FREQUENCY CONTENT EFFECTS ON DYNAMIC BEHAVIOR OF REINFORCED SILTY SANDS USING IMPROVED TRANSFER FUNCTION METHODS

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ABSTRACT :

Little is known about the dynamic behavior of reinforced soils under random excitation conditions. Yet this situation exists when geosynthetically reinforced soils are constructed to strengthen soil conditions during earthquakes. In this study, the effect of frequency content of random torsional excitation on the dynamic soil properties of geosynthetically reinforced silty sands are investigated in the laboratory using a torsional resonant column apparatus. An experimental program was undertaken where both random and sinusoidal torsional vibrations were applied. Improved estimators of the transfer function (H2, H3, H4), in addition to the conventional estimator (H1), were used to estimate the dynamic soil properties and to study the effect of frequency content on the shear moduli and damping of silty sands. Cut-off frequencies in the range of 50 Hz to 10000 Hz were considered using a band pass filter. The silt content ranged from 0 to 40 percent. In this project, geotextile layers consisting of nonwoven, staple, needle punched polypropylene with high tensile strength and puncture resistance were used to reinforce the soil. The results indicate that no correction to the shear moduli of silty sands obtained during random loading using the conventional transfer function estimator is needed. On the other hand, the damping values, particularly at high frequency contents, may have to be corrected to obtain values that are more representative of actual field conditions during earthquakes.

KEYWORDS: Frequency content, soil dynamics, shear moduli, damping, geotextiles

1. INTRODUCTION

During the field dynamic testing, the in-situ impulse test is based on the generation and recording of the propagation of shear waves through a mass of soil between two or more boreholes. The signal-generating system transmits suitable signals to the soils. However, the impact energy transmitted to the soil does not have the same frequency content in comparison with earthquake loadings. To simulate the impulse type loading used in the field and to assure the extrapolation techniques are correct, the effect of frequency content on the dynamic soil properties needs to be determined.

On the other hand, in soil dynamics problems, it is important to obtain data in the vicinity of the resonance. In this vicinity, the improved estimators of the transfer function (H2, H3, and H4) provide more valuable information than the conventional estimator of the transfer function (H1) for the purpose of estimating the dynamic soil properties, namely, shear modulus and damping values [1-3]. Although some studies on the use of improved estimators have been reported [4-13], the effect of frequency content has not been fully investigated. A prior study using the conventional estimator of the transfer function has indicated that the frequency content of a random vibration had a measurable effect on the moduli and damping values of cohesive soils [14]. In addition, little is known about the dynamic behavior of reinforced soils under random excitation conditions. The objective of this research is to investigate the effect of frequency content on shear moduli and damping of silty sands reinforced by geosynthetics under random excitation conditions and using improved transfer function estimators.

2. EXPERIMENTAL PROCEDURE AND ANALYSIS

In this project, silty sands with varying fines contents were obtained by mixing appropriate amounts of Ottawa 20-30 sands with silt. The silt had a liquid limit and plasticity index of 38, an 8, respectively. The silt content ranged from 0 to 40 percent. In this research, geotextile layers consisting of nonwoven, staple, needle punched polypropylene with high tensile strength and puncture resistance were placed at 25 mm (1 inch) intervals to reinforce the soil. Maximum and minimum void ratios and densities for each soil type, containing various amounts of fines, were determined by ASTM-4254-91 and ASTM-4253-93, respectively. Maximum void ratios were obtained by using a cylinder of 508 mm (20 in) high, and 76 mm (3 in) in diameter. The cylinder was filled about ½ full, capped, then upset and uprighted carefully several times to achieve a very loose state. Minimum void ratios were determined by vibrating dry specimens in a cylindrical mold of 127 mm (5 in) high, and 152 mm (6 in) in diameter. The confining pressure for this test series was 50 KPa. The target relative density was 50%.

In this study, a modified Drnevich type resonant column device was used to provide random excitation conditions using a random white noise generator. The cut-off frequencies ranged from 50 Hz to 10000 Hz using a band pass filter. During the test, both input random excitation and output random response were sent to a Fast Fourier Transform (FFT) analyzer. The conventional estimator (H1) was obtained using an FFT analyzer. A microcomputer was used for the purpose of obtaining improved estimators (H2, H3, and H4) of the transfer function. A frequency resolution of 0.5 Hz and a number of averages of 250 were used for sampling signals. The damping and shear moduli were calculated at various root mean squares (rms) strains. For the continuous random signals, the Hanning function, which is a cosine-squared function, was utilized in this study. Details of experimental procedures are presented in Amini et al [5] and Aggour et al [6,14].

3. RESULTS AND CONCLUSIONS

The primary objective of this study was to compare the shear moduli and damping of geosynthetically reinforced silty sandy soils at various frequency contents under random vibration, evaluated by the conventional estimator of the transfer function with those properties evaluated by the improved estimators. Table 1 shows an example of the results for shear moduli.

As shown in this Table, the frequency content of the random signal does not measurably influence the shear moduli. In addition, the variation in the method of transfer function measurement does not significantly affect the relationship between the shear moduli obtained by the various estimators and at different cut-off frequencies. This may be explained by the fact that the shear modulus of the soil is a function of natural frequency, and natural frequencies are similar using any of the estimators of the transfer function. The results of this study also imply that no correction to the shear moduli of silty sands obtained during random loading using the conventional transfer function estimator is needed. Within the range of variables considered in this study, shear moduli from routine soil dynamics testing can be directly applied to the field conditions.

Table 1. Shear moduli at various cut off frequencies and transfer function estimators (confining pressure = 50 KPa; rms strain = 0.01%; silt content = 30%)

Cut-off Frequency (Hz)	Shear Moduli (MPa) Using H1	Shear Moduli (MPa) Using H2 or H4	Shear Moduli (MPa) Using H3
50	68.1	68.1	68.2
100	68.8	68.6	68.5
500	68.4	68.4	68.6
1000	68.5	68.7	68.7
10000	68.7	68.6	68.7

Table 2. Damping values at various cut off frequencies and transfer function estimators (rms strain = 0.01%; confining pressure = 50 KPa)

Cut off Frequency (Hz)	Damping (%) Using H1	Damping (%) Using H2 or H4	Damping (%) Using H3	Ratio of Damping (H1)/Damping (H2)
50	4.4	4.3	4.3	1.02
100	4.4	4.2	4.3	1.05
500	4.0	3.7	3.8	1.08
1000	3.7	3.3	3.5	1.12
10000	3.5	2.9	3.1	1.21

An example of the results for damping values is shown in Table 2. As the cut-off frequency increased, the values of the damping decreased. As shown in the above table, the variation in the method of transfer function measurement influences the relationship between the damping values obtained by the various estimators. This may be explained by the fact that the at higher cut-off frequencies, the effect of input noise is more pronounced and therefore the various estimators of the transfer function behaved somewhat differently. This is demonstrated in the above table by noting that the ratio of damping obtained from H1 to the ones obtained at H2 (or H1/H2) increases with frequency content. In this case, H1 underestimates the true transfer function, and thus its damping values are highest. H2 and H4 (which are practically same) provide values lower than H1. H3 gives a transfer function (and hence damping values), which lies between H1 and H2. The results imply that the damping values, particularly at high frequency contents, may have to be corrected to obtain values that are more representative of actual field conditions during earthquakes.

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