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AN EXPERIMENTAL SETUP FOR DYNAMIC RESPONSE OF COHESIVE SOIL SAMPLES

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GENERAL

Earthquakes have components of motion in two horizontal directions perpendicular to each other and one in the vertical direction. To simulate an earthquake accurately a shaking table or other simulator should have degrees of freedom in all the three directions. The development of such a system would involve enormous expenditure. Also, most serious effects of the earthquake motion are produced by the horizontal component of that motion and that a great deal can be learned by simplification of the problem to a study of the effects of motion in the horizontal plane. At the present state of the art of earthquake engineering research using a shake table, such simplification is also considered to be quite justified and, hence, the system used was limited to one degree of freedom in the one horizontal direction.

THE SHAKING TABLE

The shaking table (J in Figure 1) was constructed using an aluminium plate 60 cm × 60 cm × 1.27 cm thick and 10 cm × 7.5 cm aluminium rolled joists. Two steel bars 1.27 cm in diameter were welded to the underside of the plate to provide support for the table. This resulted in a light structure while producing the required strength.

SHAKING TABLE SUPPORT SYSTEM

Several methods of supporting the table like flexure plate support, suspended support and air cushion support were considered. Linear motion bearings which limit the table movement to linear motion in one horizontal direction appeared to be the simplest and most suitable method of fulfilling the support requirements for the present study. These bearings could be in the form of sleeves with bronze or nylon bearing surfaces which slide on cylindrical bars. Alternatively, the bearings could consist of ball or roller assemblies. Commercially available roller bearings were easier to align than other linear motion bearings and were used.

METHODS OF INDUCING MOTION IN A SHAKING TABLE

Several methods of inducing motion in the shaking table were also considered. Methods using eccentric rotating mass, electromagnetic vibrator, closed loop electro-hydraulic system and pendulum-spring system were all considered. In pendulum-spring system, the horizontal motion initiated in the table can be taken as representative of shock effects of an earthquake. Also an earthquake often has aftershocks of decreasing magnitude and it is possible to provide aftershocks with this arrangement. Such a system was considered suitable to the present experimental work and was, therefore, adopted.

The simulated earthquake was excited by the impact of 63.5 Kg. pendulum (F in Figure 1) against a steel plate at one end of the shaking table. The pendulum was hung from the ceiling by a hollow steel thin tube. Subsequent motion of the table was

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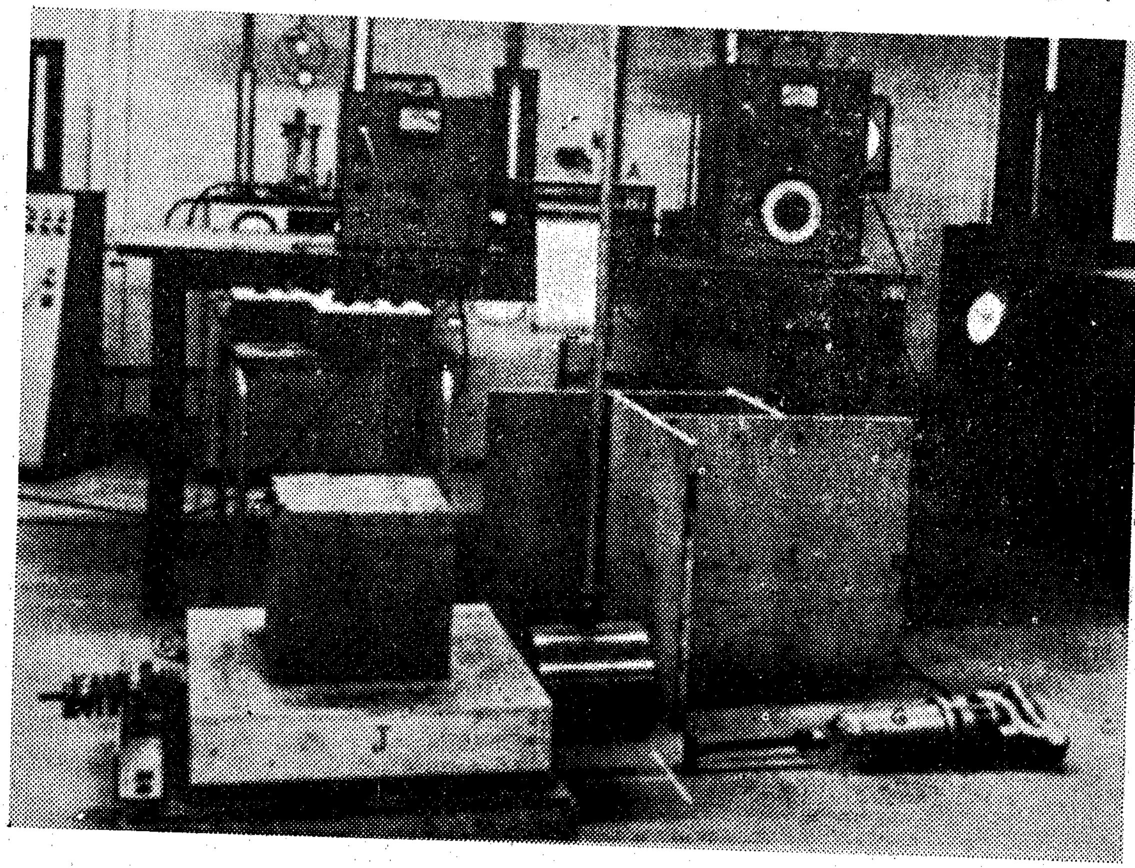
controlled by helical springs at the other end. A record of the acceleration of the shaking table is shown in Figure 2.



