SEISMIC HAZARD ANALYSIS AND PRELIMINARY MICROZONATION OF BANGALORE CITY

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SUMMARY

Seismic microzonation is the process of estimating response of soil layers under earthquake excitation and thus the variation of ground motion characteristic on the ground surface. Geotechnical site characterization and assessment of site response during earthquakes is one of the crucial phases of seismic microzonation with respect to ground shaking intensity, attenuation, amplification rating and liquefaction susceptibility. Microzonation mapping of seismic hazards can be expressed in relative or absolute terms, on an urban block-by-block scale, based on local soil conditions (such as soil types) that affect ground shaking levels or vulnerability to soil liquefaction. Such maps would provide general guidelines for integrated planning of cities and in positioning the types of new structures that are most suited to an area, along with information on the relative damage potential of the existing structures in a region. In the light of recent large earthquakes and huge damages caused due to them, various national microzonation projects of different cities such as Delhi, Dehradun, Jabalpur have been taken up by different agencies (Seismology Update January-2005). The department of Science and Technology has also initiated a similar project for Bangalore city.

Bangalore city covers an area of over 650 square kilometres and is at an average altitude of around 910m above mean sea level. It is situated on a latitude of $12^0 58''$ North and longitude of $77^0 37''$ East. The population of Bangalore city is over 6 million and Bangalore city is the fastest growing city and fifth biggest city in India. It is the political capital of the state of Karnataka. Besides political activities, Bangalore possesses many national

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laboratories, defense establishments, small and large-scale industries and Information Technology Companies. The city is also called as Silicon Valley of India/Science city of India. These establishments have made Bangalore a very important and strategic city. Recent earthquakes in different parts of country, particularly the one at Bhuj during 2001 has influenced the importance of earthquake resistant design and construction. Because of density of population, mushrooming of buildings of all kinds from mud buildings to RCC framed structures and steel construction, improper and low quality construction practice and irregular and heavy traffic conditions; Bangalore is vulnerable even against average earthquakes. Thus there is a need to evaluate the seismic hazard of this area. As per IS 1893 (2002) Bangalore is upgraded to Zone II from Zone I in the seismic zonation map. Further, findings from geologists have shown that in the Bangalore region the reactivated reverse/normal faults have a dominant strike-strip movement resulting in repeated rupturing at close intervals. This is also evident from rejuvenation of the transcurrent faults manifested in recurrent earthquakes (Valdiya, 1998). Ganesha Raj and Nijagunappa (2004) have also highlighted the need to upgrade the seismic zonation of Karnataka; particularly the areas surrounding Bangalore, Mandya and Kolar to zone III rather than the current zone II as these areas are quite active, based on the analysis using remote sensing data and neotectinic activity in the area.

In this work on seismic hazard analysis of Bangalore, the seismotectonic map has been prepared as per Regulatory Guide 1.168(1997), regional geological and seismological investigations for the Bangalore city has been carried out considering a radius of 350km around the point of interest to identify seismic sources by using literature review, study of maps, remote sensing data and ground reconnaissance study. Study area lies between latitudes 9° 50”north to17°12” north and longitudes 74° 24”east to 81°42” east covering 350km radial distance from the city center.

Brief seismic history of the area shows that many earthquakes have been reported in this region and the first reported seismic activity in the study area had an intensity of VI occurred on 10th December, 1807. However, there was no earthquake recording station in Bangalore city until recently. Recent tremors which are reported are from the Gauribidanur seismic recording station which is about 80 km from Bangalore. The historic earthquakes show that moderate earthquake of 4.0 to 5.5 in moment magnitude have occurred many times in the study area. Some of these earthquake events are listed in Table 1. In recent years much

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of the seismic activity in the state of Karnataka has been in the south, in the Mysore-Bangalore region. Historically tremors have occurred in many other parts of the state such as Bellary, which is in the north part of Karnataka. On January 29th of 2001, earthquake magnitude of 4.3 in Richter scale hit in the Mandya area, its epicentre was about 35km south of Bangalore. More than 50 buildings have been reported to be damaged at Kanakapura. Widespread panic in Bangalore and schools were closed. Minor damages are reported at Austin town and airport road in Bangalore. Even the Killari earthquake of 30th September 1993 was felt in Bangalore city. Sumatra earthquake of 2004 has triggered tremors of intensity IV in Bangalore city. As part of this work, in the year 2005 six strong motion accelerographs and two borehole sensors have been installed at different locations in Bangalore city.

