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Seismic Microzonation - Principles and Methodology

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Abstract
The string of earthquake in India has created a serious problem for engineers and administrators and even for people also. Metro cities and other big cities in India have experienced severe earthquake hazard problem. This is same for Himalayan region and even peninsular shield. On 26 jan 2001 , one of the greatest India has ever experienced strikes in Kachchh , a region of Gujrat . Magnitude of this earthquake was 7.7 (M_W) .This earthquake spread a huge damage which was almost a radius of 400 Kms. This earthquake damaged major cities of Gujrat like Ahmedabad , Bhavnagar , Surat. No one can say no for same threat for Delhi , national capital of India from local and probable catastrophic earthquake due to central himalaya . There are many more other Indian cities which are sitting in thick sedimentry basins along Indo-Gangetic plane and Brahmaputra valley . They have also the same threat. To reduce the seismic hazard, it is now important to define a correct response in terms of peak ground acceleration and spectral amplification . Both are highly dependent on local site conditions and also dependent on source characterization of future expected earthquakes . Microzonation studies are now important for a detailed ground motion modelling for urban and semi-urban cities of India. This paper presents an overview of seismic microzonation . Steps required and methodology used for seismic microzoation is also discussed here.
Keywords- seismic microzonation , Hazard , Source characterization ,Site response , seismotectonic sources , Peak ground acceleration

I. INTRODUCTION

Seismic microzonation is sub dividing a region into smaller areas having different potential for hazardous earthquake effects. The earthquake effects depend on ground geomorphological attributes consisting of geological, geomorphology and geotechnical information. The parameters of geology and geomorphology, soil coverage/thickness, and rock outcrop/depth are some of the important geomorphological attributes. Other attributes are the earthquake parameters, which are estimated by hazard analysis and effects of local soil for a hazard (local site response for an earthquake). The Peak Ground Acceleration (PGA) [from deterministic or probabilistic approach], amplification/ site response, predominant frequency, liquefaction and landslide due to earthquakes are some of the important seismological attributes. Weight of the attributes depends on the region and decision maker, for example flat terrain has weight of “0” value for landslide and deep soil terrain has highest weight for site response or liquefaction.

Microzonation has generally been recognized as the most accepted tool in seismic hazard assessment and risk evaluation and it is defined as the zonation with respect to ground motion characteristics taking into account source and site conditions (ISSMGE/TC4, 1999). Making improvements on the conventional macrozonation maps and regional hazard maps, microzonation of a region generates detailed maps that predict the hazard at much larger scales. Damage patterns of many recent earthquakes around the world, including the 1999 Chamoli and 2001 Bhuj earthquakes in India, have demonstrated that the soil conditions at a site can have a major effect on the level of ground shaking. For example, in the Chamoli earthquake, epicenter located at more than 250 km away from Delhi caused moderate damage to some of the buildings built on filledup soil or on soft alluvium. The Bhuj earthquake caused severe damage not only in the epicentral region, but even in Ahmedabad, about 250 km away, which attributed to increased ground shaking of the soft alluvium. Mapping the seismic hazard at local scales to incorporate the effects of local ground conditions is the essence of microzonation.

Earthquake damage is commonly controlled by three interacting factors- source and path characteristics, local geological and geotechnical conditions and type of the structures. Obviously, all of this would require analysis and presentation of a large amount of geological, seismological and geotechnical data. History of earthquakes, faults/sources in the region, attenuation relationships, site characteristics and ground amplification, liquefaction susceptibility are few of the important inputs required. Effect of site amplification due to soil conditions and associated damage to built environment was amply demonstrated by many earthquakes during the last century. The wide spread destruction caused by Guerrero earthquake (1985) in Mexico city, Spitak earthquake (1988) in Leninakan, Loma Prieta earthquake (1989) in San Francisco Bay area, Kobe earthquake (1995), Kocaeli earthquake (1999) in Adapazari are important examples of site specific amplification of ground motion even at location as far away as 100-300km from the epicenter (Ansal, 2004). These failures resulted from the effect of soil condition on the ground motion that translates to higher amplitude; it also modifies the spectral content and duration of ground motion. Site specific ground response analysis aims at determining this effect of local soil conditions on the amplification of seismic waves and hence estimating the ground response spectra for future design purposes. The response of a soil deposit is dependent upon the frequency of the base motion and the geometry and material properties of the soil layer above the bedrock. Seismic microzonation is the process of assessment of the source & path characteristics and local geological & geotechnical characteristics to provide a basis for estimating and mapping a potential damage to buildings, in other words it is the quantification of hazard. Presenting all of this information accordingly to develop hazard maps, for the use of planners, developers, insurance companies and common public is another important aspect of microzonation.