A. Oscillograph, B. Vibration Pickup Preamplifier, C. Accelerometer, D. Microphone Amplifier, E. Wooden Mould, F. Pendulum, G. Kango Hammer, H. Soil Sample, J. Shaking Table.
Fig. 1. Particulars of Equipment used

INSTRUMENTATION

The instruments used in the study to measure the simulated earthquake motion and also to determine the response of the soil to this motion consisted of electronic recording devices. The simulated earthquake motion of the table was determined by piezoelectric compression type transducer. The response of the soil in terms of acceleration, velocity and displacement was recorded by means of the same type of transducer. One transducer was located on one side of the shaking table and the other was fixed to the top of the soil sample, Figure 1. The output from these transducers was recorded simultaneously on a direct recording oscillograph.

The equipment employed besides the oscillograph consisted of vibration pick-up amplifiers, accelerometers and microphone amplifiers. The circuit setup of the equipment is shown in Figure 3.

TYPES OF SAMPLE

It is noted from the investigations of earthquakes and studies of earthquake damages that major damage occurs on soft soils, Steinbrugge and Moran (1957),

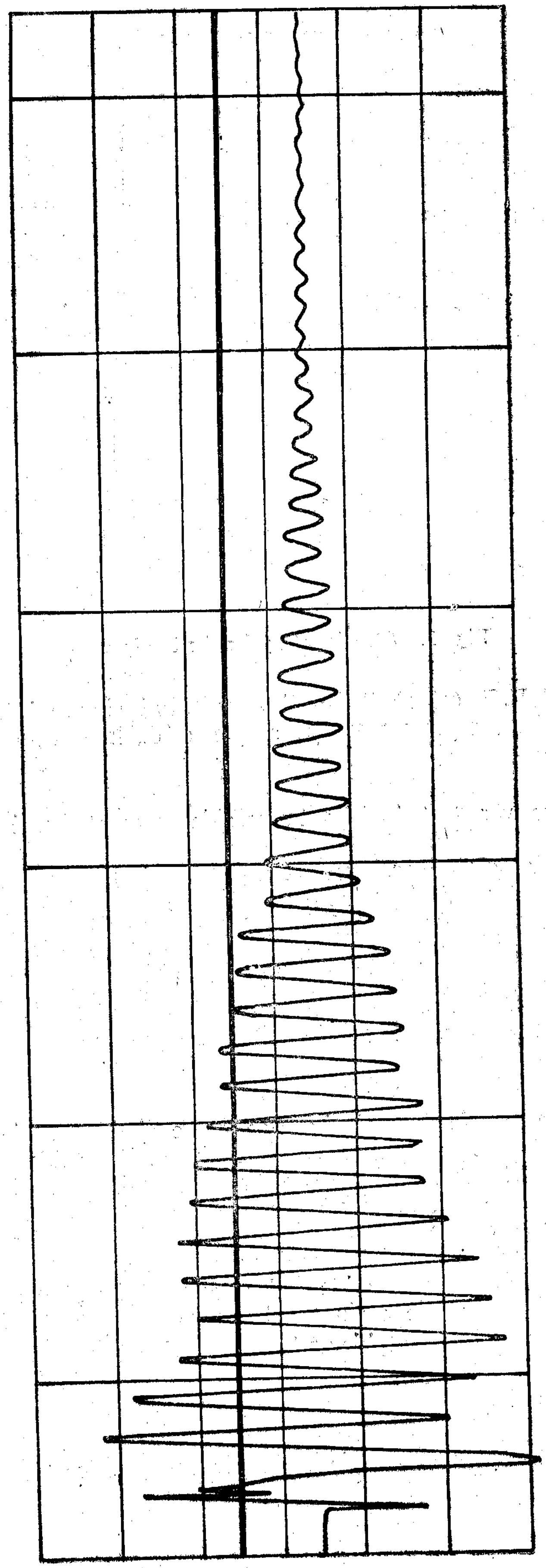


Fig. 2 Tracing of Acceleration Record of the Shaking table

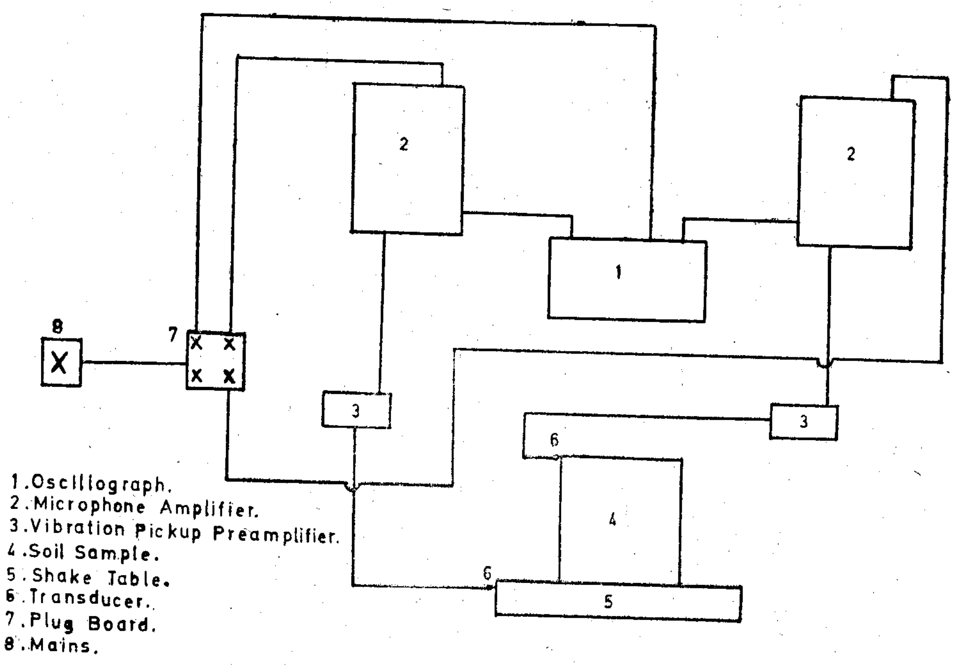


Fig. 3. Circuit set-up for the Equipment.

Berg (1964) and I.I.S.E.E. (1965). Soft soils may include silts and clays or a combination of these with sand. For the present study, samples of dark brown clay and sandy clay were used.

