STRUCTURAL RESPONSE RECORDERS

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SYNOPSIS

This paper describes the design and installation technique of Structural Response Recorders, which serve as dynamic models of engineering structures, to record the maximum response of such structures, to strong ground motion. The relevant characteristics of these models and their number at a station are so chosen that a number of points on the Acceleration Response Spectrum are available in its most crucial part when a more sophisticated accelerograph is not available.

INTRODUCTION

To design structures to resist strong ground motion economically, adequately and more precisely it is necessary to evaluate the response of structures during earthquakes through instruments designed to act as dynamic models of such structures. This paper discusses the design and installation technique of these instruments.

The strong motion measurement is a recent activity in India. Very few strong motion accelerographs of the U.S.C.G.S. and SMAC types have been installed so far. The seismic zone of India is about 2000 miles long and 300 miles wide and the number of instruments required to collect data effectively for such vast areas having different geological formations has to be much bigger. It is, therefore, proposed to design and construct more strong motion accelerographs at the Earthquake Engineering Laboratory, Roorkee and instal them all over the seismic zones. This programme would, however, be expensive and it would take quite some time before sufficient number of instruments are installed in the seismic zones. To collect the data for strong motion in the meantime, inexpensive dynamic models of structures could be made and installed in large numbers. A refined version of such a model was first introduced by Hudson [1] and these have now been installed in U.S.A. in large numbers. All these instruments have a period of 0.75 sec and damping 10% of critical. The authors have designed similar instruments and certain aspects of the design have been described in reference [2]. This paper gives a brief outline of the more important problems in their design and the special features of their installation. To describe them functionally, they have been named as Structural

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Response Recorders.

In order to obtain number of points on the standard Response Spectrum for an earthquake, it was decided that at one location there would be six instruments having three sets of period and two sets of damping. The periods chosen are 0.40 sec, 0.75 sec and 1.25 sec. The nominal damping are 5% and 10% of the critical. From Response Spectrum Curves, it will be seen that the six points obtained from a set of these instruments will cover the most important of its region.

DESIGN OF THE RECORDER

Fig. 1 shows a sketch of the recorders. The period of the pendulumn depends upon the type of suspension used, the magnitude of the weights and their distance from the point suspension. The amount of damping depends on the strength of magnets, distance between magnets and on the contact friction between the scriber and the glass plates.

The effect of the variation of each of the component parts on period and damping has been investigated with a view to effect maximum economy and efficiency of operation.

DISTANCE BETWEEN THE WEIGHTS

The distance between the weight at the bottom and weight at the middle is kept such that the pendulum could move freely over the entire working range and the adjustment of permanent magnets is possible to vary the damping.

The distance between the weight at the top and the weight at the middle controls the sensitivity of the recorder and this has been so adjusted that all instruments have more or less the same sensitivity. One of the instruments at each station would have the same characteristics (period, damping and sensitivity) as the U.S.C.G.S. Seismoscope to permit comparison of results under similar conditions.

Further, if the distance between the weights is same for all instruments, the sensitivity would increase with increase in period. The response spectrum curves of strong motion earthquakes indicate that acceleration response decreases with increase in period. It is therefore seen that during any one particular earthquake, the amplitude of motion that would be recorded on the smoked glass would be more or less the same in all the instruments. In other words, the overall sensitivity of all instruments is similar to each other. Fig. 2 shows a graph of overall sensitivity versus period.

MAGNITUDE OF THE WEIGHTS

The weight at the middle is necessary to hold the suspension in position. The weight being so close to the point of suspension, even a considerable change in weight has no effect on the period. This weight, therefore, has been designed to be as small as possible consistent with the requirement of ease of attachment.

The weight at the bottom gives stability to the pendulum. In addition, damping is provided by the movement of this weight in a magnetic field. This weight is to be in the form of a saucer so that the air gap may remain reasonably constant as the pendulum vibrates. Therefore, this weight is kept constant for the various instruments. The weight is forged from a metallic sheet of constant thickness. This weight cannot be cut down below a certain amount but beyond this critical value relative to the top weight, small changes in weights have no effect on the characteristics of the instrument.

The weight at the top holds the smoked glass plate. It is clear that of the three weights, this has the maximum effect on the period. This is because the distance between the point of suspension and the centre of gravity gets affected the most by the variation of the weight at the top.

The top weight is so designed that it has a minimum size to hold the various attachments. Provision has been made to increase the weight if necessary, for altering the periods. The range of weights adopted are :

Top - 55 gms for 0.40 sec, 60 gms for 0.75 sec and 90 gms for 1.25 sec
Middle - 55 gms
Bottom - 95 gms

SUSPENSION

The suspension consists of a thin wire of a particular length. If the suspension is very thin, it could be deemed to offer no resistance to vibration. It was found that a 32 S.W.G. wire (and thinner gauge wires) offers negligible resistance to vibration. The theoretical evaluation of period, assuming no spring action by the suspension, very nearly coincided with that of experimental period for 32 S.W.G. wire.

