Hunting Big Earthquakes in India

by Donald E. Hudson

For the past four years, the Earthquake Engineering Research Laboratory of Caltech's Division of Engineering has been engaged in a cooperative research program with the University of Roorkee, in Northern India, on problems of earthquake-resistant design of structures. Several staff members have visited back and forth between the two schools, and plans are now under way for an expansion of this joint venture.

Why do we have to go so far out of our way to find earthquakes? Aren't we satisfied with our own California variety? Oddly enough, it turns out that our California earthquakes are neither big enough nor frequent enough to satisfy us. In this respect, the engineer is in a rather different position from the seismologist or the geophysicist. These scientists can collect much basic data for their studies by measuring small earthquakes at far distant points with sensitive instruments. It is only in the near vicinity of large earthquakes, however, that serious structural damage can occur, and at present the means for studying these large quakes from the standpoint of earthquake-resistant structural design are very limited. The measurements obtained by seismologists, even if their instruments can be adjusted to record the relatively large ground motions associated with damaging quakes, do not give the complete data needed by the engineer. We have records from only a few large earthquakes that show how ground acceleration varies with time. This information is essential for the structural engineer, and, for the future development of this field it is important to get many more such records.

The Himalayan regions of Northern India are subject to large earthquakes, and there are many similarities between Indian earthquakes and our California variety. So, by measuring and studying large Indian earthquakes, we hope to get information that will be of engineering significance for all of the other seismic regions of the world. A network of strong-motion earthquake recorders in Northern India similar to that operated in California by the United States Coast and Geodetic Survey would multiply by several times the rate at which the basic data for earthquake-resistant design could be obtained.

Although India has a tradition of pioneer work in seismology, Indian engineers have only recently become interested in the structural damage aspect of the problem. The development of the country will require the construction of many engineering works in Northern India. Many large multi-purpose irrigation and power projects are being built now, and these projects call for the location of large dams, buildings, and oil refineries, in the highly seismic regions of the Himalayas. There is considerable interest in establishing studies in this field, and we have received the utmost cooperation from the Government of India in pursuing this work.

Earthquakes are associated with the same deformation processes in the earth's crust that are responsible for mountain building, and the largest and most frequent earthquakes are associated with the largest and youngest mountains. Data from past earthquakes have shown that more large earthquakes have occurred in the Himalayan regions than in the California-Pacific Coast area. During the past 50 years there have been some 18 earthquakes of Gutenberg-Richter magnitude 7 or over in the Himalayas, but only 8 such earthquakes in the California region. Data on smaller, but still potentially destructive, earthquakes in India is incomplete, because of the limited network of seismolo-

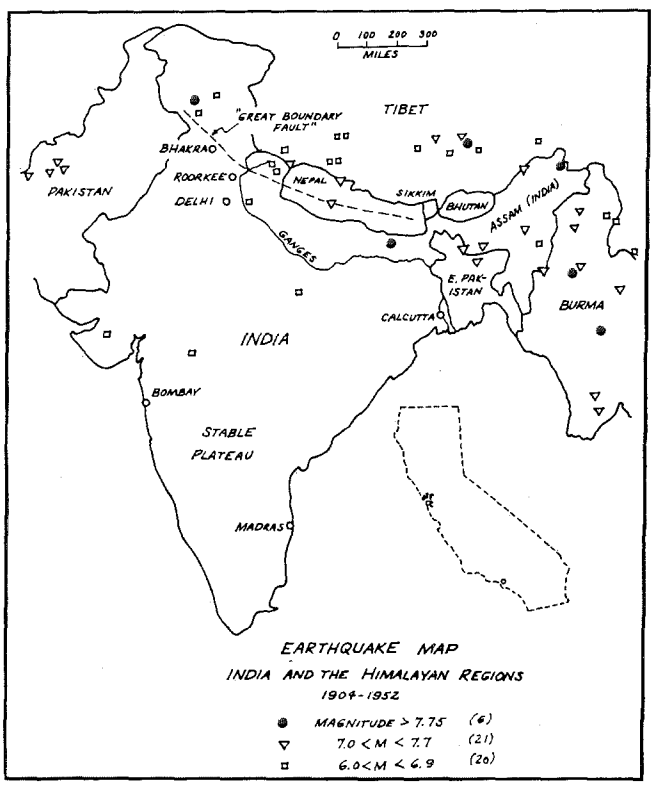
continued on page 18

gical stations. There is every reason to believe that a correspondingly large number of much smaller earthquakes is also occurring.