The soil samples were tested without any side supports and were fixed to the shaking table at the base. This method was adopted because if the samples were enclosed in a box or other type of container, there is a possibility of reverberations of vibrations affecting the soil samples. Although this could be prevented to a large extent by providing some type of packing such as foam rubber or sponge, there is still a possibility of damping due to the packing material. Also, in most theoretical analyses to date on the seismic response of soil formations, the soil formation is considered fixed only at the base, Penzien et al (1964). Idriss and Seed (1968). To simulate this in the experimental work, it was decided to test the soil samples without any side supports and fixed at the base.

The fixing of the sample through the base to the shaking table was important so that the sample could vibrate and not jump and rock on the table. For this different methods were tried. Steel plates with deep grooves and steel plates with projecting spikes bolted to the table did not serve the purpose and it was found that the sample sheared off at the level of the grooves or spikes. These were also discarded as it was thought that the grooves or spikes might provide some extra strength at the base of the sample. Different commercially available adhesives (like Araldite and Vinyl) were also tried. Finally a locally available resin Unibond was found to fix the sample in a reasonably rigid way to the shaking table and was used.

SIZE OF THE SAMPLE

The choice of the size of sample in the present case depended on the following factors:

1. Feasibility of fixing to the shaking table without wobbling.
2. Ability of the sample to withstand the applied acceleration without breaking up.
3. Feasibility of transmitting the applied vibrations to the top.

In view of the above facts, samples of different sizes were tried. The sample 60 cm × 60 cm × 60 cm was found too heavy for the shaking table. The sample of size 15 cm × 15 cm × 15 cm was considered too small for satisfactory evaluation of the response. The sample 15 cm × 15 cm × 60 cm and 15 cm × 15 cm × 30 cm did not stand on the shaking table because of the small base area even after the application of adhesive (Unibond) to the base. The sample of size 30 cm × 30 cm × 30 cm was finally found reasonably satisfactory in meeting the above requirements and was adopted.

Table I shows the type of soil used with index properties and the number of samples tested. Grain size distribution curves for the two soils are shown on Figure 4.

TABLE I: TYPE OF SAMPLE USED FOR THE STUDY

Sample Number	Description of Soil	Density gm/cc	Moisture content %	Height cm	Liquid Limit%	Plasticity Index
1.	Dark brown clay	1.92	15	30	57.3	32.9
2.	Dark brown clay	2.08	15	30	57.3	32.9
3.	Dark brown clay	1.60	15	7.5	57.3	32.9
	Dark brown clay	1.92	15	12.5	57.3	32.9
	Dark brown clay	1.76	15	10	57.3	32.9
4.	Dark brown clay	1.76	15	10	57.3	32.9
	Dark brown clay	1.92	15	12.5	57.3	32.9
	Sandy clay	2.08	10	7.5	38.6	21.9

PREPARATION OF SOIL SAMPLE

A mould of hard board 60 cm × 60 cm × 60 cm and 1.25 cm thick was made with the arrangement to change the inside dimensions so that samples of any size could be prepared. A thin film of the adhesive (Unibond) was spread on the top of the shaking table. The inside walls of the wooden mould were lubricated to prevent the soil from sticking to the sides of the mould. The required quantity of dry soil and water were throughly mixed together and the soil was then compacted directly on the shaking table in 5 cm layers by a percussion type of hammer (Kango, G in Figure 1). Trial tests were first conducted on soil samples to determine the number of blows to achieve the required density. It was found that on an average 50 blows of the hammer gave a density of 1.92 gms/cc. The mould was then removed and the top of the sample levelled carefully. A thin steel plate was fixed to the top of the sample (using Unibond) for positioning the transducer. The sample was then covered with a polythene sheet and was left for about half-an-hour to allow the resin (Unibond) to set.

