Bulletin of the Indian Society of Earthquake Technology. Vol. 6, No. 1, pp 39-44 March, 1969

INSTRUMENTS TO RECORD EARTHQUAKES AND THEIR APPLICATION IN STUDY OF STRUCTURES

Brijesh Chandra* and P.N. Agrawal*

Abstract

Ground motion data obtained from strong motion earthquake recording instruments makes possible more efficient design of engineering structures in seismic areas. The strong motion instruments available in the country have been briefly described. Their usefulness in the study of structural response has been explained. The need for extending strong motion earthquake recording programme in the country has thus been emphasised.

Introduction

Earthquake resistant design of structures stands as a big problem for several countries frequently visited by earthquakes. For an efficient design, one has to correctly estimate forces that are caused on a structure during an earthquake. Before earthquake recording instruments came in use, the earthquake occurrence could only be described in qualitative terms, basing observations on the extent of damage caused. These observations could only give a rough idea regarding the forces that might have been caused on engineering structures. It was around the middle of nineteenth century that Robert Mallet first recognized the need for having instruments for earthquake recording. Palmieri of Italy was first to develop an instrument for detecting feeble earthquake vibrations around the same time. It was only towards the close of nineteenth century John Miline of Japan developed the first effective earthquake recording instrument. Thereafter the developments in instrumental seismology have been rater rapid. The earthquake recording instruments maintained in seismological observatories yield useful scientific information regarding the earthquake and the ground properties. In general these do not give complete information during earthquake in the area where it has been of any consequence to engineering structures, because they are more sensitive and invariably go out of scale during strong ground motions. This difficulty has been overcome by the development of the strong motion instruments designed to yield ground motion records specially useful for interpretation in terms of data required for design purposes[1]. In the following paragraphs, these are briefly discussed. Their usefulness in studying structural response is also explained.

The Seismograph

A seismograph records many useful details of ground movements following an earthquake. It consists of a sensitive device called a seismometer and a recorder. Generally the recorders employed are the photographic type and yield continuous records. These records as a routine are utilized for determining the origin time, epicentre, depth of focus, magnitude and regional travel time etc. for the earthquake. If such data is available for a sufficient period, then it would help estimating the following :

(a) The magnitude of the largest shock that has occured in the area.

(b) Earthquake frequency-magnitude relationships.

* School of Research and Training in Earthquake Engineering, University of Roorkee, Roorkee, U.P., India.

(c) Predominent periods of ground vibration.
(d) Predominent period of earthquake waves.

The above data would help designers to make an estimate of the largest size of earthquake expected within the lifetime of proposed structures in the area apart from providing other useful guide lines.

However, such instruments go out of scale and get damaged during strong motion earthquakes. Therefore, in order to obtain records of strong ground motions, specialised instrumentation has to be provided.

The Accelerograph

The strong motion accelerograph differs from a conventional seismograph used for tele-seismic purposes in the following respects :

(a) Is is less sensitive so as to stay in operation during violent motions.

(b) It has to be located at sites where important structures are to be constructed. The other seismographs are generally housed in observatories in remote areas.

(c) Recording speed of an accelerograph must be much higher compared to the other seismographs. This would enable clear interpretation of records.

(d) Since only once in several years such instruments would generally yield an earthquake record, their continuous maintenance with high recording speed would be expensive and wasteful. A self starting device during an earthquake solves this problem.

(e) Since this instrument has to start suddenly for earthquake recording, use of electronic components has to be avoided.

