A MACROSEISMIC STUDY OF NOVEMBER 6, 1975 ROORKEE EARTHQUAKE, ROORKEE, INDIA

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SYNOPSIS

A moderate earthquake of magnitude 4.7 occured on November 6, 1975 around Roorkee, India. The earthquake was felt at Delhi, Dehradun, Bijnor and other adjoining districts in the state of Uttar Pradesh. Different degrees of damage were caused mostly to the older constructions around Roorkee (29°51'N, 77°53'E). Cracks along mortar joints and fall of plaster were commonly observed in a number of residential buildings. On the basis of macroseismic studies the epicenter was estimated to be about 6 km south of Roorkee. The maximum observed M.M. intensity was VI. The earthquake was recorded on Multiple Structural Response Recorder. The isoseismal map and the structural response results obtained have been presented.

INTRODUCTION

The area around Roorkee was shaken violently on the early morning hours of November 6, 1975. Loud rumbling noise was heard during the earthquake which lasted six to eight seconds. No casuality was reported in the area. The earthquake was felt at Delhi, Dehradun and other adjoining districts of Uttar Pradesh. No damage has been reported from these areas. Old constructions in Roorkee and its surrounding area suffered varying degrees of damage in the form of cracks along mortar joints, fall of plaster, cracks in brick arches etc. A large number of mud walls in the surrounding villages of Roorkee developed cracks. The maximum Modified Mercalli intensity reached VI around Roorkee.

The parameters of the earthquake are as follows:

Date:	November 6, 1975	Origin time:	00h 11m 30s GMT
Epicenter:	29°48.78'N, 77°51.8'E	Magnitude:	4.7

The preliminary determination of epicenter and magnitude reported by India Metereological Department were 29°48'N, 78°18'E and 4.7 respectively. The epicentral location reported here was redetermined from the seismograms of Delhi, Narendranagar and Bhakra seismological observatories. Considering the uncertainities involved in epicentral location using instrumental data, it is in very good agreement with the macroseismic data observed during the field survey.

The earthquake was well recorded by the Multiple Structural Response Recorder (MSRR) installed at the premises of the School of Research and Training in Earthquake Engineering, University of Roorkee. This is for the first time that an earthquake has been recorded on a strong motion instrument installed at Roorkee.

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GEOLOGY AND SEISMICITY

The area around Roorkee is covered by thick (3000m) cover of Recent Gangetic Alluvium (Raghava Rao, 1965). The region north of the area consists of Terai and Bhabar formations which are unconsolidated young deposits. Further to the north the Indo-Gangetic Plain is terminated by the folded Tertiary Siwalik formations, which have been affected by the Quarternary tectonic movements. The geomorphological evidences indicate the existance of two important faults near Roorkee in the unconsolidated young deposits viz; the Ganeshpur fault and another fault here named as Roorkee fault. The Roorkee fault (figure 1) runs just north of the terrace bluff of Roorkee. The apparent termination of the tilted terraces, sudden swing of regional drainage from N-S to W-E, apparent relative young age of the sediments in the zone north of the fault and the terrace bluff are evidences of the existance of this fault which strikes nearly NW-SE direction (Meijerink, 1974).

The area is about 40km south of the tectonically active Main Boundary Fault which seperates the Himalaya and the Indo-gangetic plains. The area is flanked on east and west by seismically active Moradabad fault and Delhi-Hardwar Ridge respectively. However, no moderate earthquake with epicenter close to Roorkee has occured in recent times. The reported historical earthquakes in the vicinity of the area are Mussorie earthquake of March 5, 1842 (Oldham, 1883) with its epicentre estimated to lie at a distance of 60km from Roorkee towards NE and Kangra earthquake of April 4, 1905 which had a secondary zone of high intensity near Rajpur at a distance of about 54km NE of Roorkee.