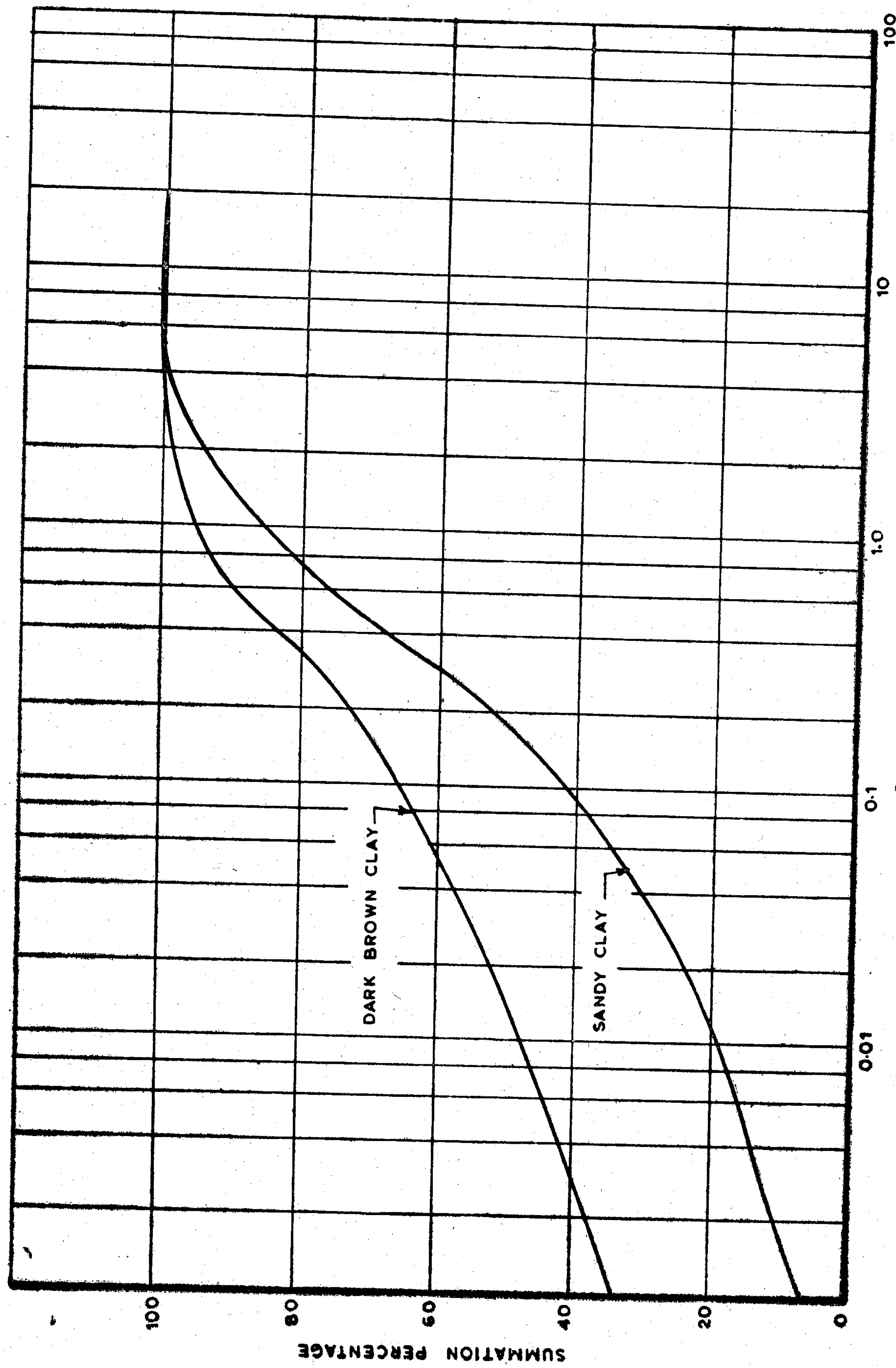


Fig. 4 Grain size Distribution curves for the Soils

MEASUREMENT OF RESPONSE OF SOIL SAMPLE

It is mentioned earlier that the response of the soil sample should be measured in terms of acceleration, velocity and displacement, these response measurements being taken relative to the movement of the table. This procedure would require six transducers for the simultaneous measurement of the response of the sample. Hence, measurement of one response could only be made on any sample at one time. The soil sample were, therefore, carefully prepared to ensure similar properties.