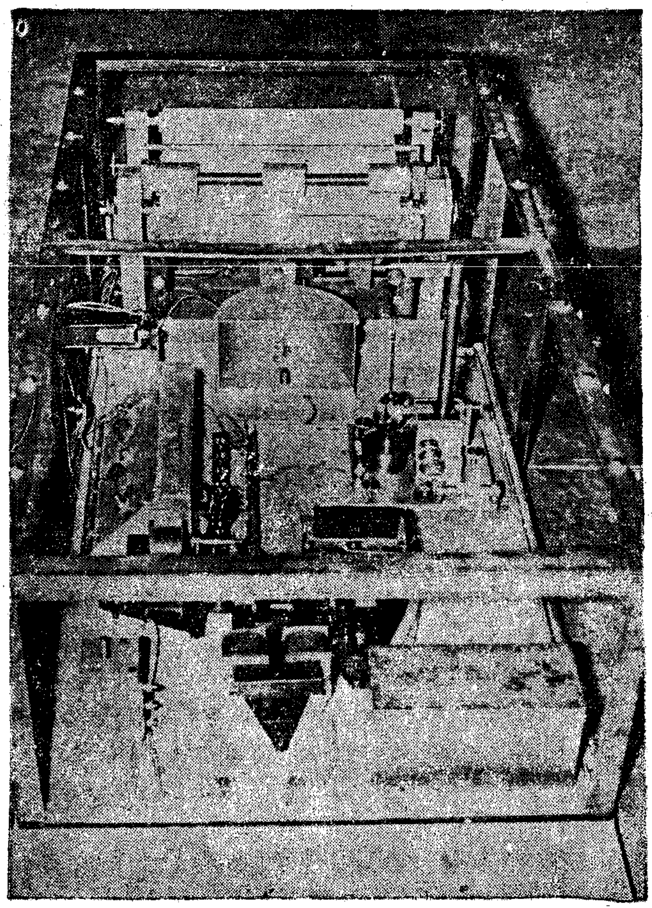

Fig. 1. Strong Motion Accelerograph

Fig. 1 shows the strong motion accelerograph made at the School of Research and Training in Earthquake Engineering, University of Roorkee, Roorkee. It contains three torsion seismometers, each having natural period of vibration as 1/20 seconds. Two of these respond to horizontal components of ground acceleration in mutually perpendicular directions and the third to the vertical component. The seismometers are critically damped by magnetic eddy currents produced

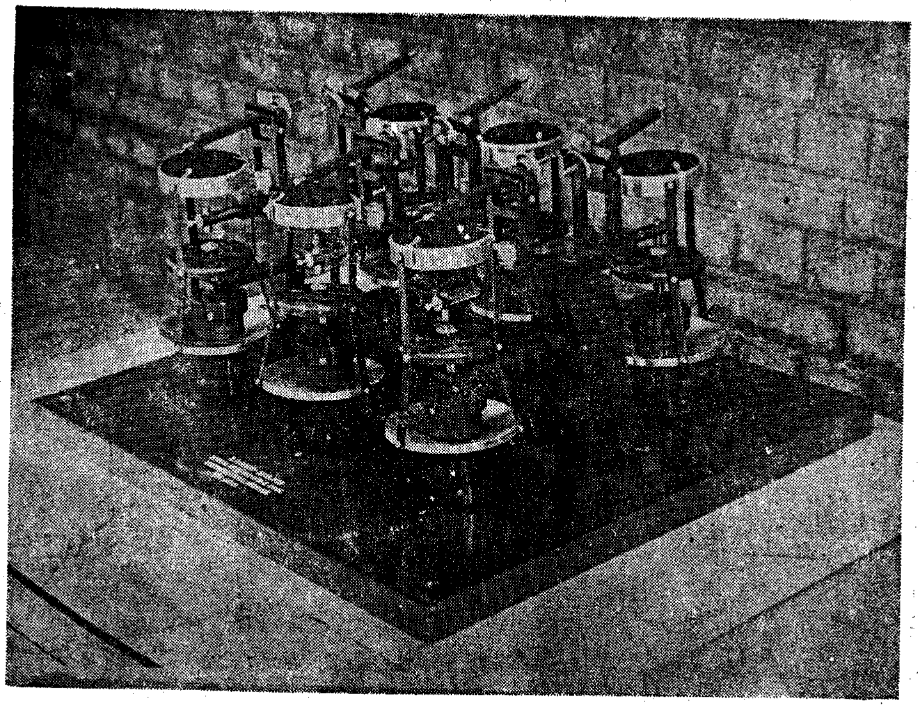

Fig. 2. Structural Response Recorder Set (MD-2)

