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Effect of Mica Content in Sand on Site Response Analyses

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***Abstract*—**This study presents the site response analysis of mica-sand mixtures available in certain parts of the world including Izmir, a highly populated city and located in a seismically active region in western part of Turkey. We performed site response analyses by employing SHAKE, an equivalent linear approach, for the micaceous soil deposits consisting of layers with different amount of mica contents and thicknesses. Dynamic behavior of micaceous sands such as shear modulus reduction and damping ratio curves are input for the ground response analyses. Micaceous sands exhibit a unique dynamic response under a scenario earthquake with a magnitude of Mw=6. Results showed that higher amount of mica caused higher spectral accelerations.

***Keywords*—**Micaceous sands, site response, equivalent linear approach, SHAKE.

I. INTRODUCTION

THE seismic response of soil layers in a region can amplify the effect of earthquakes depending on the properties of the local soil conditions, i.e., dynamics soil properties, topology of the site, etc. [1]-[7]. For the sites which are not susceptible for liquefaction, the site response analyses are widely used for evaluating this site amplification, namely spectral acceleration and also factors affecting them. The response of a site under earthquake excitation mainly depends on the dynamics properties of soils such as shear modulus degradation as well as damping ratio curves. These dynamic properties are used as the input parameters for site response software, SHAKE [8]. SHAKE is often used by engineers to determine the response of soils layers. It is based on "equivalent linear approach", and determines the lateral displacements, velocity, and acceleration response of a free field by approaching non-linear behavior of soils via a linear iterative method which takes care of well-known curves of modulus reduction and damping ratio curve with increasing shear strain values. Engineers often rely on these parameters (i.e., accelerations) to take earthquake loads into account in earthquake resistant design of buildings.

This study focuses on the soil layers representing the micaceous sand layers mostly found in Izmir. The dynamic response of this type of layers is important in the region since Izmir is one the largest and highly populated cities of Turkey and located in the earthquake hazard region. Therefore, ground response analyses of soil deposits containing micaceous sand to analyze the site amplifications carry essential importance for urban development.

Dynamic response of mica-sand mixtures took attention of some researchers. A short summary of previous works regarding the dynamic behavior of micaceous soils may be as follows: Reference [9] studied the influence of mica content on the compressibility of sand, and showed that increment in mica content results in an increase in the void ratio of the uncompressed material as well as an increase in compressibility. Most current basic soil mechanics texts show that mica particles; (i) decrease the strength [10], (ii) alter the internal shear mechanism [11], (iii) increase the compressibility [12].

Leighton Buzzard sand with addition of mica, which consists of fine and platy particles, considerably affects the elastic threshold strain, modulus degradation which is a function of strain, and damping ratio. The addition of a small proportion of fine mica considerably reduces the small strain shear modulus, increases shear-strain susceptibility, and increases the damping ratio of the mixture.

Limited studies showed that mica grains could cause a considerable change in dynamic parameters of the sand such as shear modulus, damping ratio, and shear wave velocity. Reference [13] has shown that the shear wave velocity, which is related to shear modulus, is dependent on angularity, sphericity, and roundness. Reference [14] reported values of G/G_{max} and D/D_{min} of mica-sand mixtures measured at 50 kPa, 100 kPa, and 150 kPa effective stresses.

Reference [15] showed the influence of effective stress on shear modulus of mica-sand mixtures; the higher the confining pressure, the higher the shear modulus. Shear wave velocity (V_s) increases due to its direct proportionality with shear modulus G_{max} [16].

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

The aim of the current study is to employ the site response analysis and to investigate when different ratio of mica added to Leighton Buzzard sand, how further presence of mica in soil changes dynamic response of soil layers and instantly affects amplification ratio as well as spectral acceleration.

