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# ROUTINE MEASUREMENTS OF DYNAMIC STRAINS IN ENGINEERING STRUCTURES DURING EARTHQUAKES

**P.N. Agrawal***


## ABSTRACT

It has been suggested that routine measurements of dynamic strains induced in important engineering structures during earthquakes need to be planned; because these would be more useful compared to ground motion measurements for solving earthquake engineering problems. The requirements for an instrument needed for this purpose have been discussed in light of the attempts made by the author.


## INTRODUCTION

An important aspect of earthquake studies has been to investigate how the structural damage due to earthquakes can be minimised, if not eliminated. Instead of this problem being studied under the science dealing with earthquakes, i.e. seismology, it has been classed separately under earthquake engineering, perhaps, because it is equally connected to structural engineering as much as to earthquakes. The instrumentation employed for the purpose has also been different from seismological instrumentation to the extent that it has to obtain records for strong motion earthquakes only. Considerations to the requirements for aseismic design of engineering structures (Hudson 1963) bring out the need for measurement of ground accelerations for the purpose. Strong motion accelerographs and, recently, simple pendulum recorders (Hudson 1958) have been in use. These ground motion records have been utilised for determining maximum ground accelerations caused by earthquakes or the response of idealised structures and the earthquake force for which provisions are to be made in the design of structures. Apart from the design of structrures taking into account the pertinent ground accelerations, there remains much to be studied for minimising most economically the structural damage as:

(a) The actual strength of the structure, to resist lateral forces, may be quite different from the design strength.

(b) The failure of a structure may be due to the relative weakness of a particular structural member.

(c) The structural damage depends upon the dynamic properties of structure, the geological conditions, nature of the ground and characteristics of earthquake movements. Influence of all these factors is reflected in the structural behaviour.

* Scientist, Regional Research Laboratory, Jorhat, Assam, INDIA.

(d) Utility of providing lintel level bands, diagonal bracings, wire mesh and plaster on both sides of plain brick wall etc. may not comensurate with what may be calculated theoretically.

Some of the problems associated with these points have been tackled by shaking actual buildings or ground by vibrators, the study of models of stuctures on shaking tables and effect of explosion generated elastic waves on actual models of structures. Such investigations are certainly of great advantage but it seems necessary to tackle these problems making use of natural earthquake vibrations and actual structures so that the findings are of direct practical utility.

Even after recognising the fundamental design requirement as the dynamic strains induced in structures (Hudson 1963) we record only ground movements and get into involved computational and analysis techniques to determine structural response. This also involves several assumptions out of which, we know, few are only remotely true. Though Structural Engineers and Seismologists are specially alert to the need for measurements of dynamic strains in engineering structures and the instrumentation for the purpose is rather well advanced, yet no thought seems to have gone through the possibility of evolving a routine observational net-work which could directly yield the aseismic design requirement and practical solutions to the problems mentioned earlier. Therefore, author feels and suggests that routine measurements of dynamic strains in critical positions of structures during earthquakes need be planned for earthquake engineering. Those earthquakes which might shake the structure appreciably although causing no or very little damage, would also yield useful data. It would then be possible to predict the performance of existing structure during future earthquakes. Thus an instrument for permanant installation and recording of dynamic strains induced in important engineering structures during earthquakes has to be developed which can suitably be called as "Structural Strain Recorder".

## PRELIMINARY CONSIDERATIONS FOR THE INSTRUMENT

(1) The dynamic strains developed in normal structures during earthquakes before their failure are of the order of $10^{-4}$. Therefore, the strain recorder necessary should have magnification of the order of $10^{4}$.

(2) Though in more active seismic areas such instrument may frequently record useful information but at places of less seismicity no records may be obtained for years. A useful instrument for this purpose should not therefore require any maintenance.

(3) Because these will have to be fixed at various points to the structures, it should be small, compact and not of awkward shape.

(4) It is to be used for routine observations for collecting useful data for earthquake engineering, a very large number of these will have to be installed. Therefore,

the device should cost very little.

(5) It will experience daily as well as annual temperature variations and therefore should have a temperature compensating device.

## DISCUSSIONS ON POSSIBLE INSTRUMENT

With foresaid points in mind it was thought that a mechanical device, which could measure the displacement caused in the vicinity of a point where strain has to be determined, would be most useful. The first instrument designed and fabricated, consisting of lever mechanism, was for measurement of maximum strain at a point around which the distribution of strain was symmetrical and gave a record on a plain smoked glass.. Length of the record on smoke glass was proportional to the maximum strain. Assumption was made that the material used in the structural member, where it would be installed was isotropic and homogeneous. Further, that no stress was present normal to the surface at which measurement would be made. For rendering the instrument temperature compensated, advantage was taken of the fact that the shear stresses for mutually perpendicular direction are numerically equal and opposite in sign. This was achieved by arraning the strain coupling rods suitably. The temperature variation could only result in an increased load on the first pivot of the mechanism leading to increased friction, i.e. decrease in magnification, which could be taken into account in the calibration curve. Another instrument was designed for measurement at a point where the strain distribution around it was not symmetrical. The first instrument was found to respond faithfully to the structural strains due to static loads.

A critical examination of these assemblies revealed that these may not be adequate for dynamic strain recording during earthquakes. Firstly, the short period characteristics of the strain variation during earthquakes may make it essential to render the instrument with similar period characteristic as otherwise due to its inertia of rest it may not respond to the strains at all. Secondly, the orientation of the insrument should not influence its record as in the actual earthquake movements, apart from the stresses being created in the structural member where the instrument is fixed, the whole base of the structure might be tilted, resulting into elongated record conveying the impression as if the strain was of higher order. Therefore, the restoring force in this mechanism should come from some force other than gravity. Thirdly, in practice even the stresses normal to the plane of measurement would be present in structural members specially due to effect of joint rotation at various junctions. Lastly, it would be certainly more useful and may even be necessary that not only maximum strain but also the details of its variation with respect to time are recorded.

The instrument for such measurement has got to be extremely sophisticated and it is felt that the facilities available to the author fall short for its further development. As stated earlier the two assemblies designed were not found satisfactory (hence details are not reported). The objective in presenting this paper is that the development for such an instrument can be taken up by those with whom such facilities may be available. It might be worth—while to mention here that utility of such records as compared to the ground motion records will probably be understood more clearly, only after sufficient data has accumulated through such routine observations. It is felt that this instrumentation would also become the most significant reason for the problem of earthquake engineering being not considered as a part of seismology and being given a status of a new subject.

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