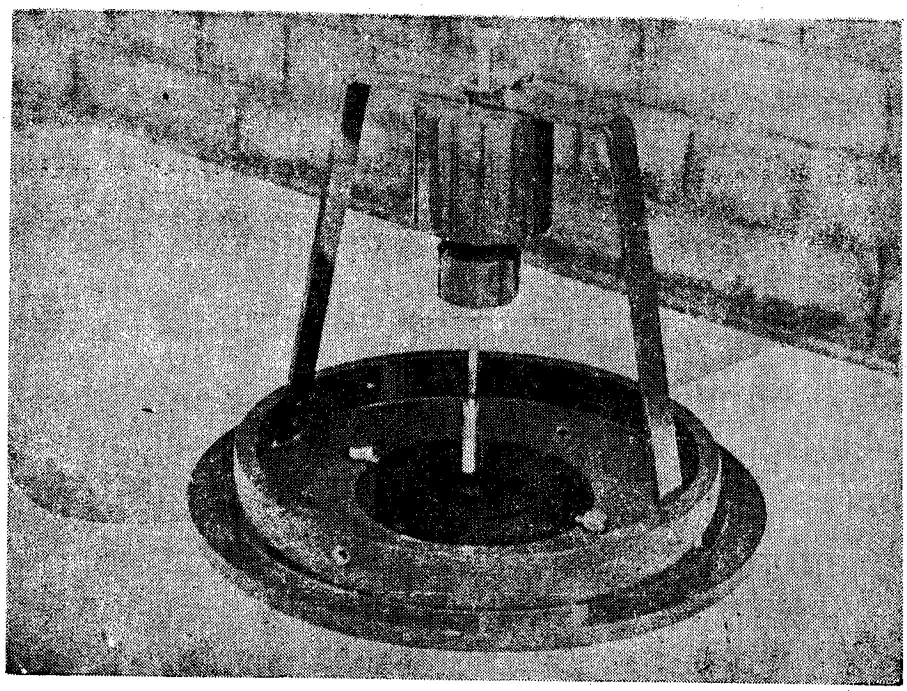

Fig. 3. Roorkee Seismoscope

in a vane attached to the pendulum. Electromagnets are employed for the purpose. A mirror is attached to each seismometer pendulum which reflects a light beam from a suitably placed light source to a recording drum through a lens, enabling the recording on a photographic paper. The recording speed is 1.5 cm/sec. The instrument gets started by a pendulum starter, when the ground acceleration has exceeded 5% of g. This instrument gives ground acceleration records (accelerogram) during strong earthquakes. Analysis of these records would yield useful information regarding the forces caused on structures during earthquakes[2]. These accelerographs are however very expensive. Also the records have to be processed through a digital computer for obtaining response of structures. This makes the channel even more expensive. Therefore, simplified instruments called structural response recorders or seismoscopes are now finding increased application in strong motion earthquake recording programmes for obtaining response of structures directly.

The Structural Response Recorder

These simplified earthquake recorders[3] measure directly the maximum dynamic response of structures having the same vibration characteristics, namely damping and natural period, as the instrument. Fig. 2 shows the Structural Response Recorder set manufactured at School of Research and Training in Earthquake Engineering, University of Roorkee, Roorkee, incorporating six pendulums representing the crucial range of response spectrum. These have already been installed at more than forty selected sites in seismic areas of the country. The interpretaion of the records[4] obtained on these instruments is relatively simple. The instrument has a self recording device for recording the shock on a smoked glass. Recently another simplified and more sensitive recorder—the 'Roorkee Seismoscope'[5] has been developed. This would yield a bigger trace on the smoked plate for smaller earthquakes. The new recorder will be more effective for recording spectral accelerations upto 30% g. This is shown in the figure 3.

Study of Structures

The acceleration records obtained through the strong motion accelerograph enable calculation of the forces experienced by structures situated close to this instrument[6]. Referring to fig. 4, the following equation governs the behaviour of the structure shown therein—

$$M\ddot{Z} + C\dot{Z} + KZ = -m\ddot{y}(t) \qquad (1)$$

where M, C and K represent the mass, damping and stiffness characteristics of the structure and Z is the relative displacement of mass (M) with respect to ground. $\ddot{y}(t)$ is the ground acceleration recorded as function of time. The solution of eqn. 1 is obtained by using standard numerical techiques. For small values of damping, the solution could be expressed as,