Seismic hazard analyses involve the quantitative estimation of ground shaking hazards at a particular area. Seismic hazards may be analyzed deterministically as when a particular earthquake scenario is assumed, or probabilistically, in which uncertainties in earthquake size, location, and time of occurrence are explicitly considered (Kramer, 1996). A critical part of seismic hazard analysis is the determination of Peak Ground Acceleration (PGA) and development of the response spectrum for an area. Seismic hazard analysis and determination of PGA is crucial and very important base for any earthquake resistant design and Microzonation. In seismic hazard analysis, identification of the source for the future earthquake is a very important process. To evaluate seismic hazards for a particular site or region, all possible sources of seismic activity must be identified and their potential for generating future strong ground motion should be evaluated. Analysis of lineaments and faults helps in understanding the regional seismotectonic activity of the area. Lineaments are linear features seen on the surface of earth which represents faults, features, shear zones, joints, litho contacts, dykes, etc; and are of great relevance to geoscientists. Scientists believe that a lineament is a deep crustal, ancient, episodically reactivated a linear feature that exerts control on the make up of the crust and associated distribution of ore and hydrocarbons (O' leary et. al 1976, Ganesha Raj and Nijagunappa, 2004). In this paper, attempt has been made to determine the maximum credible earthquake (MCE) of generation of synthetic acceleration time history plot for the Bangalore region by considering the regional seismotectonic activity in about 350km radius around Bangalore city. Developing response spectrum for different over burden such as rock, dense soil and loose soil. We have attempted to develop preliminary seismic microzonation map for Bangalore city considering a large database of geotechnical data

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consisting of standard penetration test results and engineering properties of the soils. The database contains about 850 boreholes distributed uniformly over the Bangalore city and up to a maximum depth of 45m below the existing ground level. The digital map of Bangalore city with geotechnical borehole locations are shown in Figure1. The seismotectonic map has been prepared by considering all the possible sources of seismic activity such as faults, lineaments, shear zones and historic earthquake events (of more than 150 events). Synthetic earthquake ground motion has been developed by using Boore (1983) model. The site response and response spectrum for different sites have been estimated using one-dimensional shake analysis (SHAKE 2000). We have also developed 3-D subsurface map of Bangalore city, developed for the microzonation purpose which comprises of about 220 sq km area. The quantification of hazards in terms of amplification rating, peak ground acceleration values and factor of safety against liquefaction have been presented along with other layers of infrastructure and building distribution maps of Bangalore city.

To prepare the preliminary microzonation map, Bangalore map along with different layers as discussed earlier have been developed. Generally, the amplification rating for Bangalore city can be described under three groups, which is group Nil-A identifies the rock out crops and shallow depth rock areas. Sandy silt, sandy clay and silty soil come under the Low-B group. Soft clay and clay soil having depth more than 3m, comes under the Moderate-C group. Peak ground horizontal acceleration (PHA) of sites has been grouped in two groups. The analyses reveals that if the shear wave velocity of site is less than 360m/s, the PHA of site is 0.06g and if it is more than 360m/s, the PHA of site is 0.05g for the earthquake magnitude of 6 in Richter scale. For the earthquake magnitude of 7 in Richter scale, for the velocity of site less than 360m/s, the PHA of site is 0.112g and for more than 360m/s, the PHA of site is 0.092g. Liquefaction 'susceptibility' is a measure of a soil's inherent resistance to liquefaction, and can range from not susceptible, regardless of seismic loading, to highly susceptible, which means that very little seismic energy is required to induce liquefaction. Susceptibility has been evolved by comparing the properties of a given deposits to the other soil deposits where liquefaction has been observed in the past (based on Seed et al, 1985). The primary relevant soil properties considered were grain size, fine content, density, degree of saturation and age of the deposit. Liquefaction susceptibility was evaluated and a map of Bangalore for liquefaction susceptibility area is developed. Only for susceptible area, the factor of safety against liquefaction has been calculated as described earlier. The factor of safety against liquefaction has been grouped in to 7 groups for the purpose of map

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preparation. The preliminary microzonation map has been prepared with considering history earthquakes of magnitude 6 and 7 in Richter scale. However there is need to revise the preliminary microzonation based on the MCE and detailed site response analyses using SHAKE2000.