Need For Seismic Microzonation

Seismic microzonation is the first step in earthquake risk mitigation study and requires multidisciplinary approach with major contributions from the fields of geology, seismology, geophysics, geotechnical and structural engineering. This is very important to identify the tectonic and geological formations in the study area which is essential for determining the seismic sources and also for establishing a realistic earthquake hazard models for the investigation. Seismic microzonation involves a very detailed field investigation to evaluate the hazard. It is very effective in delineating the spatial variations in the seismic hazard. They are also useful to evaluate the risk scenarios in the study area. Seismic microzonation maps are very useful in urban planning because they help to predict the impact of future earthquakes and can also be used to locate key facilities like hospitals, fire stations, emergency operation centers etc. Microzonation studies are also very useful to save the heritage and important structures from future major earthquakes.

Seismic Zoning and Seismic Microzonation

Seismic zoning consists of subdividing a national territory into several seismic zones indicating progressive levels of expected seismic intensity or peak ground acceleration for different return periods based on historic and predicted intensity of ground motion. It is common to see countries classified into three, four or more seismic zones and seismic design requirements for buildings are generally the same within a defined seismic zone. Such maps are small scale maps covering a large territory.

Seismic microzoning provides detailed information on earthquake hazard on a much larger scale. It recognizes the fact that spectral acceleration values for sites within a seismic zone vary in tune with the location specific geological conditions. It therefore consists of mapping in detail all possible earthquake and earthquake induced hazards. It necessarily involves seismological, geological, geotechnical and hydro-geological mapping and their integration to provide a picture of levels of hazard distribution comprehensible to urban planners, engineers and architects.

Principles of Seismic Microzonation

A ground motion prediction is important key to assess and mitigate the earthquake hazard. There are some factors by which level of strong ground motion is controlled . The main factors are Source , Site conditions and Path . Among these, site condition played van important role on damage to structures as seen from previous Bhuj earthquake and Mexico earthquake . It is important to validate the effect of local site conditions for estimation of strong ground motion and mitigation of earthquake hazards . For this purpose , methods for characterizing site effects is required keenly . It is also required for the study of soil behaviours during strong ground shaking . As it has been noticed from many past earthquakes , the major damage to property and man - made structures is mostly found in the region of soft sediments . The constructive interference of incoming waves due to effect of structures created very strong ground motion . Determination of seismic ground motion is one of the most basic problem associated with seismic microzonation . Use of wide database of recorded strong ground motion and group those accelerogram , that have similar source , site condition and path may be an ideal solution for above problem. But such a database is not available in country like India . Actually , the numbers of recorded signals is comparatively low and the installation of local arrays i each zone with a high level of seismicity is quite costly for an operation that requires a long time interval to collect statistically appropriate data sets . So one has to choose some analytical , empirical solution based on theory of seismic waves , propagation of seismic waves and excitations due to soft sedimentary layers .

Levels Of Seismic Microzonation

Levels of Seismic Microzonation generally float with the choice of scale of mapping as also with the degree and scope of scientific investigation fashioned to minimize uncertainties in seismic hazard evaluation for a specific set of objectives. The quantum and quality of basic maps and information required for making a head tart with the mapping work are rarely available. Since seismic microzonation work cannot wait for all the required information, a first cut microzonation map is prepared based on a minimum programme of investigation. Choosing an appropriate mapping scale and thinking to scale while mapping are the two challenges common to every such programme. What is to be included and what is to be left out for future investigation will have to be decided on a case to case basis. Degree of detailing and scrutiny expands with increase of mapping scale.

Three levels of Seismic Microzonation expressed as Grade1: General Zonation; Grade 2: Detailed Zonation and Grade 3: Rigorous Zonation were favoured by the Technical Committee on Earthquake Geotechnical Engineering of the International Society of Soil Mechanics and Foundation Engineering (1993). The recommendation essentially meant making a beginning with relatively small scale mapping and move on to higher levels of microzonation by obtaining added quality inputs that could justify large scale mapping.