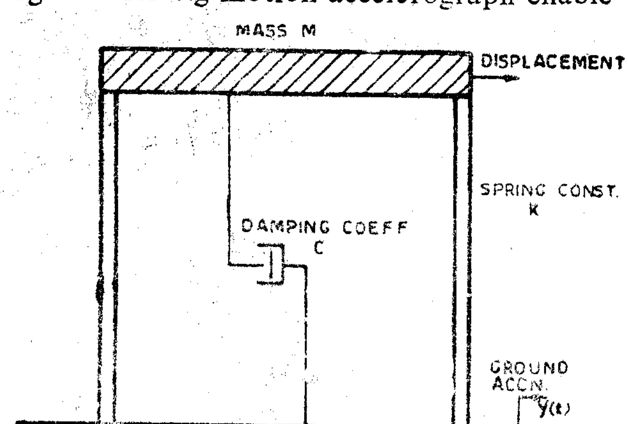

Fig. 4. The Idealised Structure

$$Z_{max} = \frac{1}{p} Sv \text{ where } p = \sqrt{K/M}, \text{ and } n \text{ is defined as } C/2M.$$

The maximum force experienced by structure is given by

$$F_{max} = K. Z_{max} \tag{2}$$

Expressing F_{max} as fraction of mg, the so called seismic coefficient α works out as

$$\alpha = \frac{K}{Mg} \cdot \frac{Sv}{p} \tag{3}$$

Calling the period of structure as T, and putting $K/M = p^2$, we have

$$\alpha = \frac{2\pi}{T} \cdot \frac{Sv}{g} \tag{4}$$

The maximum trace obtained on the smoked glass of the Structural Response Recorder is proportional to the seismic coefficient, 'α' mentioned in eqn. 4, Instruments having different periods and damping would yield response spectra[7] of a wide range of structures, during actual earthquakes. This information will be of utmost value in estimating forces on structures in the region where such instruments are installed.

Strong Motion Measurement Programme

For studying earthquake occurrences and recording scientific data for computing of structural response in seismic zones, a network of strong motion instruments to obtain ground motion records would form a basic requirement. For this, a number of seismographs, accelerographs and structural response recorders must be installed at selected location throughout the active seismic zones of the country. Whereas a set of structural response recorders is expected to yield response spectra of the earthquake at the site directly, an accelerograph must be installed to record the basic data which could be used for estimating response of any particular system with any restoring force and damping characteristics. The seismograph installed at various such stations would produce useful information regarding the characteristics of earthquake waves and the ground properties. Installation of such instruments in requisite number may appear to be a costly preposition, but the expenditure involved will be in general a very small fraction of the expected expenditure on various construction projects in those areas. Also more efficient design of structures on the basis of this data would result in an over all economy. Thus the strong motion earthquake recording programme must be intensified in the active seismic zones considering the invaluable scientific data that would be obtained for design of structures.

Conclusion

For design of engineering structures in seismic zones, the basic data regarding earthquake motion is obtained by stsong motion instruments like the accelerograph and the structural response recorders. The strong motion earthquake recording programme must, therefore, be intensified to get this basic data for future. In the absence of strong motion data at any particular site, data obtained in other location with similar ground properties could be used as guide-lines.

Acknowledgements

The paper is being published with the kind permission of the Director, School of Research and Training in Earthquake Engineering, University of Roorkee, Roorkee.

References

1. Hudson, D.E., (1963),"The Measurement of Ground Motion of Destructive Earthquakes", Bull. Seism. Soc. Am. Vol. 53.

2. Hudson, D.E. and G.W. Housner (1958), "An Analysis of Strong Motion Accelerometer data from the San Fransisco Earthquake of March 22, 1957". Bull. Seism. Soc. of America, Vol. 48.

3. Jai Krishna and A.R. Chandrasekaran (1966), "Structural Response Recorder", Proceedings of the Third World Conference on Earth. Engineering, 1965, New-Zealand, Vol. I.

4. Agrawal, P.N. (1969), "Structural Response Results During the June 27, 1966 Earthquake in Nepal India Border Region", Bull. Seism. Soc. Am. Vol. 59.

5. Agrawal, P.N. (1968), "Roorkee Seismoscope", School of Earthquake Engineering, University of Roorkee, Roorkee. (unpublished Report)

6. Hudson, D.E. (1956), "Response Spectrum Technique in Engineering Seismology", Proc. World Conference on Earthquake Engineering, Berkeley, 1956.

7. Housner, G W., R.R. Martel and J.L. Alford (1953), "Spectrum Analysis of Strong Motion Earthquakes", Bull. Seism. Soc. Am., Vol. 43.