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# KOYNA EARTHQUAKE INVESTIGATIONS*

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The area around Koynanagar, district Satara, Maharashtra State, witnessed a very severe easthquake on the early hours of December 11, 1967 and caused considerable loss of life and damage to structures. Due to lack of data, sporadic minor earthquake activity and the sheild character of the Peninsula, the region was generally considered inactive and stable, and the occurrence of this major earthquake has caused great concern and panic in the area. This report gives a summary of the investigations being carried out at the School of Research and Training in Earthquake Engineering, Roorkee.

The School was established in 1960 as a grant-in-aid unit of the Council of Scientific and Industrial Research at the University of Roorkee. One of the projects of this School is to collect data on damage and nondamage to various types of buildings during major earthquakes and behaviour of the ground and strong ground motion. These surveys pinpoint the good and weak and vulnerable features of the various structures and construction practices in the region, and help in evolving suitable modifications in the design and construction of structures to make them earthquake resistant with minimum additional expenditure. With this in view a team of scientific staff visited the site immediately after the occurrence of this earthquake to study the behaviour of various structures in the region and related problems.

The field survey conducted by the School (Chandrasekaran, Srivastava and Arya, 1968) show that the traditional construction in the area was non-seismic and had little resistance against lateral forces. In the villages the basic frame work was of timber which could offer lateral resistance and failure was mostly confined to the cladding walls. In the modern construction random-rubble masonry was used which has very poor lateral resistance and these structures suffered extensive damage. The severe damage is limited in a small area of nearly elliptical shape, about 7 miles wide and 13 miles long and the maximum observed intensity in the region was VIII+ on the MM scale (Fig. 1). Investigations are being carried out to determine the effect of the earthquake upto distances of 150 miles and evaluate the forces to which the various structures were subjected to during the earthquake. This will lead to a better and more correct assessment of the seismic coefficient for the design of structures in the region.

A study of damage and non-damage indicate that it is possible to have earthquake resistant construction with locally available materials. The great devastation done by the earthquake necessitated immediate rehabilitation and reconstruction in the area, and as a first step towards this, the school suggested an earthquake resistant design with timber or pipe supports for rebuilding the houses utilising the plinths, roof trusses and sheets of damaged buildings. Detailed recommendations for construction of small buildings (Arya, 1968) were also given for the reconstruction of the houses in the area.

Data of true ground motion (displacement, velocity, acceleration) due to the earthquake at a site is required to determine forces acting on the structure for its earthquake resistant design. Special strong motion instruments are required to record the character of these movements. There are two accelerogaphs located in the Koyna dam, and the accelerograph situated in the right abutment in Monolith 'I a' functioned at the time of the earthquake. The accelergram recorded is the strongest ever recorded from the point

