(12) PROBABILISTIC SEISMIC RISK MAPS OF THE NORTHERN INDIAN REGION AND THEIR UTILIZATION AS DESIGN AIDS

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INTRODUCTION

Design earthquake motions used in India date from the mid 1960's and are based largely on the 1940 El Centro accelerogram. Since the present design motions were set, many accelerograms stronger than the 1940 El Centro have been recorded and our understanding of engineering seismology and of seismicity of India has improved. Therefore, it is appropriate to re-evaluate design earthquake motions for India and to present the results in a probabilistic form that can be readily used in design.

Further, damage survey of a recent earthquake in the region by the author showed that masonry buildings are the most common type of construction and suffer the maximum catastrophic damage. The IS code of practice for earthquake resistant design IS:1893-1984 envisages that structures would normally exhibit elastoplastic or inelastic behaviour and therefore the seismic coefficient given in this code is much smaller than that to be used for elastic design. However, in brittle structures like brick buildings absence of such behaviour would render them liable to much larger forces. Hence, as a practical application of the seismic risk analysis, the risk maps are proposed to be utilized as input for design of masonry buildings such that their potential seismic damage is limited to a specified tolerable level.

In this research an analysis of the seismic risk has been made for the northern Indian region, lying between 20^{o}N to 35^{o}N latitude and 72^{o}E to 100^{o}E longitude, adopting a computer program <ERISA-P> (Ref 1). The region has been divided into 200 grid points (1^{o}x1^{o}) and analysis performed at each point utilizing a simple Poisson's model, together with historic occurrence data. The earthquake data used for this analysis are taken from Catalogue of earthquakes in India and neighbourhood (ISET)(from 1896-1979) and data file of U.S. Coast and Geodetic Survey (1980-1987).

TYPE OF RISK MAPS

EQUI-SPECTRAL ACCELERATION MAP: An engineering model of acceleration response spectra proposed by Katayama(1982) has been utilized to prepare period dependent seismic risk maps at two representative periods of T=0.2 (Fig. 1) and T=4.0 seconds. These maps have been prepared for a probability of exceedance of 64%, 100 year service life of the structure and assuming alluvial soil condition. The results of the risk analysis at each grid point are used to classify the region into three zones (Fig. 2), depending upon the value of the ratio, S, of the spectral acceleration at T=4.0 and 0.2 seconds.

PEAK GROUND ACCELERATION MAPS: Acceleration at each grid point for all earthquakes in the source domain is calculated assuming the following attenuation relation,

$$A= 227*10^{0.308M}(D+30)^{-1.2} \qquad (1)$$

Fig. 3 shows the map of equi-risk areas in terms of expected peak ground acceleration (called A_{100E}) for a return period of 100 year and a probability of exceedance of 64%, assuming alluvial soil condition. Equi-risk areas in terms of probabilities of not exceeding an acceleration level of 100 gal in 50 year service life of the structure are shown in Fig 4. Assuming a simple Poisson process to generate earthquake recurrence conditions, the relationship among ν, Q and t is given by, $Q=\exp(-\nu t)$ where,

- Q= Probability of the peak acceleration level corresponding to the occurrence rate being not exceeded in t years
- ν= Mean occurrence rate (=1/T, where T is return period)
- t= Service life of the structure

Hence, the following simplified relationships may be developed to facilitate generation of peak ground acceleration (PGA) for any Q and t under given A_{100E}:

$$A_{100Q}=f_Q*A_{100E}=(-1.0003*\mathrm{Ln}\ Q)^{(1/-B)}*A_{100E} \qquad (2)$$

$A_{tE}=f_t*A_{100E}=(100/t)^{(1/-B)}*A_{100E}$ (3)

where f_Q and f_t are normalization factors and B is regression parameter in equation,

$\text{Log}\,\nu = A - B*\text{Log PGA}$ (4)

The region has been classified into three zones, depending upon the value of the parameter B and a zoning map prepared (Fig. 5). The mean values of B in each sub-zone has been used to prepare Figs. 6 and 7. These graphs show the variation of f_Q and f_t for different Q and t respectively. It is proposed to use these graphs in conjunction with Figs. 4 and 5 to obtain the acceleration for any Q or t.