II. DYNAMIC PROPERTIES OF SAND-MICA MIXTURES

Shear modulus reduction curve and damping ratio curve obtained from the experiments [15] have been given as input parameters to SHAKE. Reference [15] used two different geo-substances, which were Mica and Leighton Buzzard Sand, in

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the experimental work. The Leighton Buzzard Sand that used in the test was a fraction B provided by the David Ball Group, Cambridge, U.K., confirming to BS 1881–131:1998. Its specific gravity, minimum and maximum dry densities were found to be 2.65, 1.48 g/cm^3 and 1.74 g/cm^3 accordingly. Here, it was noticed that more than 90% of the coarse sand particles, which were rounded and chiefly quartz, were between 0.6 mm and 1.1 mm. Mica content used in the test was 52-105 μm muscovite minerals supplied by Dean and Tranter Ltd. Its specific gravity, minimum and maximum dry densities were found to be 2.9, 0.725 g/cm^3 and 0.916 g/cm^3 accordingly [17]. The amount of mica used in this experiment refers to the dry weight of mica relative to the total dry weight of the mixture. In the resonant column test, two mica percentages were considered 5% and 10%. Results were compared with clean Leighton Buzzard sand.

Shear modulus reduction, damping ratio curves with increasing strain, and shear wave velocities of mica-sand mixtures will be the main input parameters as dynamic soil properties for SHAKE. SHAKE is formulated in term of total stress and it does not account for excess pore pressures which may develop in fluid-saturated soils during a seismic excitation. It employs an iterative algorithm to follow shear modulus reduction versus shear strain and damping ratio versus strain curves so that nonlinearity of soil behavior can be accounted at large displacements. Nevertheless, the code is subjected to the variations in the input material parameters.

There are numerous works on different models including nonlinear models to analyze the dynamic response of layered soil deposits; however, SHAKE was employed for the analyses because of its wide use in practice and well-known capabilities and also limitations.

III. RESULTS AND DISCUSSION

The example considered here has three geometrically identical soil profiles consisting of six layers each of which has layer thickness of 10 ft. However, each soil profile has different mica contents which are 0%, 5%, and 10% as shown in Fig. 1. Example is chosen to help us to determine how mica content of soils amplifies the spectral accelerations for the identical soil profiles. Shear modulus degradation and damping ratio curve have been chosen such a way that confining pressure at the mid-point of the layer corresponds to confining pressure used in the resonant column test. This confining pressure value for 60 ft soil at the middle of the layer thickness was calculated as 150 kPa.

As stated in the already available papers [18] and [19], mica has great influence on void ratio. Increasing mica content causes void ratio increase, then compressibility of soil also rises. High mica content decreases the density since soil grains move away from each other, also shear modulus decreases and damping ratio increases. This phenomenon makes the soil more vulnerable to liquefaction and also increases the spectral acceleration. This behavior can be seen in Fig. 2; spectral acceleration was found to be different at various mica contents as shown in the same figure. It was observed that the higher spectral acceleration occurs at higher mica content.

As illustrated in Fig 2, the spectral acceleration increases from 0.48 g for 0% mica content to 0.52 g for 5% mica content and then to 0.56 g for 10% mica content for the same soil profile under same confining pressure value. The spectral acceleration value was more amplified at 10% than 5% and 0% as expected since overall mica content effect is found to increase the spectral acceleration. Hypothetically, for the same soil profiles, if we use modulus degradation and damping ratio curves obtained at 50 kPa confining pressure which states that soil deposit is not compacted and looser compared to the first case, the spectral accelerations amplify dramatically. While the spectral acceleration value for the sand with 10% mica was 1.2 g, the spectral acceleration for clean Leighton Buzzard Sand is nearly 0.85 g as seen at Fig. 3.

The fact is that the sand behaves like clay with addition of mica, and then the mixed material would have a less shear modulus and more damping ratio. As it can be seen from Fig. 1, shear wave increases as the depth increases, whilst mica content increases. Consequently, ground motion in soils with low shear wave velocity amplifies more than those with higher shear wave velocity. There is a direct proportion between shear wave and shear modulus, and inverse proportion with amplification. Thus, geologic structure of low shear wave velocity such as soft clays and loose sands may amplify ground motions more.