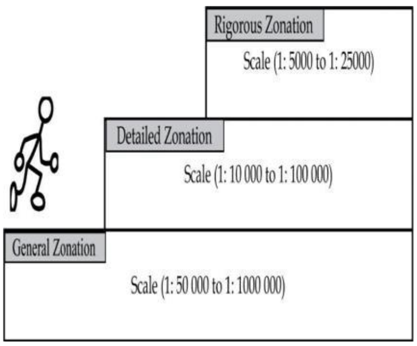

FIG 1 - Three Grades of Seismic Microzonation recommended by the Technical Committee of the International Society of Soil Mechanics and Foundation Engineering (ISSMFE)

Microzonation Framework

Seismic microzonation process is initiated with rudimentary assessments based on existing regional level hazard estimation, seismotectonic and macro-seismic studies . Several local specific hazard factors are, thereafter, evaluated and mapped on a Geographical Information System (GIS) platform with a uniform and consistent geo-referencing scheme. A general methodology in doing the seismic microzonation of a region can be divided into the following four major heads :

[1] Estimation of the ground motion parameters using the historical seismicity and recorded earthquake motion data which includes the location of potential sources, magnitude, mechanism, epicentral distances.

[2] Site characterization using geological, geomorphological, geophysical and geotechnical data.

[3] Assessment of the local site effects which includes site amplification,predominant frequency, liquefaction hazard, landslides, tsunami etc.

[4] Preparation of the seismic microzonation maps.

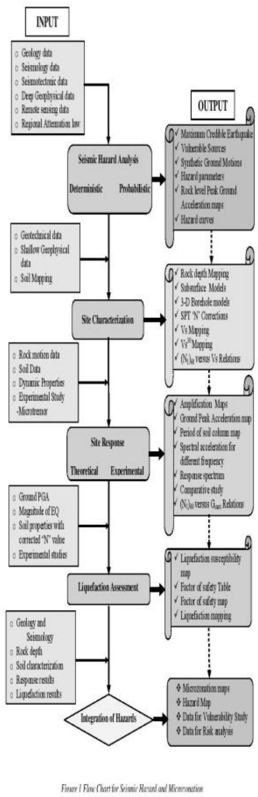

FIG 2 : A General Framework For Microzonation Studies

Microzonation Experiments in India

Summary of seismic hazard analysis and microzonation works carried out in Indian urban centers is presentated here.

Seismic Microzonation Of Jabalpur

First experiment of seismic microzonation was initiated by Department Of Science And Technology , New Delhi. This work was carried out by Geological Survey Of India , Indian

Metrology Department , CBRI (Roorkee) and Government Engineering College , Jabalpur . Deterministic approach was used for seismic hazard analysis and deterministic peak ground acceleration map was published which was based on attenuation relation given by Joyner and Boore(1981) . Study of geological , geotechnical , geophysical investigations were used for ground characterization . After this information , the first level of microzonation map was published . Liquefaction hazard assessment was carried out using approach of Seed and Idriss (1971) . Experiment of Nakamura type studies and receiver function type studies were carried out for site response .

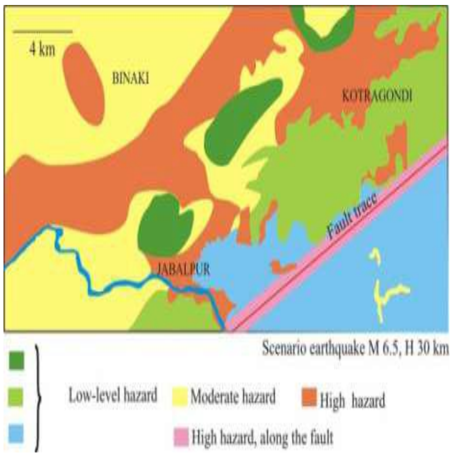

FIG 3: Final hazard map of Jabalpur (after PCRSMJUA, 2005)

Seismic Microzonation Of Delhi

Microzonation of Delhi has been carried out by a group of members from different institutions . Scale for this microzonation map was 1 : 50,000 . This microzonation map include geology , base map , seismic hazard map , peak ground acceleration , shear wave velocity . The area for this study has been grouped into three hazard zones i.e. low , moderate , high . Complete seismic hazard analysis by both deterministic and probabilistic approach was done by Iyengar and Ghosh (2004) . Peak ground acceleration map at bedrock level for five different sources in Delhi was carried out by Rao and Neelima satyam (2005) by using computer code FINSIM , a finite fault simulation technique . Soil amplification estimation was carried out by using software DEGTRA and microzonation map for amplification was prepared .