EARTHQUAKE DAMAGE

Most of the buildings which suffered damage in the area are fairly old constructions (about 60 to 130 years). These constructions are mainly single storeyed houses in mud mortar with lime plaster and have in general, high roof (5m and above). Damage to some of the buildings very close to the Roorkee fault is described below:

Administrative Building Complex, University of Roorkee: This building which housed the famous Thomson College of Engineering is about 120 years old. It is built around a quadrangle. The north block of the building has a central corridor with rooms on both sides of the corridor and a verandah in front. The height of the building is about 10.5m. The construction is in mud mortar with thick walls (50 to 75cm). The roof consists of jack arches supported in rolled steel joints. The sky light openings are provided at various points in the roof. The south block of the building is partially double storeyed. Extensive damage was confined to the roof with similar jack arch construction and upper story of this block. A crack about 1.5 to 2.0mm wide developed at the crown in the arch roof of a 28m long gallery (Fig.2) in the east-block. The crack runs for the entire length of the N-S oriented gallery. Disjoining at the corners of two walls with opening of about 2cm width was also observed in the upper story. Chipping of the plaster and diagonal cracks at the openings were observed at many places. Almost all the sky-light openings at the roof developed cracks.

Vice-Chancellor's Lodge, University of Roorkee: This is the oldest building in the area. It is a single storeyed construction with jack arch roof. Chipping and fall of plaster was observed at many places. At some openings diagonal cracks were also observed. In some of the walls, vertical cracks running from roof to floor were observed particularly at corners. In the roof of one of the rooms, the tie rods were detached from the main girders. This occurred due to rusting of the rods at ends. The girder webs when opened out by removing the masonry on either side showed varying degree of rusting along the length and even complete vanishing of web at many points, as shown in Fig. 3.

Chipping of plaster, development of minor cracks, etc., was observed in many old buildings in the area in the vicinity. Most of the barrack type constructions with dome type arch roof supported on walls suffered damage. A 47m high R.C.C. tower with rectangular plan (under construction near to top) situated about 100m from University administrative building did not suffer any damage. Moreover about 1.5km West of Roorkee terrace little or no damage was observed. Even some of the precariously hanging projections remained intact. However, further west, the damage increased and was significant in Rampur village about 6km from the bluff (Figure 4).

Damage Around Roorkee: The maximum intensity is mainly confined to NW-SE direction and decreases rapidly in directions perpendicular to it. Most of the construction in the SE side of Roorkee consist of mud houses and only a few houses are in brick and mud mortar with very poor construction. Most of the mud walls developed cracks and a few of them collapsed (Fig. 5). The damage in the brick houses in the form of fall of plaster at many places, the diagonal and vertical cracks starting from the openings were observed.

Fissures were observed in the sand flats on the bank of Solani river (Figure 6) about 8km southeast of Roorkee. The fissures are subparallel to the Roorkee fault.

STRUCTURAL RESPONSE RESULTS

The earthquake was recorded clearly on a Multiple Structural Response Recorder installed at the premisses of the Earthquake School, University of Roorkee, Roorkee. The records are shown in Figure 7. The structural response results are given in Table 1. A large drop in the peak acceleration response (Sa) values with increasing periods is observed. Such a behaviour is expected when the recordings are very close to the epicenter. Therefore the above findings confirm that the epicenter of this earthquake was very close to Roorkee. Amongst the events so far recorded by MSRR installations in India (Agrawal, 1974), this earthquake is associated with the highest response values, although the magnitude of the event is small as compared to others. On the basis of the comparison with other earthquakes recorded on MSRR, the epicentral distance is expected to be within about 5km from the instrument site. The nature of recording on MSRR may be used to infer the direction of fault plane (Agrawal, 1969). In the present case it suggests a fault strike roughly at an angle to the N-S direction.

INTENSITY AND ISOSEISMAL MAP

The Modified Mercalli intensity scale was used in preparing the isoseismal map. The earthquake was felt strongly in Roorkee and its surrounding villages. A questionnaire was sent to the Post Masters of the adjoining districts of Roorkee. No significant damage was reported. An extensive survey of the damage was made in and around Roorkee immediately after the earthquake. Figure 1 shows the isoseismal map based on these field observations. The maximum M.M. intensity of the earthquake is estimated to be VI. The general pattern of the isoseismals is NW-SE, which is parallel to the direction of the Roorkee fault mentioned earlier.