One transducer was fixed to the vertical side of the shaking table and the other was fixed to the thin steel plate capping the sample, Figure 1. The necessary connections were made and the measuring equipment was switched on. The integration switch of the vibration Pick-up Pre-amplifier was set to acceleration, velocity or disolacement as required.

The shaking table was given an impact blow with the pendulum. For this the pendulum was pulled back to a distance of 30 cm from the shaking table and then suddenly released. It was found that for a blow with this swing, the sample did not

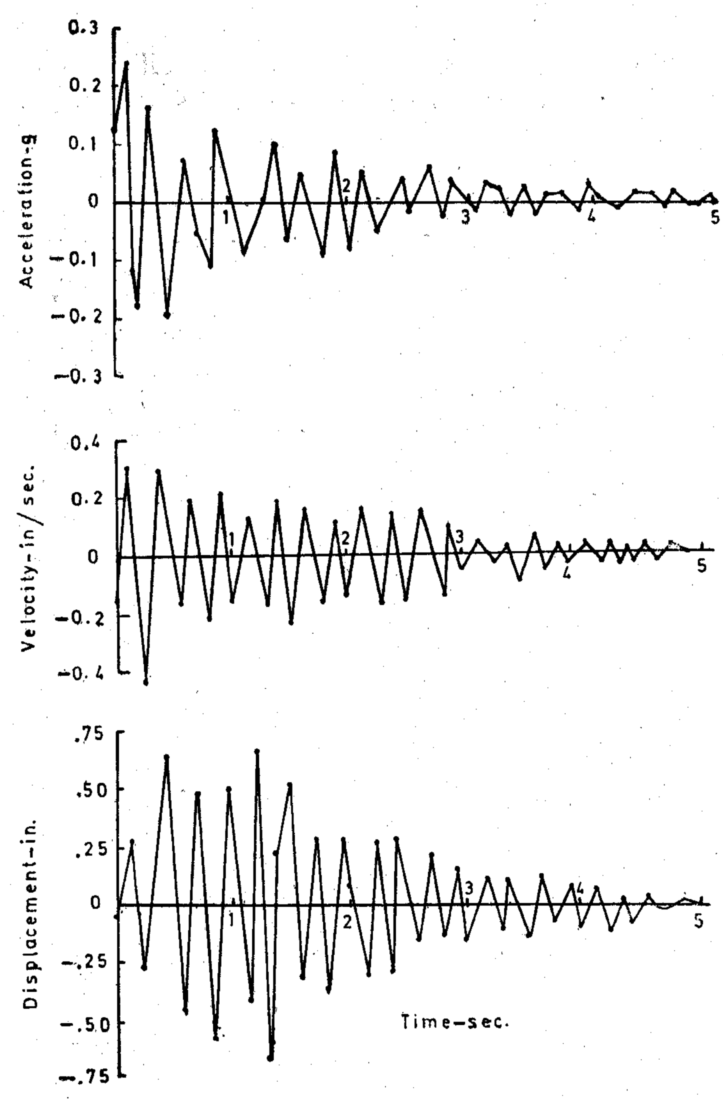


Fig. 5. Response Values of Sample 1.

shear and vibrations of desired order were produced. To prevent the pendulum from banging against the table after the initial impact, the pendulum was held away from the table for the duration of measurement. The direct recording oscillograph was set for recording with the release of the pendulum and the record of response was obtained on recording paper. For the sake of brevity, response values of sample No. 1 are only shown in Figure 5.

CONCLUSION

The method presented herein provides a simple means of experimental evaluation of dynamic response of soil samples. The shake-table pendulum method of inducing motion is also a convenient method aptly suited to laboratory simulation of earthquake motion.

The response of four samples evaluated in terms of acceleration, velocity and displacement indicate the potential influence of changes in soil condition on the ground motion characteristics. The soil property studied was the degree of compactness and was found to have a marked effect on the response values.

The study also involved effect of soil layers on the response and it has been observed that layers of different soil or layers of same soil with different degrees of compactness also effect the response especially the displacement response.

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