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Experimental Study on Vibration Transfer from Shaking Table to the Surrounding Environment

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ABSTRACT: Interaction study on shaking tables is considered necessary for such devices to guarantee their operational accuracy in vibration simulation. In such studies, accurate estimation of dynamic characteristics of the foundation of shaking tables and their neighboring soil is usually required. In this regard, experimental studies on the soil the foundation after its completion are recommended to reduce uncertainties in the operation of the table in future. In this work, a forced vibration study on the foundation of a six degrees of freedom shaking table (to be operated by the international institute of earthquake engineering and seismology) has been performed. In addition to the measured excitation data collected for determination of dynamic characteristics of the foundation, that part of the vibration that transfers to the soil (at different distances from the foundation) was also evaluated. Based on the results of such measurements, dynamic characteristics of the shaking table foundation using a single degree of freedom model are estimated. Later the magnitude and the frequency contents of the vibration that was transferred to the soil in distances up to 25 meters from the edge of the foundation (in both vertical and horizontal directions) were also determined. According to the results of this study, the level of transferred acceleration to the soil reduces, rapidly, by distance from the foundation. However, the results of these measurements indicate that acceleration magnitude in the range of high-frequency vibration remains untouched.

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1. INTRODUCTION

Accuracy in experimental studies using shaking table devices depends on a variety of different parameters. Among those, determination of dynamic characteristics the foundation for such tables is considered quite important. On the other hand, operating such large-scale vibrating systems may cause undesirable vibrational effects on the surrounding environment. To address such problems, performing a series of forced vibration tests on the foundation is usually recommended [1].

In this work, a preliminary forced vibration test on the foundation of a moderate size shaking table system (to be operated in IIEES) has been performed to find its dynamic characteristics and to understand the mechanism of vibration transfer from the system to its neighborhood [2] [3].

2. FORCE VIBRATION TEST

The Foundation of the table is in the form of a square in plan with a dimension of 15×15 and a depth of 9 meters. The total weight of the foundation is about 40000 kN. Forced vibration of the foundation has been carried out using an electro-mechanical shaker with the maximum capacity of 30 kN in the range of 0-35 Hz excitation frequency. This device was installed in the middle of the foundation in a cavity with a depth of 3 meters below the top surface of the foundation (shown in Fig. 1).

In the test, 12 one-dimensional accelerometers at 4 different locations (shown in the figure) are used to record the movement of the foundation and its surrounding area. The sensors are arranged in both vertical and horizontal directions to find dynamical aspects of the system in all directions.

Three series of forced vibration tests based on sweeping

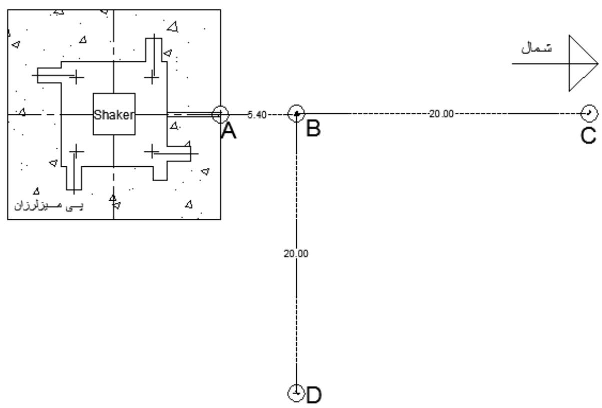

Fig. 1. Acceleration ratio at distance 25/4 meter from foundation edge.

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Table 1. Soil-foundation dynamic parameters.