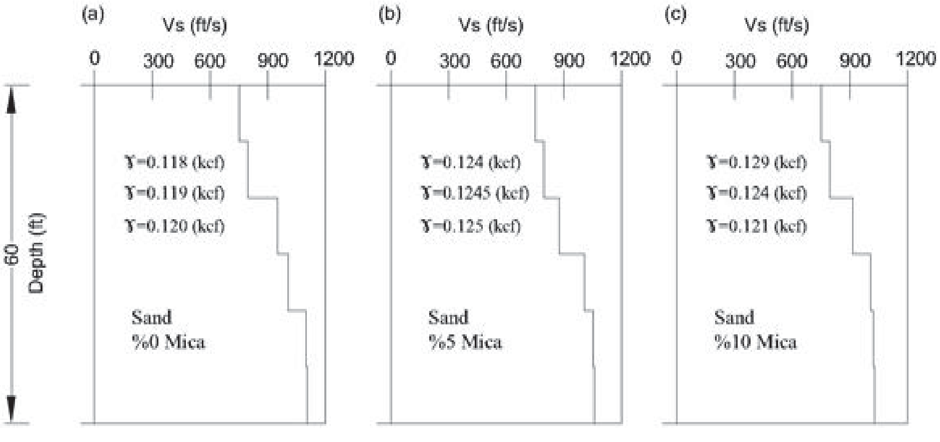

Fig. 1 Shear wave velocity, unit weight, and mica content variations for the soil profile

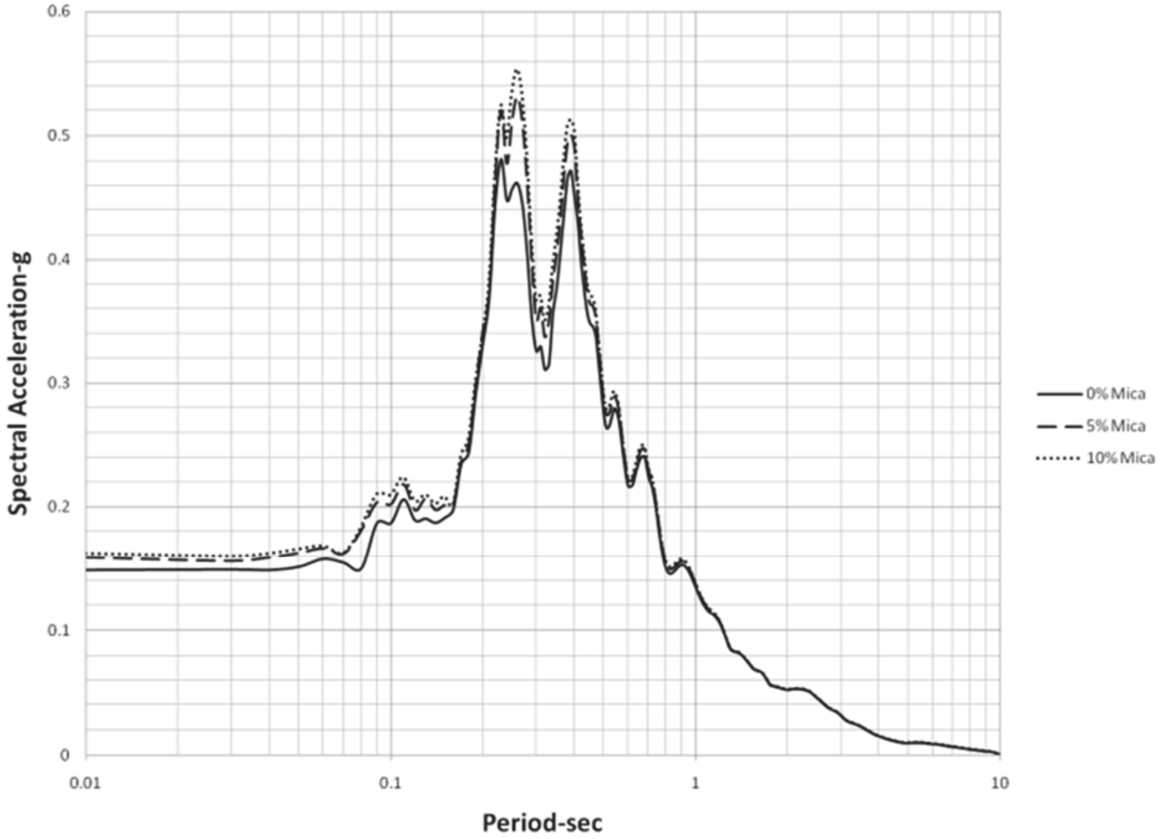

Fig. 2 Spectral Acceleration for different mica contents for the 60 ft thick soil deposit

