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An Experimental Study on the inFluence of Particle Size on Small-Strain Shear Modulus of Granular Soils

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1. Introduction

Under small-strain circumstances, both shear wave velocity and maximum shear modulus of soils are considered the most important parameters for evaluating dynamic behaviors of soils. Due to the influential effects of particle size on engineering behavior of soils, it may be remarkable to figure out the effects of grain size on shear wave velocity. According to the relevant literature, the influences of grain size on shear wave velocity of soil were completely different in various research studies so that their findings could be classified in four major groups. Firstly, some researchers believed that shear wave velocity increases with increasing soil grain size; however, some observed that any increase in particle size of soil could diminish its shear wave velocity. Meanwhile, in a few studies, it was seen that shear wave velocity was not sensitive to soil grain size. Moreover, in a range of grain size, shear wave velocity increases with the increase in the average diameter of soil grain and in the other range, shear wave velocity decreases as the average diameter of soil grain increases. In this study, the effects of grain size of soil on both shear wave velocity and maximum shear modulus of dry sand were experimentally investigated under different circumstances of confinement and excitation frequency using bender element test.

2. Experimental Program

This research focused on the influences of particle size on shear wave parameters in a particular type of sandy soil. To this aim, a digitally controlled triaxial testing machine equipped with bender elements was used. The material used in this study was local river sand collected from the Dinevar area located in the north-eastern part of Kermanshah, Iran, and precisely classified as per the guidelines presented in the literature (ASTM C136/C136M 2014). The sandy soil was categorized into 10 specific groups with particular sizes. More details can be found in Table 1.

In this study, homogeneously identical samples were assumed as a prerequisite for all experiments. Therefore, it was necessary to take practical measures to ensure this crucial prerequisite in all specimens. In this regard, various experimental methods may be used to achieve a desirable void ratio, including the wet and dry tamping method, dry pouring technique, and water precipitation methods. In this study, the dry tamping method was used to prepare similar specimens with an identical void ratio. Using this method, three-layer samples were prepared, in which the soil was poured through a funnel for each layer, without a falling gap, and compacted using an appropriate tamper.

Table 1. Physical properties of all 10 classified soil groups using standard ASTM C136 sieves

Soil group	Used Sieve No.(#)	Particle size (mm)	d_{50} (mm)
R1	100-50	0.15-0.30	0.225
R2	50-40	0.30-0.42	0.363
R3	40-30	0.42-0.60	0.513
R4	30-20	0.60-0.85	0.725
R5	20-16	0.85-1.18	1.015
R6	16-14	1.18-1.40	1.290
R7	14-10	1.40-2.00	1.700
R8	10-8	2.00-2.36	2.180
R9	8-4	2.36-4.75	3.555
R10	4-3/8	4.75-9.53	7.140

To prepare cylindrical BE test specimens, a two-way split aluminum sampling mold with internal diameter of 105 mm (F03586, STRASSENTEST OHG, Germany) equipped with a rubber membrane was used. For all samples of the 10 soil groups, under confining pressures of 50, 100, 150, 200, 250, 300, 350, 400, 450, and 500 kPa, the transmitted shear wave signals and the corresponding received wave signals were generated and recorded, thereby determining the resultant shear wave travel time.

3. Results

Figure 1 displays the alteration of shear wave velocity under different confining pressures (50-500 kPa) for all 10 soil groups. It can be seen that, for mean particle diameters from 0.225 to 1.29 mm, the shear wave velocity increases with increasing mean particle diameter, while this trend is reversed for mean particle diameters from 1.29 to 7.14 mm. Apparently, the initial increase in Vs is associated with an increased number of contact points and increased friction among particles, based on the Hertzian contact theory. Moreover, for this specific particle size (0.225 to 1.29 mm), the shape of the particles changes from a smooth rounded type to a rough angular type, which may result in higher interlocking among soil particles, thus increases the soil shear modulus. However, this phenomenon shows an approximately opposite trend for soil samples with mean particle diameters from 1.29 to 7.14 mm.

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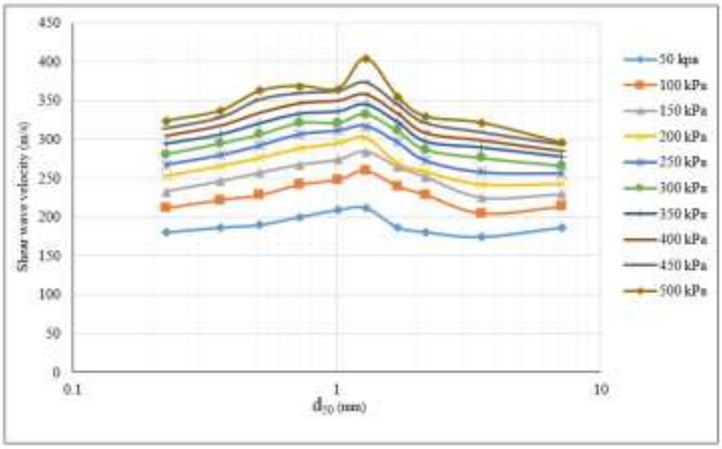

Figure 1. Changes of shear wave velocity in terms of soil particle size under all confining pressures and frequency of input signal, 10 kHz

4. Conclusion

This research study has been aimed at comprehensively assessing the effects of grain size on the amount of maximum shear modulus of sand. The results indicated that the maximum shear modulus of sand was considerably affected by changes in grain size. In a particular range of grain size, shear modulus increased as the diameter of soil grains rose, while, in the other range, maximum shear modulus diminished with increasing grain diameter. This increment in shear wave velocity might be related to fine-grained particle of sand, whereas shear wave velocity reduced along with increasing the diameter of coarse-grained of sand.