DISCUSSION

The area affected by the earthquake lies 40km south of the main seismo-tectonic belt of Himalayas. It is covered with about 3000m thick sedimentary cover and is separated from the Himalayan zone by the Main Boundary Fault (MBF). The recorded seismic activity in the past century has been mainly confined to the north of MBF with an occasional earthquake occuring in the plains. A few focal mechanism solutions derived for these earthquake have shown two main directions for fault planes. One is the NE-SW direction parallel to the old tectonic Arravalli trend which has been shown to continue towards NE under the alluvium (Tandon, 1975). The other faulting direction is parallel to the Himalayan axis and has been interpreted to signify earth movements due to the convergence of Indian and Chinese plates. (Molnar et.al., 1973). From the available evidence the Roorkee fault might be classed with the later group. This interpretation would tend to indicate that stresses that are developing owing to the plate collisions are a risk factor in areas bordering the plate boundaries. This calls for greater attention to be given to the study of these areas through relatively inexpensive recording instruments like Multiple Structural Response Recorders, Tiltmeters and Strainmeters on a continuing basis. The continued observations alone would enable evaluating future earthquake risk and taking steps to minimize consequences.

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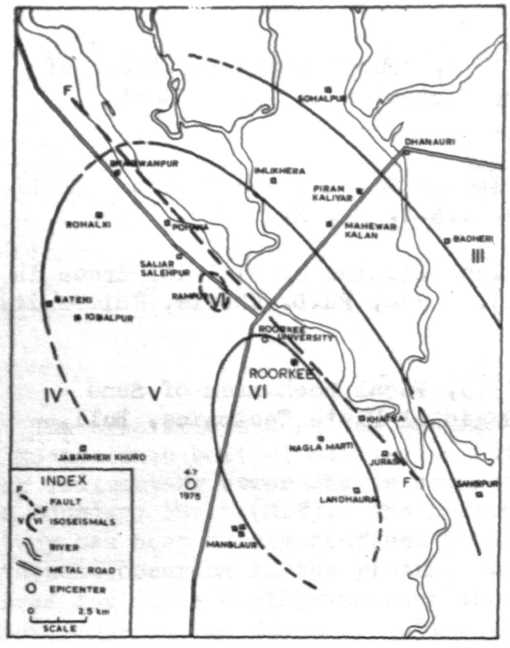