Suspension made of thicker wires offer spring action. Consequently, the period of vibration of the pendulum decreases with increase in thickness of suspension wire.

The length of the wire has some influence on the period of the instrument but for convenience a standard minimum length (7 mm) has been adopted to allow free movement. 22 S.W.G., 26 S.W.G. and 30 S.W.G. wires have been respectively used for instruments having periods of 0.40 sec., 0.75 sec. and 1.25 sec..

STYLUS

Due to the contact between stylus and the glass plate, dry friction develops. The amount of this friction depends upon the stylus pressure. This friction is non-linear and therefore it is better to keep this stylus pressure as low as possible.

The stylus assembly can be balanced on its knife edges by adjusting the knurled nut with the spring disconnected so that vertical inertia forces do not disturb the stylus force. A nominal stylus force is necessary to ensure proper contact at all times between the stylus and the glass. A force of 1 gram has been chosen as the stylus force. This gives rise to a damping of about 3%, and the distance between the magnets is, therefore, so adjusted that the overall damping due to both sources is the desired value.

MAGNETS

The permanent magnets are of Alnico. The intensity of the magnetic force could be varied by charging the magnets to different degrees. There is a provision for varying the distance between the magnets.

When the bottom disc moves in the magnetic field, it gives rise to eddy current damping which is viscous in nature. The amount of damping depends on the air gap and intensity of magnetism. Both of them could be varied. Damping decreases parabolically with increase in air gap.

Fig. 3 shows a plot of amplitude of motion versus damping. This shows that damping varies with amplitude which is due to non-linearity of stylus friction force.

The nominal damping of instruments relates to an amplitude of 1/2 inch on glass (which is about mid-amplitude). An amplitude damping curve is obtained for each instrument and will be used for correcting the records.

The actual damping in the instrument thus is a combination of friction and viscous damping and the idealised equation does not fully apply to represent the overall behaviour of an instrument. Since we are concerned only with the overall damping to get a point on the Structural Response Curves, this does not vitiate the purpose. Further, in an actual structure, damping is partly viscous and partly due to friction between parts of the structures. Thus it is not a poor representation of the actual conditions.

TILT SENSITIVITY

For making tilt sensitivity tests, a tilt sensitivity tester (Plate I) is used. The tester could be levelled and the base plate on which the recorder is to be mounted could be tilted through 0° to 40°. There is a dial which indicate the angle of tilt. At any position of tilt, the base plate could be rotated through 360°. Tilt records as obtained on the tester is given in Fig. 4.

LOCATION OF STRUCTURAL RESPONSE RECORDER STATIONS

Fig. 5 shows the places in which the epicenters of past earthquakes have been located. An effort has been made to site these stations as close to the epicentres as possible with one additional care that the site lies in the predominently inhabited area. Since most of the inhabited areas are founded on alluvium and since alluvium undergoes more intense vibration compared to that of rock, the stations are located on alluvial soil. This would give data of the motion that structures, sited an alluvium, would undergo whenever earthquakes occur.

REFERENCES

1. Hudson, D.E., "The Wilmot survey type Strong Motion Earthquake Recorder.", Earthquake Engineering Research Laboratory, California Institute of Technology, 1958.

2. Krishna, J. and A.R. Chandrasekaran, "Design of Structural Response Recorders", Second Symposium on Earthquake Engineering, University of Roorkee, India, November, 1962.

3. Housner, G.W., "Behaviour of Structures DuringEarthquakes," Journal of the Engineering Mechanics Division, Proc., A.S.C.E., Vol. 85, No. EM 4 October, 1959.

STRUCTURAL RESPONSE RECORDER

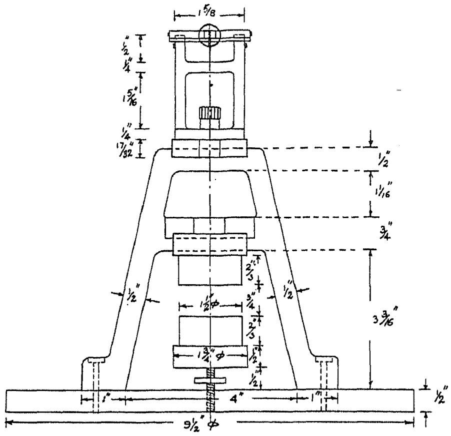


FIG.1a_ FRONT ELEVATION
(PENDULUM REMOVED)