The general picture of the distribution of Himalayan earthquakes is shown below. The line marked "Great Boundary Fault" is the region of major geological disturbance at the edge of the high Himalayas, and a center of seismic activity. For the past 50 years the eastern end of the arc in Assam has been the most active, and this is reflected in the fact that the headquarters of the seismological department of the Government of India is located there. In 1950 one of the greatest earthquakes in history occurred just on the border of Assam and China. Whole mountains were rearranged, and the resulting topographical changes so disrupted the river systems that floods are still taking a heavy toll each year. Oil has been discovered in the Assam region, and now an oil refinery is being constructed there. The design of various refinery structures which will resist earthquake forces has been a major consideration in the planning of this installation.

The other end of the Himalayan arc in Kashmir has also been visited by very large earthquakes. One of the most notable quakes of all time occurred in 1905 very close to the site of Bhakra Dam, which, when it is completed next year, will be the world's highest gravity dam. Earthquake-resistant design techniques developed by the United States Bureau of Reclamation were used in the planning of this dam.

At present there are in this whole vast region only three strong-motion seismographs of the type needed for structural engineering data, whereas there should be hundreds. This compares with some 70 such instruments installed in California, and about 50 in Japan.



Map showing locations of major Indian earthquakes for the past 50 years. Insert map of California shows the scale.

Roorkee — a strategic location

The University of Roorkee is located in a strategic position for studying earthquakes. Several other factors make Roorkee a logical choice as headquarters for a graduate research school in earthquake engineering. This school, started 110 years ago, is the oldest technical school in the Orient, and has a well-established civil engineering department with a strong group in structural engineering. A good-sized group of competent graduate students who are interested in problems of structural dynamics is also available. The nearness of the school to Delhi, the capital of the country, is also important, as it is necessary to work closely with various government agencies in order to embody the results of the studies in official building codes.

The Roorkee area is an interesting part of India, the campus being just 20 miles from the point at which the Ganges River emerges from the mountains onto the plains. At this point is located the town of Hardwar, one of the most revered of the Hindu Holy cities. The area is a headquarters for pilgrims who throng to hermitages along the river.

The campus affords a magnificent view of the whole chain of the high Himalayas, and a series of 25,000-foot peaks on the Tibetan border are visible, extending over a vast arc of hundreds of miles.

Roorkee is a starting point for hunting parties. Typical Northern India jungle country starts about 15 miles from the campus, and tigers, leopards and elephants are still to be found in the region.

The University of Roorkee has grown out of a technical school which was developed to train surveyors and technical workers for the irrigation canal systems. The British built up a most remarkable system of canals in Northern India, and Roorkee was the headquarters for the design and construction of the main canal outlet of the Ganges River. This Northern Indian irrigation system is still in some respects the most extensive anywhere in the world, and students now come to Roorkee from all over Asia for special studies in water resources development.

Since becoming the first technical university in India in 1949, the school has been engaged in an extensive expansion program, and many new buildings

continued on page 20

have been completed or are in the course of construction. This development has received the personal attention of Prime Minister Nehru, who has been the moving spirit behind many of the scientific and technical developments in India. The Prime Minister visited the new Earthquake Engineering Laboratory at the school and expressed the opinion that such studies would be of great importance to many of the new construction projects now being planned.

A network of earthquake recorders

Our work in helping with the establishment of the Earthquake Engineering School at Roorkee involved a number of different activities. For instance, an important part of the program is to install a network of strong-motion recording instruments in the Himalayan regions. India is very short of foreign exchange dollars and cannot afford to import such instruments, so it was necessary to set up shop facilities and to train personnel in the design and production of suitable devices. To begin this program, a recording instrument of a simplified type, which had been designed at Caltech, was taken to Roorkee, where it was redesigned in such a way that local materials and processes could be used.

We were fortunate in having in Roorkee the services of a skilled machinist, who was able to understand just what was needed. Everything had to be built quite differently than in Pasadena. For example, no stock sizes of materials were available, so all parts had to be machined from castings. No standard nuts and bolts of any kind could be had, and everything of this sort had to be individually made to order. One interesting problem which arose was the procurement of the small permanent magnets which were used to damp the pendulum in the instrument. Such magnets were not made in India, nor could they be imported under the foreign exchange rules. It developed, however, that small radio loudspeakers were available, and one type was found which had just the right-sized magnets in it.