EXPECTED MAXIMUM MAGNITUDE EARTHQUAKE: Fig. 8 shows the map of the expected maximum magnitude earthquake in the region. Recurrence parameters, a and b, computed at each grid point in combination with the relation given by Campbell(1976) are adopted to estimate the expected magnitude (M_E), where

$M_E= (\text{Log } L/L_O + a)/b$ (5)

L: Design life of structure

L_o: Recurrence period of probable maximum magnitude earthquake (M_{PME})

a & b: Parameters in equation Log N= a - bM

In this analysis, assuming M_{PME}=7, L_o is calculated at each grid point from the recurrence relation and substituted in equation 5 to obtain the expected maximum magnitude earthquake. The assumption of M_{PME} has been made on the basis of the seismicity of the region and an average service life of 50-100 years for ordinary structures. The results are presented in the form of equi-magnitude contour lines.

APPLICATION OF RESULTS

RISK SPECTRA: A procedure has been defined elsewhere (Ref 1) to utilize the equi-spectral acceleration maps to predict approximate risk spectra at any site, with S defining the shape of the spectra.

DAMAGE LIMITING DESIGN: A damage index for masonry has been defined by Ang and Kwok (Ref 2) as a function of the maximum deformation and the absorbed hysteretic energy. The calibration of the damage index was checked by evaluating the damage indices of a double story apartment building damaged in a recent earthquake in the region (Ref 3) and comparing with actual damages. Ang has proposed a simple method to estimate the damage index of a structure, in which damage is evaluated as the ratio of the seismic load to the structural resistance. The rms acceleration, A_a, the duration of the strong motion phase, t_d, and the predominant period of ground motion are used to represent the seismic load. The structural resistance is defined by the ultimate displacement, u_u and the fundamental period, T. Therefore, the damage index may be written as,

$D= L(A_a,t_d,T/T_g)/ R(T,u_u)$

It is proposed that a suitable value of A_a may be judiciously chosen using Figs. 4 to 7, depending upon the economics and importance of the project. The duration of strong ground shaking may be approximated by the empirical relationship suggested by Bolt(1979) as, t_d=17.5*tanh (M - 6.5)+ 19 (in seconds) (6)

where M is the expected maximum magnitude at the site and may be obtained from Fig. 8

The above data are to be utilized to design the structure for a tolerable level of seismic damage so that damage would not be excessive in the event of an earthquake.

DISCUSSION AND CONCLUSIONS

It is strongly believed that the zoning maps prepared for engineering use can vary significantly depending on the intended application, and therefore attempts to prepare an all purpose zoning map are self-defeating. Hence, zoning maps, S and B, have been prepared for particular applications. The S-zoning map reflects the structural response characteristics of the region in terms of the shape of the response spectrum, fixed by the value of the parameter, S. The B-zoning map reflects the seismic source characteristics of the region in terms of the relative occurrence of earthquakes causing weak and strong ground shaking at the site, fixed by the value of the parameter, B. Finally, equi-risk maps along with normalizing graphs have been presented to leave the final design decision in the hands of the engineer.

In conclusion, it may be said that a comprehensive macrozonation of the Himalayan region has been attempted and in future attempts may be made to modify it, as and when attenuation relations based on Indian data become available.