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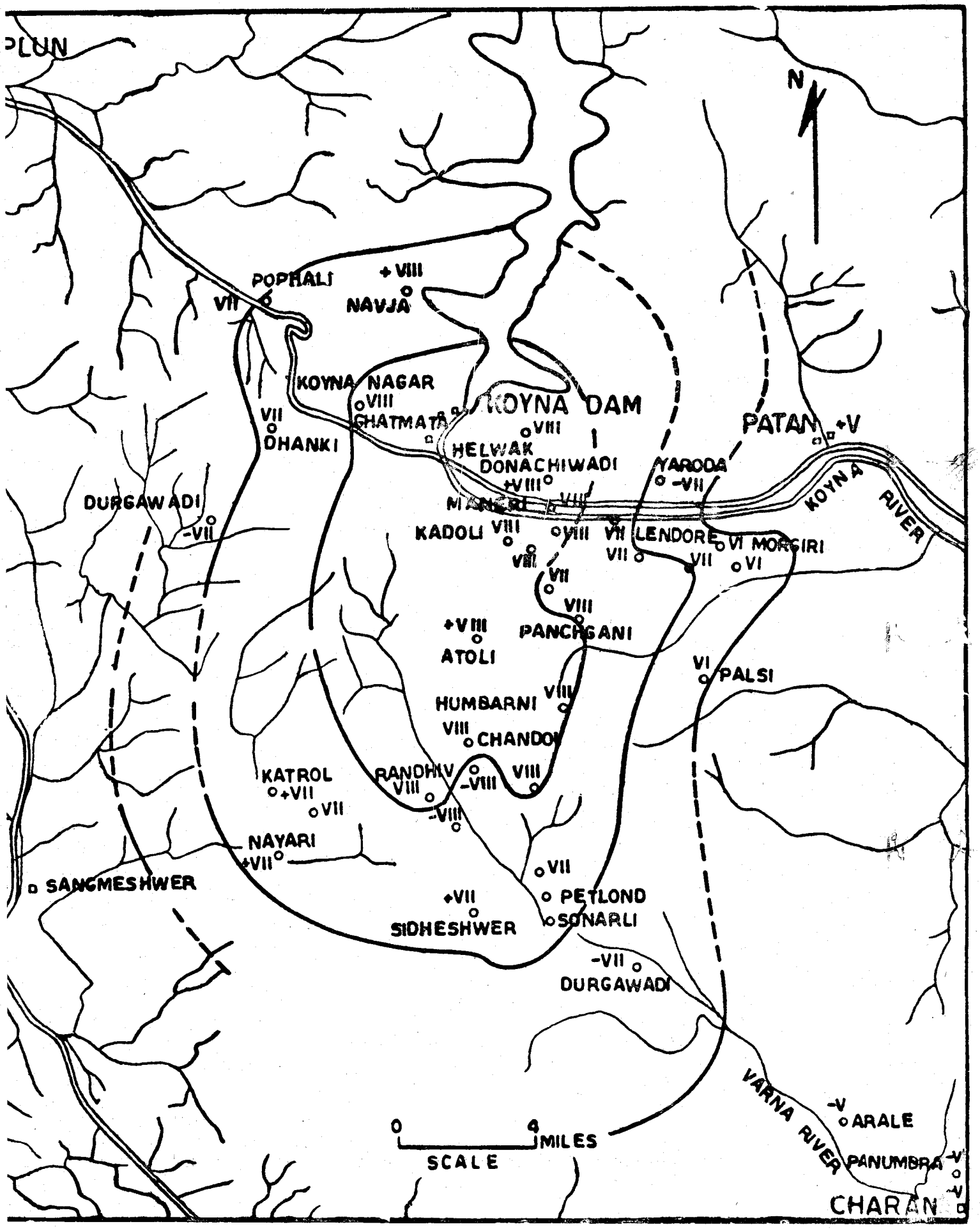


Fig. 1. Isoseismal Map of the Koyna Earthquake of December 11, 1967, (M.M. Intensity Scale).

of view of maximum base acceleration. Response spectra curves have been drawn for the various components of this accelerogram (Chandrasekaran and Saini, 1968). Fourier spectra have also been determined which give an indication of the amplitudes associated with various frequency components. Comparing spectral intensities of this earthquake with some of the earlier records it is observed that Koyna accelerogram is not the most intense, even though its peak ground acceleration was the maximum.

In addition to the two accelerograph located in the body of the dam, the School has suggested to the project authorities to instal two accelerographs in the tallest monolith of the dam, one in the foundation gallery and other at the top. This would give the ground acceleration and the response of the monolith respectively. The School has designed and manufactured accelerographs and will be supplying the accelerographs to the project authorities for installation.

Because of the relatively high cost and complexity of the accelerograph, and the necessity for obtaining more information on the effect of local geological conditions and greater instrumental coverage, a low cost simplified strong motion earthquake recorder has been developed by the School, which has been termed as Structural Response Recorder. The recorder does not measure ground motion, but rather records the maximum response of a mechanical system idealising dynamic characteristics of a structure which effect its over all behaviour. A structural response recorder simulating Koyna Dam has been installed in the region. Similar recorders simulating other structures in the region are being manufactured and will be installed shortly.