STRUCTURAL RESPONSE RECORDER

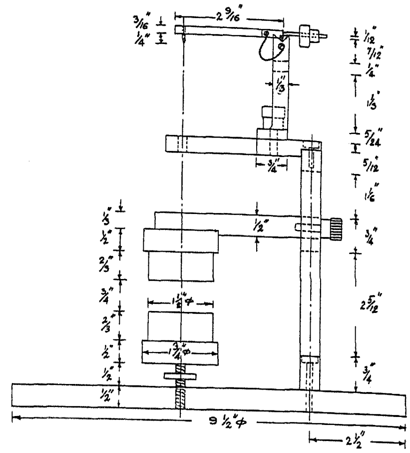


FIG.1b _ SIDE ELEVATION
(PENDULUM REMOVED)

STRUCTURAL RESPONCE RECORDER

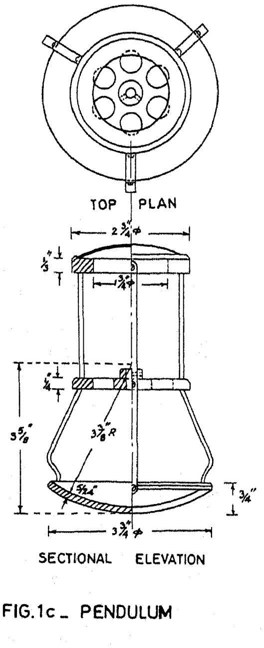
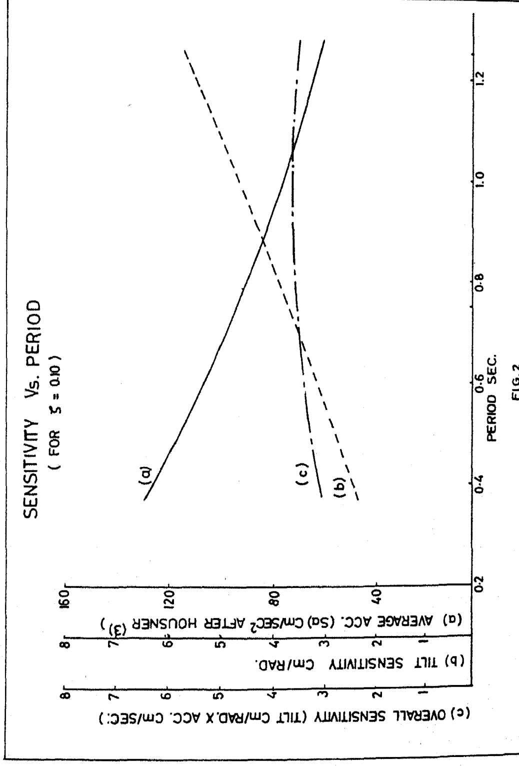
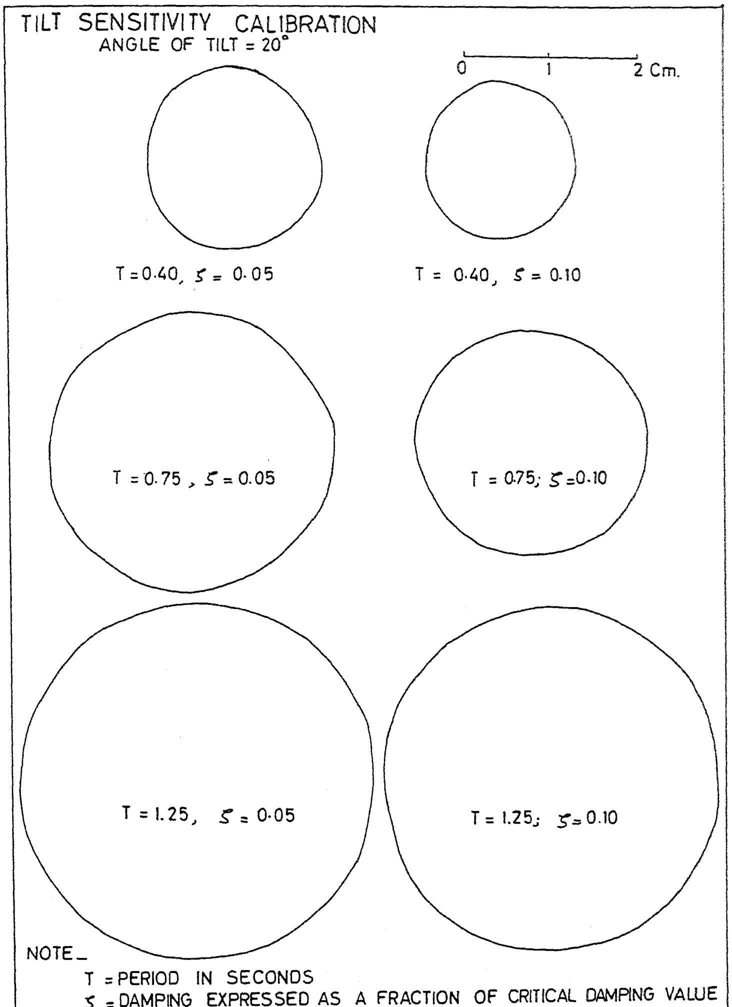