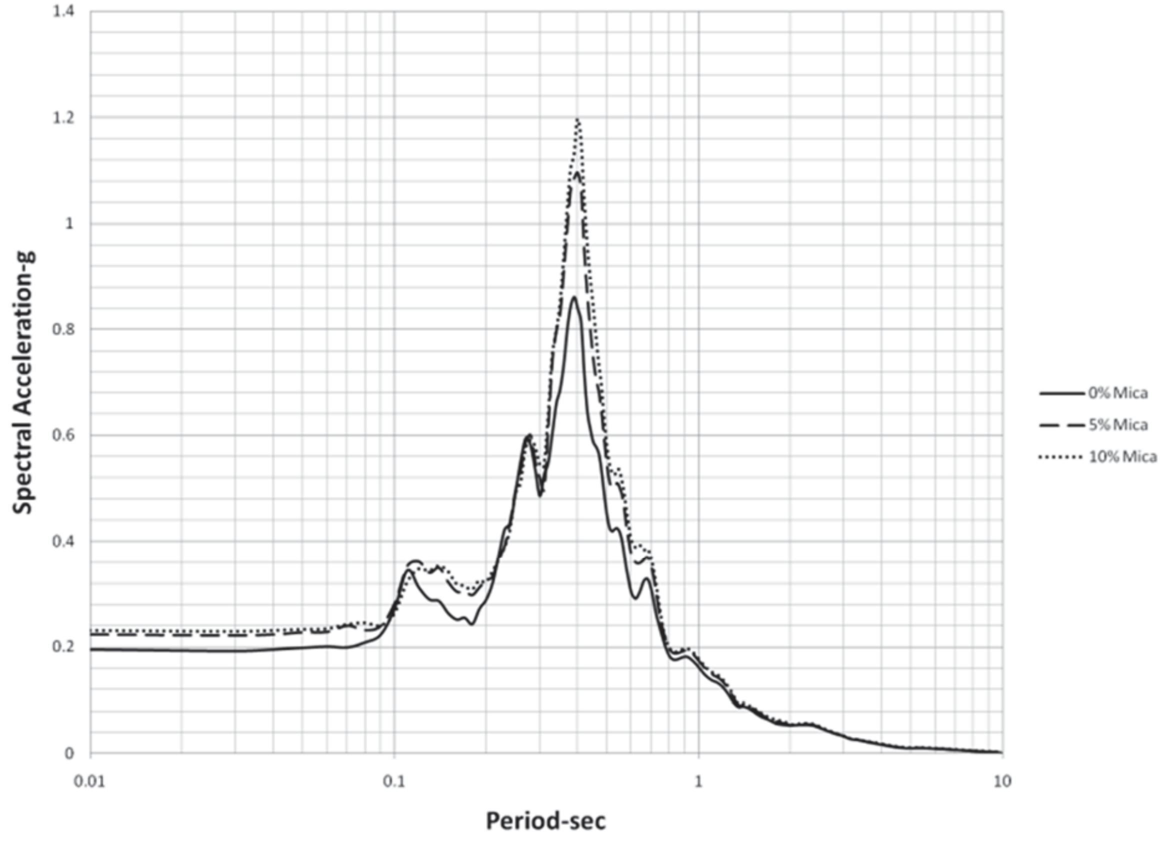

Fig. 3 Spectral acceleration for different mica contents at 50 kPa confining pressure

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IV. CONCLUSION

Effect of mica on the ground response of sites has been investigated by a simple example. Results showed that spectral accelerations are larger when mica content in mixtures increases. It is a significant outcome of the analyses, especially, for cities such as Izmir and surrounding areas where the composition of the soil deposit includes various amount of mica. The mica content decreases the shear modulus, and shear wave velocity (V_s). Analyses also indicated that amplification would be larger when there is loose mica-sand mixture lying on top of the site.

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