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EFFECT OF FREQUENCY CONTENT ON DYNAMIC SOIL BEHAVIOR OF SILTY SOILS USING IMPROVED TRANSFER FUNCTION METHODS

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SUMMARY

To simulate the impulse type loading used in the field, and to ensure that the various extrapolation techniques of different field data are correct, the effect of variation in the frequency content of random loading on the dynamic soil properties of silty soils, namely, damping and shear moduli, was studied. The main objective of this study was to compare the shear moduli and damping values of silty soils at various frequency contents under random vibration conditions, evaluated by the conventional estimator of the transfer function with those properties evaluated by the improved estimators. To accomplish this objective, random torsional vibrations at various cut off frequencies were applied to silty specimens in a resonant column device. Confining pressures in the range of 40 KPa to 220 KPa were considered. The liquid limit and plastic limit were approximately 49% and 26%, respectively.

In this study, improved estimators of the transfer function (H2, H3, H4), in addition to the conventional estimator (H1), were used to evaluate the dynamic soil properties and to study the effect of frequency content on shear moduli and damping of soils. The frequency contents ranged from 50 to 10,0000 Hz. The findings of this study indicated that as the cut-off frequency increased, the damping values decreased. The variation in the method of transfer function measurement influences the relationship between the damping values obtained by the various estimators. The results also 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. On the other hand, the frequency content did not significantly influence the shear moduli using any of the transfer function estimators. This is explained by the fact the shear modulus is a function of natural frequency, and natural frequencies are similar using any of the transfer function estimators. The results also indicate that shear moduli from routine soil dynamics testing can be directly applied to the field conditions.

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INTRODUCTION

Seismic waves are usually generated in the field by either an impact force or by detonation of small charges. Such signal generating systems transmit appropriate impulse energies to the soil; however, the energy sent to the soil does not have the same frequency content in comparison to laboratory or earthquake loading. To simulate the impluse type loading used in the field and to assure that the extrapolation techniques of the different field data are correct, the effect of frequency content on the dynamic soil behavior will have to be investigated.

It has been shown in recent years that the improved estimators of the transfer function (H2, H3, and H4) [1-3] are particularly significant in soil dynamics problems where pertinent modal data parameters are needed near the resonance [4-14]. The two primary dynamic soil parameters for site response analysis are the damping and shear moduli. The objective of this study was to investigate the effect of frequency content on damping and shear moduli of silty soils under random excitation conditions and using improved transfer function estimators.

EXPERIMENTAL PROCEDURES AND ANALYSIS

In this research, clayey silty soils were obtained from a local construction site. The liquid limit and plastic limit were approximately 49% and 26%, respectively. The relationship between the moisture content and dry density was first determined using the modified compaction test. This was done to obtain compacted samples with high degree of saturation. The soil specimens were then obtained from the compacted specimens using a tube. The tube was first lubricated inside and outside to eliminate friction from the soil. The tube was pushed vertically into the compacted soil in the mold so that all of the obtained specimens would have the same soil structure.

To study the effect of frequency content, a modified Drnevich type resonant column device was used to provide random excitation conditions using a random white noise generator. Confining pressures in the range of 40 KPa to 220 KPa were considered. Cut-off frequencies in the range of 50 Hz to 10000 Hz were utilized 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 0.3 Hz and a number of averages of 350 were used for sampling signals. 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].

RESULTS AND CONCLUSIONS

The main objective of this study was to compare the damping and shear moduli of silty 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. The data obtained from the FFT analysis were used to obtain damping and shear moduli. An example of the results is shown in Table 1.

Table 1. Damping values at various cut off frequencies and transfer function estimators (rms strain = 0.01%; confining pressure = 100 KPa).

Cut off Frequency (Hz)	Damping (%) Using H1	Damping (%) Using H2 or H4	Damping (%) Using H3	Ratio of Damping (H1)/Damping (H2)	Shear Moduli (MPa) H1	Shear Moduli (MPa) H1 or H2	Shear Moduli (MPa) H3
50	4.8	4.6	4.7	1.04	83.1	83.2	83.5
100	4.7	4.5	4.6	1.04	83.0	83.3	83.2
500	4.3	4.0	4.1	1.05	83.1	83.2	83.4
1000	4.0	3.6	3.8	1.14	82.9	83.0	83.1
10000	3.7	3.1	3.4	1.23	83.3	83.2	83.3

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. In addition, as shown in Table 1, the frequency content did not significantly influence the shear moduli using any of the transfer function estimators. This is explained by the fact the shear modulus is a function of natural frequency, and natural frequencies are similar using any of the transfer function estimators. It can be also concluded that within the range of variables considered in this study, shear moduli from routine soil dynamics testing can be directly applied to the field conditions.

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