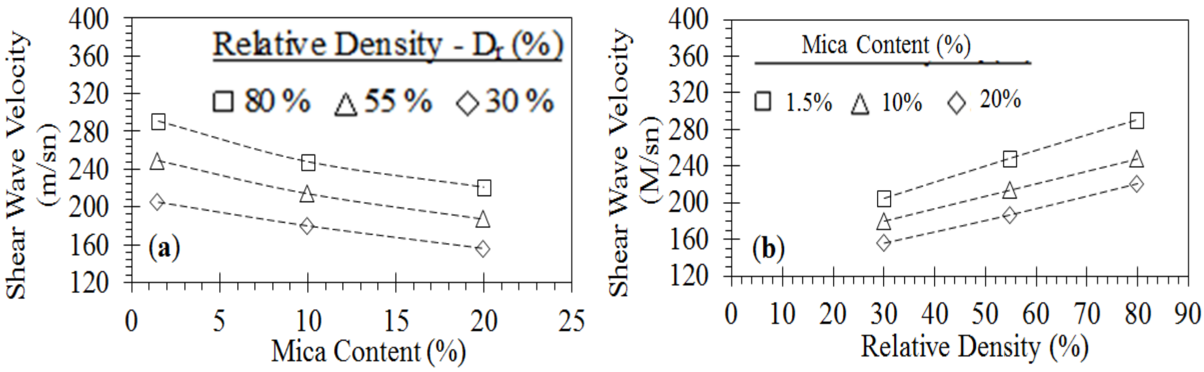

Figure 8. Effects of Platy mica grain and relative density on shear wave velocity.

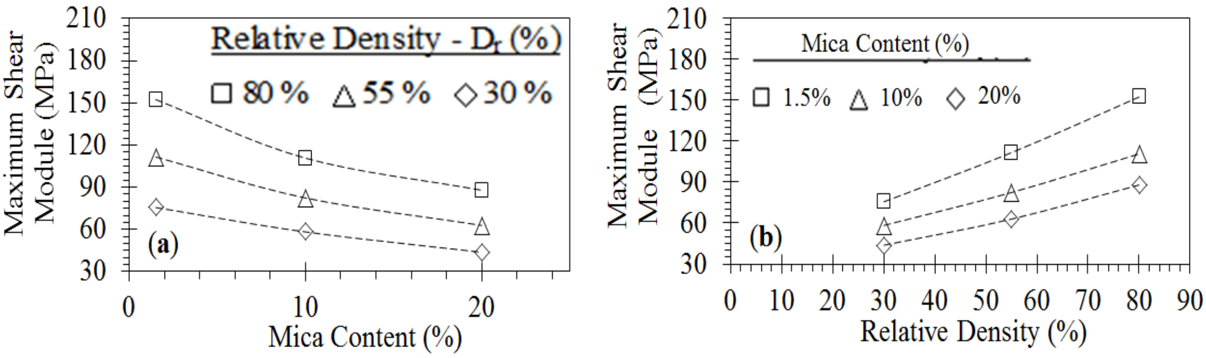

Figure 9. Changing of the maximum shear modules with mica content and relative density.

Conclusion

In this experimental study, the effects of the platy mica grains, on shear waves and maximum shear modules of the sandy soils within the liquefaction depth (20 m) of the study area have been researched.

Soil samples that were recovered from the study area were used in the testing program. Apart from the present study, dynamic experimental studies regarding the Old Gediz River Delta are scarce. Therefore, the findings of this study have significant importance since they will be informative and advisory for future researches to be conducted on the sandy soils of the area.

Platy mica content of the soils within the study area was determined down to 20 m from the surface. Soils of the survey area contain platy mica mineral ranging between 5% and 20%. Such mica content for sandy soils may be sufficient to change major engineering properties especially dynamic properties of the sandy soils. In order to estimate soil behavior correctly, mica content of the sandy soils were studied in detail.

Influence of platy mica grains on shear wave velocity and maximum shear modules were observed during bender element tests. For all mica contents, shear wave velocity and maximum shear modules decrease as relative density and effective confining pressure decreases. It was noticed that shear wave velocity and maximum shear modules were inversely proportional with mica content

Test results shows that, small amount of mica can change shear wave velocity and maximum shear modules of sandy soils. As seen in Figure 8 and Figure 9, when the mica content increases 1.5% to 20%, maximum shear modules decreases 111.6 MPa to 62.9Mpa for dense sand (Dr:55%). Maximum shear modules were decreased about 43.6% rate. Similar effects were observed loose (Dr:55%) and very dense (Dr:80%) sands. When the mica content increases 1.5% to 10%, maximum shear module decreases about 42.1% and 42.3% for loose and very dense sand respectively. An increasing about 10% in mica content caused to decrease in maximum shear modules about 22.9%, 26.1% and 27.4% rates for loose, dense and very dense sand respectively. Shear wave velocity is effected similarly by the platy mica grains. Increasing of platy mica grain contents caused a diminish in shear wave velocity as seen in Figure 8. 10% and 20% mica content caused diminishes about 12~15% and 23~25% in shear wave velocity respectively.

Platy grains have considerable effects on dynamic properties of the sandy soils. Ignoring the effects of platy grain on the sandy soils leads to significant errors in dynamic soil response analyses and other dynamic analyses. Empirical relations should not be used for estimation of soil parameters which contain platy grains.

Acknowledgements
The authors are grateful to the support of The Scientific and Technological Research Council of Turkiye (TUBITAK) provided in the scope of research project 106G159. Also the authors are grateful to the support of TUBITAK-BIDEB and ULAKBIM. We would like to thank TUBITAK for all their supports.

References

Başarı, E. (2012). Influence of fine content and fine mineralogy on strength and stiffness characteristics of sandy soils in Gediz River Delta. Ph. D. Thesis, Graduate School of Natural and Applied Sciences of Dokuz Eylül University, İzmir, Turkey.

Cho, G. C., Dodds, J., & Santamarina, J. C. (2006). Particle shape effects on packing density, stiffness and strength: natural and crushed sands. Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 132 (5), 591-602.

Geredeli, A., & Özbayoğlu, G. (1995). Simav feldspatının flotasyonu. Endüstriyel Hammaddeler Sempozyumu. 71-81, İzmir, Türkiye.

Ishihara, K. (2003). Soil behavior in earthquake geotechnics. 2. Press, ISBN: 0-19-856224-1, New York: Oxford University Press.

Lee, J. S., Guimaraes, M., & Santamarina, J. C. (2007). Micaceous sands: Microscale mechanisms and macroscale response. Journal of Geotechnical and Geoenvironmental Engineering, 133 (9), 1136-1143.

Modeling of Seismic Behavior of Soils for Safe Structural Design in Izmir Metropolitan Area and Aliaga, Menemen Towns. (2011). Earthquake Research Center of Dokuz Eylul University (DAUM) and TUBITAK. TUBITAK Project No: 106G159, Izmir, Turkiye

Santamarina, J. C., & Cho, G. C. (2004). Soil behaviour: The role of particle shape. Proceeding Skempton Conference. London. 1-14.

Tabban, A. 1980. Kentlerin Jeolojisi ve Deprem Durumu, T.C. İmar ve İskan Bakanlığı, 343p, Ankara.

Thevanayagam, S., (2007). Intergrain contact density indices for granular mixes - I: Framework. Earthquake Engineering And Engineering Vibration, 6 (2), 123-134.