The instrument manufactured in Roorkee turned out to be entirely satisfactory, and at present a number of them are being built. Although labor in India seems inexpensive, a great deal of it is required; this, plus the high materials cost, makes such instruments relatively much more expensive in India than in the United States. Soon it may be possible to develop and build a more complicated type of time-recording strong-motion accelerometer in Roorkee.

A second type of activity involved the establishment of graduate courses in structural dynamics and in earthquake engineering, to provide the trained men necessary to carry the work forward. Here we were fortunate in having both a fine group of competent and interested postgraduate students, and also several very capable young staff members who could carry on the courses once they were organized. A regular postgraduate course in structural dynamics was worked out and special mimeographed material was prepared.

All lectures in the school are given in English, although it is expected that a gradual changeover to Hindi will take place over the next 10 years or so. The older professors, who have practically all studied in England or in the United States, are of course completely at home in English. The younger staff, the graduate students, and then the undergraduates all show a progressive decrease in proficiency in the language. The Hindi language has not yet developed a suitable technical vocabulary in many fields and there is likely to be a period of some confusion before the complete changeover can be made. The number of people in the country who speak English is so small, however, that the development of the Indian languages seems inevitable.

Setting up laboratory facilities

A second type of teaching activity involved the setting up of laboratory facilities for teaching and research work in dynamic measurements and engineering seismology. Funds of about $5000 were obtained from the Technical Cooperation Mission of the International Cooperation Administration, and about $40,000 were obtained through the United States Wheat Loan arrangement administered by the Government of India University Grants Commission. With this money a good start was made in supplying the basic instrumentation and laboratory equipment needed, and the laboratories are now well equipped. The Indian students seemed to be very interested in laboratory work because it is relatively new in their experience.

Another important part of our research activities was to organize for field inspection of earthquake structural damage. Upon our arrival at Roorkee, we were told by everyone that, although there were earthquakes elsewhere in India, they never had them in Roorkee. Within a month or so, the ground started shaking, and everyone was very frightened. Ever after this, our Earthquake Engineering School was regarded with a certain amount of suspicion. Roorkee is located in the midst of innumerable small villages, in which the construction of the mud houses is of the most elementary type. The usual construction does not even employ sun-dried bricks, but consists simply of heaping up mud to form a thick wall. Even without earthquakes, such construction can hardly hold up.

Earthquake damage studies are often troublesome

continued on page 22

to make in India because of the difficulties of travel in the Himalayan areas. This particular earthquake turned out to have an epicenter right in the region which is being argued over by the Indians and the Chinese, which introduced some additional uncertainties into a proposed field trip to the region.

The members of the geology department of the University of Roorkee were very interested in our studies, and were most cooperative in arranging field trips in the Himalayas to investigate earthquake phenomena. One portion of the main boundary fault area of the Himalayas was easily accessible from Roorkee, and a number of interesting trips were made to that region.

Another phase of the work at Roorkee involved the communication of information on earthquake engineering to the practicing engineers in the country. To this end, a symposium on earthquake engineering was organized, and an interesting three-day program was held at Roorkee. About 50 engineers from all over India attended, and many of them contributed technical papers. The proceedings of the symposium have since been published by the University. Professor George W. Housner, on his way from Caltech to the symposium, arranged for the director of the Japanese Earthquake Research Institute to attend the meeting, so that the symposium had quite an international flavor.

A useful result of the symposium was the appointment by the Government of India of a special committee to formulate an official building code to provide earthquake-resistant design regulations. The chairman of this committee is Dr. Jai Krishna, head of the Structural Engineering Division at Roorkee, who spent some time at Caltech in 1957 and 1959 on earthquake engineering studies.

Since our return from India we have had good news concerning the further development of the program. The Government of India, through the Council of Scientific and Industrial Research, has provided financial support, and the foundations have been laid for a new Earthquake Engineering Laboratory building. We have just heard that one of the young staff members from the structural engineering group will come to Caltech next year for special studies in this field.

As a result of this cooperative research program, there is every reason to hope that Indian engineers will soon be making studies of future Himalayan earthquakes which will be of interest to structural engineers all over the world.