The Koyna dam and the appurtenent structures have with-stood the shock admirably well, though a little distress was noted in some parts. Theoretical investigations to determine response of various monoliths of the Koyna dam have been carrid out assuming the monolith to behave as a one-dimensional structure (Chandrasekaran, Arya and Saini, 1968). This study indicated the likely forces to which the highest monolith of the non-overflow section was subjected to during the shock, and the stresses produced at various sections of the monolith have been worked out. Model studies on a horizontal shake table were carried out to determine the dynamic behaviour of the monoliths of the Koyna dam. Models were made of plaster of paris and sand mixture. These were subjected to free vibrations, steady state sinusoidal vibrations and impulsive shock type (initial velocity) vibrations (Arya, Chandrasekaran, Mathur, Gosain, Thakkar and Khurana, 1968). Hydro dynamic pressures were also evaluated. Based on the therotical and experimental study the stresses acting on the dam monoliths due to static and dynamic loads have been evaluated and the required strengthening at various points to safe-guard the structure against furture shocks have been indicated. Further model experiments are under progress. The various monoliths are also being anlysed as two dimensional structures. Investigations are also in progress concerning strengthening measures to be adopted for future shocks.

As stated earlier the region was considered seismically inactive and stable. A study of past historical documents and records reveals occurrence of many earthquakes in the region. Geologic and seismo-tectonic studies of the Peninsula show evidences of recent movements in the region (Srivastava and Tipnis, 1968), and detailed geological and tectonic mapping of the area has been undertaken by the School. The geological and tectonic set up indicates that the region has a relatively higher level of seismicity and requires modification in the existing seismic zoning of the country. The seismic zones, as hither-to adopted in the country, has more emphasis on the seismic history of the country. The occurrence of this earthquake indicates that greater emphasis is needed on the tectonic features vulnerable to movements in the various zones. Based on these considerations revision of seismic zoning map has been proposed.

It has been observed that in the active seismic belts with gradual accumulation of strain the ground undergoes deformations. These deformations are an indication of the tectonic and seismic activity of the region. In the long range the measurment of these deformations may help in predicting future earthquake activity. The school has designed and manufactured a portable water tube tiltmeter (Agrawal, 1968) which would measure changes in ground level correct to a few microns. These water tube tiltmeters are being installed in the area, and would lead to a better assessment of the causes of the earthquakes in the region.

## References

1. Arya, A.S., (1968), "Construction of Small Buildings in Seismic Areas", Symposium on Koyna Earthquake of 11th December 1967 and Related Problems, Calcutta, June, 1968.

2. Arya, A. S., A, R. Chandrasekaran, B. C. Mathur, N. Gosain, S. K. Thakkar and K. K. Khurana, (1968), "Experimental Study of Koyna Dam Models", Earthquake Engineering Studies, SRTEE, University of Roorkee, Roorkee, Unpublished Report.

3. Agrawal, P.N., (1968), "Development of Portable Water Tube Tiltmeter", Earthquake Engineering Studies, SRTEE, University of Roorkee, Rookee, Unpublished Report.

4. Chandrasekaran, A.R., L.S. Srivastava and A.S. Arya (1968), "Behaviour of Structures in Koyna Earthquake of December 11, 1967", Indian Concrete Journal, (Under publicatcn).

5. Chandrasekaran, A.R., A.S. Arya and S.S. Saini, (1968), "Stresses in Koyna Dam due to Earthquake of December 11, 1967", Earthquake Engineering Studies, SRTEE, University of Roorkee, Roorkee, Unpublished Report.

6. Chandrasekaran, A.R. and S.S. Saini (1968), "Spectral Analysis of Koyna Earthquake of December 11, 1967", Earthquake Engineering Studies, SRTEE, University of Roorkee, Unpublished Report.

7. Srivastava, L.S. and R.S. Tipnis, (1968), "A Note on Geologic and Seismo-Tectonic Setting of Peninsular India with Special Reference to the Earthquakes in Maharashtra", Symposium on Koyna Earthquake of 11th Dec., 1967 and Related Problems, Culcutta, June 1968.