NOTES

TARGETING EAST-WEST NORMAL FAULTS IN PENINSULAR INDIA FOR SEISMIC HAZARD STUDIES

During the last ten years or so, India has witnessed a number of damaging earthquakes that occurred both in the Himalayan belt and the Peninsular Indian shield. Within the Himalayan belt, large earthquakes struck in 1988 (north Bihar-Nepal), 1991 (Uttarkashi) and 1999 (Chamoli), whereas Peninsular India experienced devastation due to Latur (September, 1993), Jabalpur (May 1997) and the recent Kutch (January 2001) earthquakes.

At least on two counts, the Peninsular Indian earthquakes are intriguing; firstly, all the three earthquakes are associated with roughly E-W trending rift system of Proterozoic age. They have a history of rejuvenation during the Palaeozoic and/or Mesozoic when they were reactivated as reverse faults during the contemporary north-south compressive stress regime to generate these earthquakes. Secondly, the gap between the three successive events is 3 years 8 months (3.66 years). While the second observation could just be a coincidence (till we encounter another earthquake at a comparable gap), the first point gives us a certain food for thought. Site-specific, causative fault system for each of the three Peninsular Indian earthquakes is as follows:

- The Latur earthquake of 1993 was caused due to thrusting along an E-W fault that is located below the Deccan trap cover. The fault is likely to be a part of the Proterozoic concealed rift basin.
- After 3.66 years, further north, occurred the Jabalpur earthquake of 1997 that ruptured (with reverse slip) the E-W segment of the Narmada fault, more precisely the Narmada South Fault, a member of the Son-Narmada-Tapti (SONATA) Proterozoic rift system (with Palaeozoic-Mesozoic reactivation) traversing across the Indian Peninsula.
- With the lapse of another 3.66 years came the devastating Kutch earthquake of 26th January, 2001. This earthquake occurred due to activity along the E-W Kutch Mainland Fault, a member of the roughly east-west trending family of faults that constitute the Mesozoic Kutch rift basin between the Nagar-Parkar Ridge in the north and the Kathiawar Uplift in the south. Reactivation with reverse slip along the Mesozoic normal fault is considered to be the immediate cause of this earthquake.

Occurrence of these three damaging earthquakes, all with magnitude ≥ 6.0, indicates that the E-W trending, steeply dipping, major normal faults belonging to Proterozoic-Mesozoic rift system with protracted history of reactivation could be the potential source of earthquakes in Peninsular India. These faults appear to be ideally oriented to reactivate as reverse faults in the contemporary north-south compressive stress regime and generate earthquakes.

Following the foregoing arguments, the faults/regions discussed below are to be studied carefully to document strain build-up if any, for possible future earthquakes:

1. The SONATA fault system is more than 1500 km long dividing India into northern and southern segments. The Jabalpur earthquake is located almost in the mid-segment of this fault zone. Western extremity of this fault zone has already been ruptured to generate the Broach earthquake of 1970. The 700-800 km segment east of Jabalpur defines the Gondwana basin of Son and Damodar valleys. The Palaeozoic normal fault system in this part, though has not produced any major earthquake in the historical past, remains a potential source of earthquake hazard in the contemporary stress field. The area west of Rihand is particularly interesting as a few low magnitude earthquake clusters occur in the region.
2. In the southern part of the SONATA fault zone, swarm type activity is known for quite sometime and deserves attention.
3. Though not associated with Palaeozoic-Mesozoic rifts, the east-west faults/shears traversing Karnataka-Tamil Nadu cannot not be overlooked.
4. But the most potential E-W trending, sub-vertical normal fault occurs further northeast, i.e., the Dauki fault between the Shillong plateau and the Sylhet plains. Geological records indicate the fault to be active during the Mesozoic with effusion of Sylhet Traps and the fault was rejuvenated during the Tertiary. In the contemporary stress regime, this fault will behave in a fashion similar to the Narmada South and the Kutch Mainland faults to generate earthquakes with reverse slip. The region around the Dauki fault is seismically active and more active than the other faults

mentioned above, probably due to its proximity to the Himalaya.

5. The time gap of 3.66 years could become a magic figure if an earthquake of magntude ≥6.0 actually occurs by rupturing the eastern segment of the Son-Narmada fault or the Dauki fault through reverse slip mechanism. Therefore, September 2004 could turn out to be ominous.

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INDO-ITALIAN WORKSHOP ON SEISMIC RISK EVALUATION

Seismic risk evaluation is being considered as one of the fields of collaborative research programmes under the Protocol of Cooperation between the Governments of India and Italy. As a first step, an Indo-Italian Workshop on Seismic Risk Evaluation was organized from March 3 to 9, 2001. The workshop was sponsored by the Department of Science and Technology (DST) of Government of India, and the Ministry of Foreign Affairs of Government of Italy. This workshop was planned as a forum for deliberations amongst a close group of scientists directly involved in this field, with a test area for microzonation and seismic risk evaluation as the core topic of discussion. The Committee for the Indo-Italian Workshop on Seismic Risk Evaluation, set up by the Department of Science and Technology of Government of India, selected Jabalpur as the test area and formed a working group for carrying out the test exercise. Intensive preparatory work was carried out by Geological Survey of India (GSI) and National Geophysical Research Institute (NGRI), Hyderabad in the Jabalpur area. A reference document detailing the geological, geotechnical and geophysical information was prepared for presentation and discussions during the technical sessions. The workshop had two components (1) A field visit to Jabalpur from March 3 to 5, 2001 and (2) Technical sessions at NGRI, Hyderabad from March 6 to 9, 2001. The field visit to Jabalpur during March 3-5, 2001 was organized by GSI. The visiting group comprised 8 members of the Italian delegation, members of NGRI, and the working group and scientists of GSI and Jabalpur Engineering College. The field programme included visits to a number of type areas to give exposure to regional geological and tectonic settings, as well as visits to specific geotectonic and lithological type areas in the Jabalpur city and its close vicinity, which had experienced different scales of damage during the 1997 earthquake of Mw 5.8.

The technical sessions at NGRI were attended by about 45 participants comprising 8 members of Italian delegation and representatives of DST, Italian Embassy in India, NGRI, GSI, IMD, IITs, WIHG, CBRI, CMMACS, Kurukshetra University, Jabalpur Engineering College and others. The deliberations essentially included about 20 oral presentations on the approaches for seismic hazard assessment and risk evaluation as well as presentation of case studies from Italy and India. The presentations broadly covered the three important themes which are the essential components of seismic risk evaluation viz. seismic hazard assessment, microzonation and vulnerability studies. The Indian and the Italian scientists also reviewed the status of the seismological networks, the geological, geophysical and tectonic data for hazard analysis and microzonation. It was opined that although the seismological network in India now enables detection of earthquakes of Magnitude 4 and above, it is important to fill the gaps with installation of new observatories so that the detection level may be brought down to Magnitude 3. Also, the need for a network of strong motion accelerographs was emphasized, to enable realistic estimates of seismic hazard.

It was felt that the approaches for detailed microzonation of urban areas must be based on a deterministic approach. In these, theoretical computations of synthetic seismograms can be used to estimate the expected ground motion for a set of possible scenario of earthquakes, using different fault geometries, source complexities like rupture dynamics, propagation characteristics of media and site effects. Such numerical modelling of ground motion, coupled with the geotechnical data generated from soil penetration techniques (for N values) and directional dependence of attenuation would thus lead to a pre-disaster microzonation. In cases where strong motion records are available, the synthetic ground motion can be compared to the observed ones, to include more complex source models and 2D site amplification effects. Concern was raised about appropriate