FIG. 1 _ ISOSEISMALS OF NOV. 6, 1975 ROORKEE EARTHQUAKE. ROORKEE FAULT IS ALSO SHOWN IN THE FIGURE

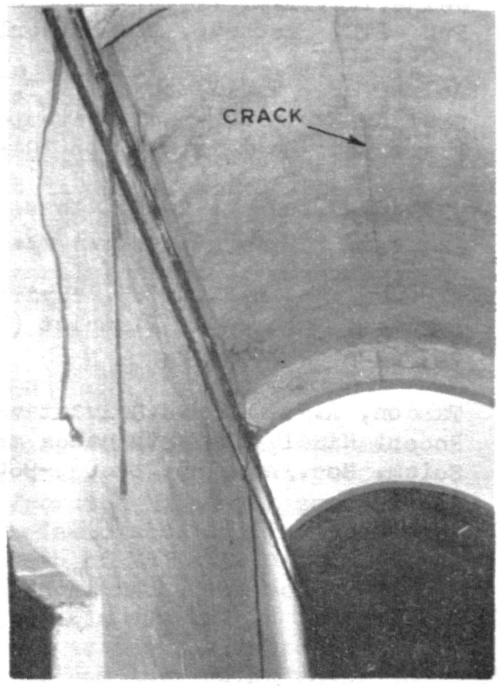

FIG. 2 _ CRACK DEVELOPED AT THE CROWN IN THE ARCH ROOF OF A 28 M LONG GALLERY

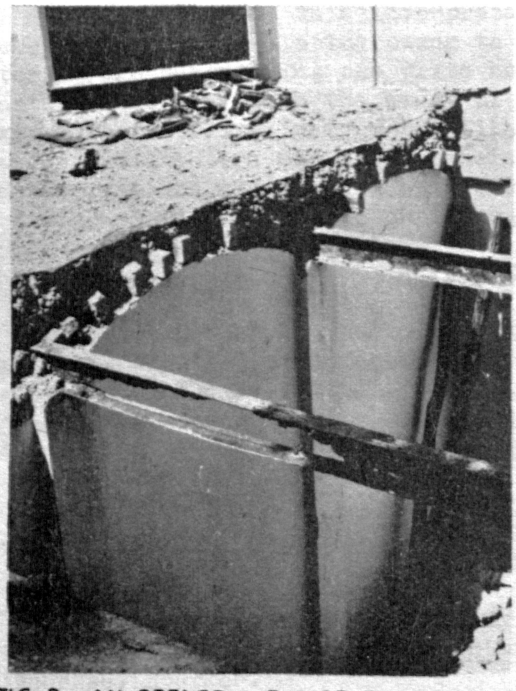

FIG. 3 _ AN OPENED VIEW OF THE GIRDERS SHOWING RUSTING AND VANISHING OF GIRDER WEBS

FIG. 4 _ DIAGONAL CRACKS AND FALL OF PLASTER IN A BRICK MASNORY HOUSE AT RAMPUR VILLAGE

FIG. 5 _ WIDE CRACKS AND PARTIAL COLLAPSE OF MUD WALL NEAR POHANA VILLAGE

FIG. 6 _ DEVELOPMENT OF FISSURES ON THE BANK OF SOLANI RIVER ABOUT 8 km S.E OF ROORKEE

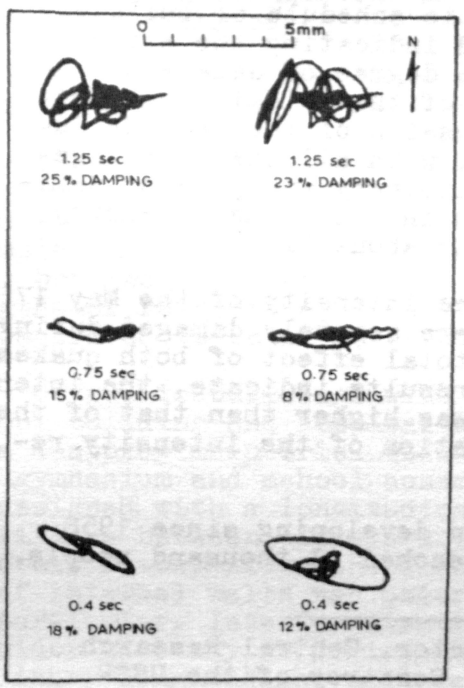

FIG. 7 _ RECORDS OF STRUCTURAL RESPONSE RECORDER INSTALLED AT THE UNIVERSITY OF ROORKEE

TABLE - I

THE STRUCTURAL RESPONSE RESULTS FROM NOV. 6,1975, ROORKEE EARTHQUAKE RECORDED AT ROORKEE UNIVERSITY

PERIOD/ TILT SENSITIVITY sec / mm/rad		ORDER OF DAMPING % OF CRITICAL	AMPL x 12 mm	ϕ_{max} rad	S_d cm	S_v cm/s	S_a cm/s^2
0.4	16	10	27	0.141	0.5601	8.802	138.321
0.4	16	18	22	0.115	0.491	7.715	112.815
0.75	40	8	26	0.054	0.7542	6.321	52.974
0.75	41	15	18	0.037	0.517	4.330	36.297
1.25	63	23	27	0.0331	1.397	7.023	25.316
1.25	69	25	25	0.0301	1.168	5.873	29.528

TABLE 1_ STRUCTURAL RESPONSE RESULTS FROM NOV 6,1975 ROORKEE EARTHQUAKE