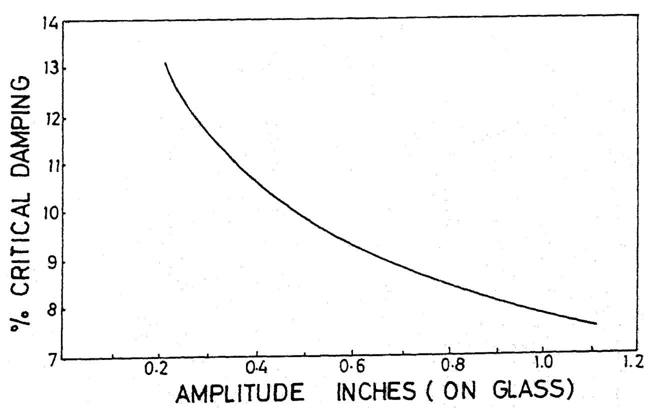
FIG.1c _ PENDULUM





TILT SENSITIVITY CALIBRATION
ANGLE OF TILT = 20°
0 1 2 Cm.
T = 0.40, ζ = 0.05
T = 0.40, ζ = 0.10
T = 0.75, ζ = 0.05
T = 0.75; ζ = 0.10
T = 1.25, ζ = 0.05
T = 1.25; ζ = 0.10
NOTE_
T = PERIOD IN SECONDS
ζ = DAMPING EXPRESSED AS A FRACTION OF CRITICAL DAMPING VALUE

FIG. 4



% CRITICAL DAMPING
14
13
12
11
10
9
8
7
0.2
0.4
0.6
0.8
1.0
1.2
AMPLITUDE INCHES (ON GLASS)

FIG. 3

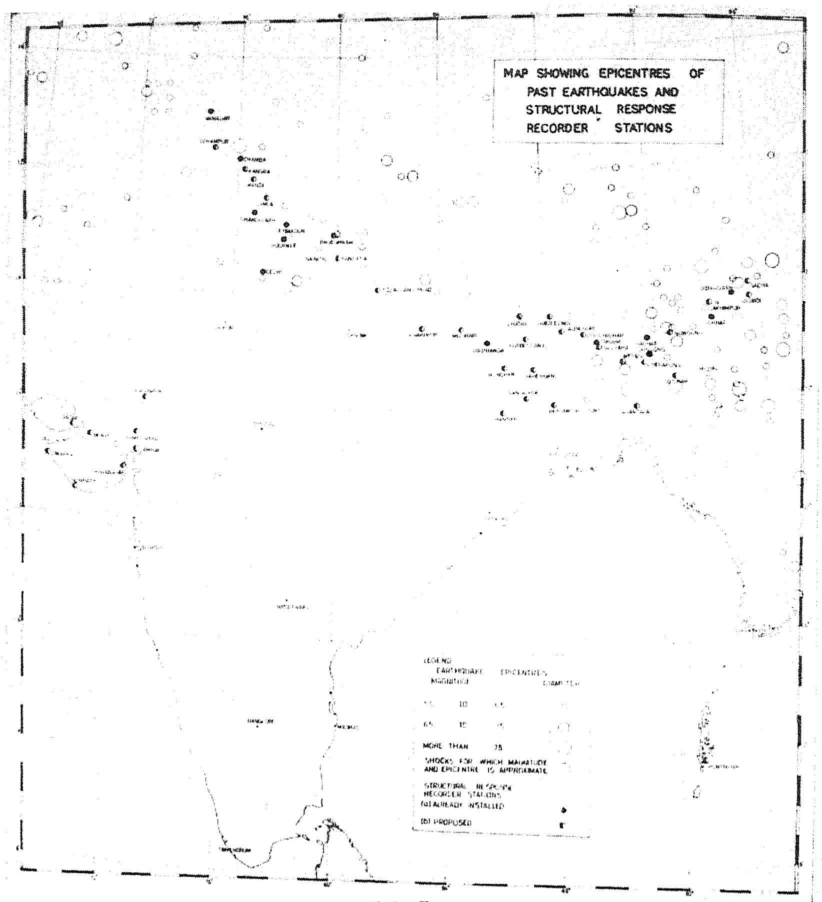

MAP SHOWING EPICENTRES OF PAST EARTHQUAKES AND STRUCTURAL RESPONSE RECORDER STATIONS
MORE THAN
SHOCKS FOR WHICH MAGNITUDE AND EPICENTRE IS APPROXIMATE
(a) ALREADY INSTALLED
(b) PROPOSED

FIG. 5