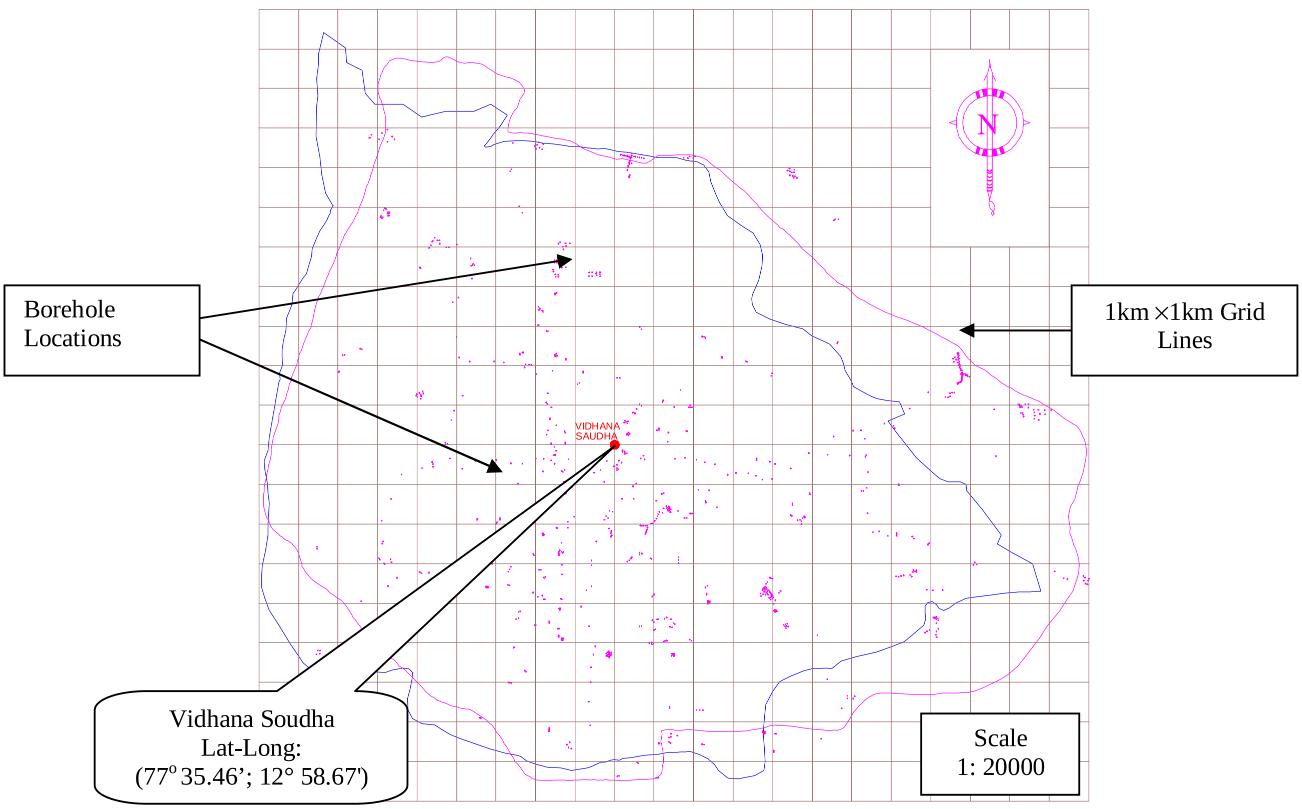

Figure1. Digital map for the Bangalore city with geotechnical data points

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