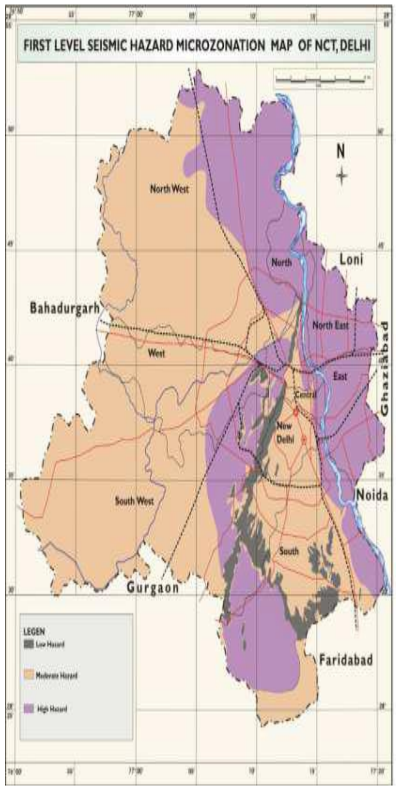

FIG 4: Final hazard map of Delhi (after Bansal and Vandana, 2007)

Seismic Microzonation Of Guwahati

The first level microzonation map of Guwahati was prepared by Baranwal et al (2005) . This map was based on shape and constituents of overburden material inferred from geophysical surveys , slope of exposed rocks , ground motion amplification . On the basis of susceptibility to amplification , they categorized soil profiles . There were various themes included for preparation of microzonation maps for Guwahati . These themes are geology , geomorphology , seismotectonics , soil characteristics , peak ground acceleration , seismic hazard , demography .

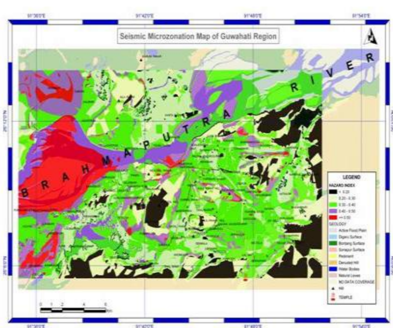

FIG 5: Hazard index map of Guwahati (after Nath, 2007)

Seismic Microzonation Of Dehradun

International institute for Geo - Information Science and Earth observation Enschede , Netherlands initiated study of seismic hazard assessment and site response for seismic microzonation of Dehradun . Information o geology and geomorphology of Doon valley in regional scale were compiled , analyzed , interpreted by Anusuya Barua (2005) . Information on subsurface , landforms , tectonic , lithology , were used for generation of database for seismic microzonation . Field study of 31 locations and measurements of shear wave velocity and soil thickness by use of MASW was carried out by Rajiv Ranjan (2005) . He also used SHAKE2000 program with measured shear wave velocity and recorded ground motion for the site response study of Dehradun . Microzonation spectral acceleration map of Dehradun at different frequency was also developed by him .

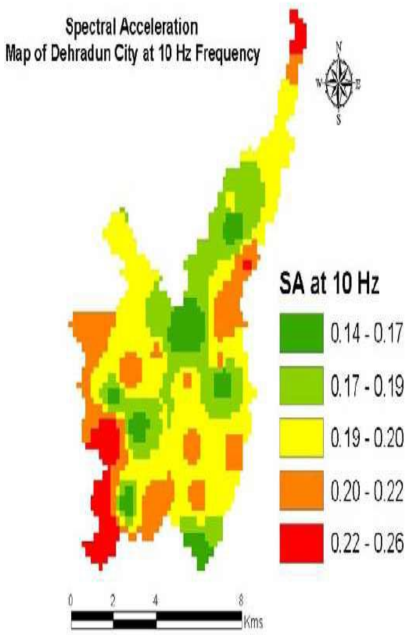

FIG 6: Spectral acceleration map of Dehradun (after Rajiv Ranjan, 2005)

Issues Related To SeismicMicrozonation In India

In India , seismic microzonation was initiated in 2001 .Even after many years , there are many problems in microzonation studies . It can be grouped in three parts -

- Geology and grade related issues
- seismology related issues
- geotechnical related issues

II. CONCLUSION

This paper shows the details about seismic microzonation . Methods and approaches used for seismic microzonation studies are also discussed in this paper . This paper also discuss the principles related to seismic microzonation . Experiments of seismic microzonation done in India is briefly highlighted here . Problems related to seismic microzonation in India is also mentioned here .

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