Vibration	Damping ratio (%)	Stiffness (N. mm)	Natural frequency
Horizontal	10	$1/4\times10^7$	9.4
vertical	20	$2/47\times10^7$	12.1

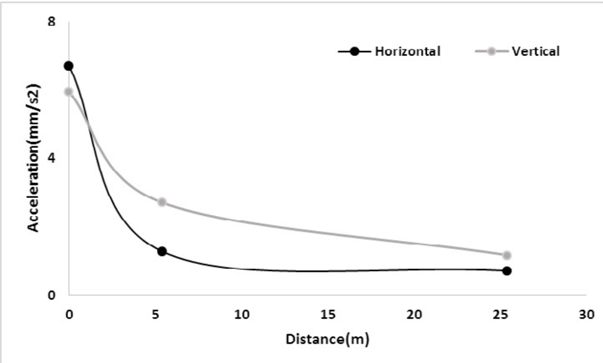

Fig. 2. Variation of acceleration amplitude according to distance

frequency technique, using vibration excitation at a very slow frequency increment rate, have been performed on the foundation. The excitation range of frequency was limited to 0-20Hz in both vertical and horizontal directions due to a mechanical problem that was discovered in the shaker during operation. The frequency increment step size was 0.2 Hz and in each step, the excitation continues for 20 seconds to ensure a stabilized steady-state forced vibration status for the foundation system.

3. DYNAMIC CHARACTERISTICS OF THE FOUNDATION

Using a single degree of freedom model for the foundation, the steady-state maximum acceleration response of the system on top of the foundation subjected to harmonic loading can be written as follows [4] [5]:

$$m\ddot{u} + c\dot{u} + ku = p_0 . \sin(\varpi t) \qquad (1)$$

In this equation ω is the natural frequency of the foundation, while ϖ and P_0 are excitation frequency and its amplitude, respectively. In above relationship c and k are stiffness and damping ratio of the foundation located on the ground. Having known the values of m, P_0, and ϖ the above equation can be solved to find approximate values for the two unknown c and k using trial and error for each frequency increment in the test result.

Later, using this technique, the dominant values for c and k for both vertical and horizontal direction have been determined to serve for the whole range of frequency excitation (tabulated in Table 1).

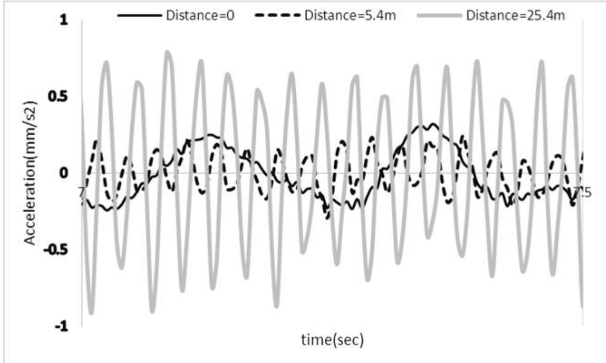

Fig. 3. Changes in the accelerated amplitude range at a steady acceleration of 4.5 Hz for different distances.

4. VIBRATION TRANSFER TO THE SURROUNDING ENVIRONMENT

The main objective of this study was to understand the mechanism of vibration transfer from the foundation to its neighborhood. Acceleration records on the ground at distances of 5.4 and 25.4 meters, far from the tip of the foundation during forced vibration tests, are used for such investigation. According to the results of this study, if the excitation frequency matches the natural frequency of the foundation, the amplitude of acceleration on the ground rapidly decreases by distance from the foundation (shown in Fig. 2).

However, the amplitude of recorded acceleration in other excitation frequencies follows a different trend in terms of distance. According to these results, in distances far from the foundation, acceleration responses are not represented by a simple trend in terms of distance. In fact, as shown in Fig. 3 acceleration responses are mostly dominated by high-frequency components at far distances due to refraction and reflection of body waves on a buried foundation at nearby installations in the area.

5. CONCLUSIONS

In this article a force vibration study on the foundation of IIEES shaking table have been performed. According to measured data dynamic parameters of foundation has been calculated and amplitude and frequency contents of transferred vibration was to its neighborhood determined. Study shows that level of transferred acceleration was reduced but its frequency contents does not have a specific pattern.

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