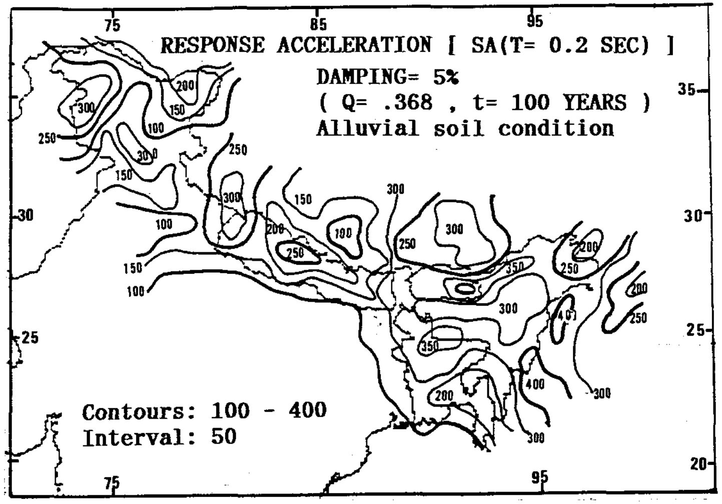

Fig. 1 Expected spectral acceleration map at T=.2 sec

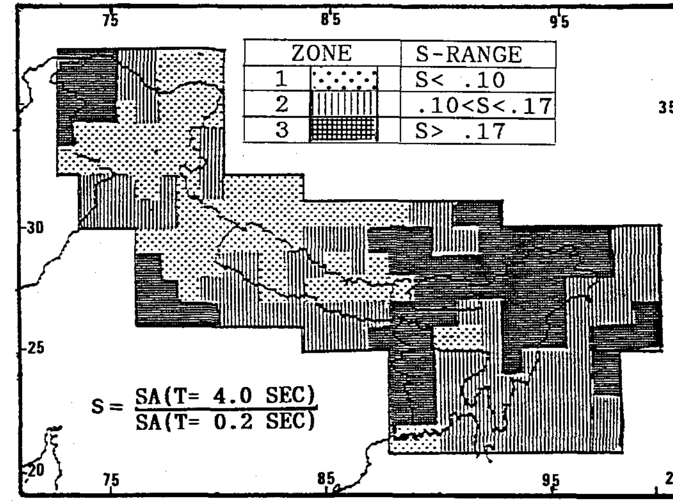

Fig. 2 Spectral characteristic zonation (S-zoning)

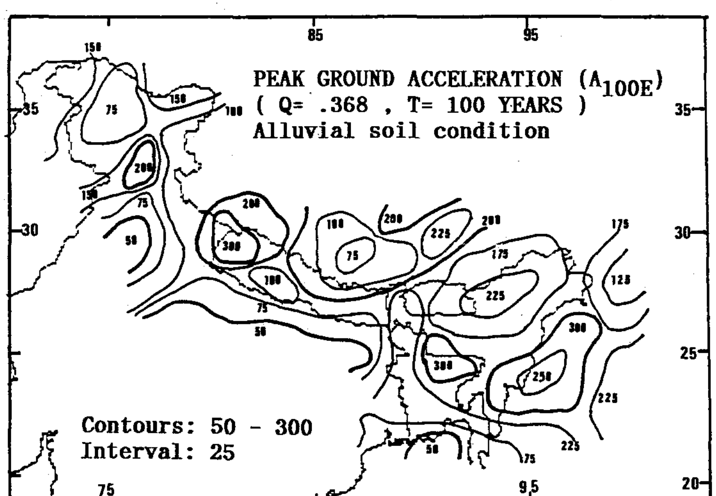

Fig. 3 Expected maximum acceleration map

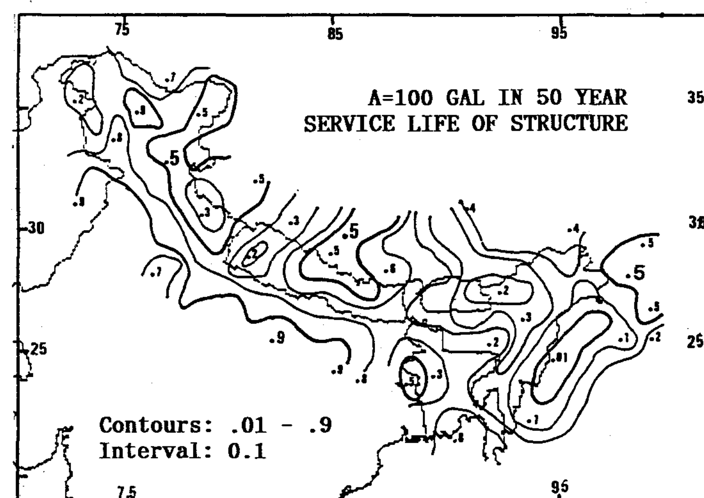

Fig. 4 Probability of non-exceedance contour map

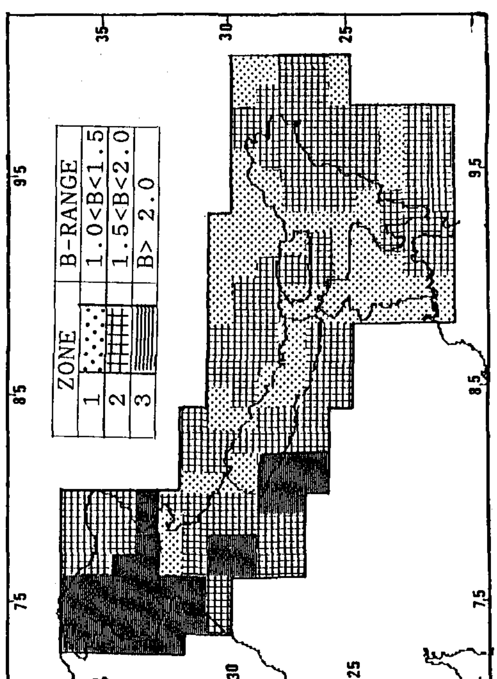

Fig. 5 Zonation based on relative contribution of different shaking levels (B-Zoning)

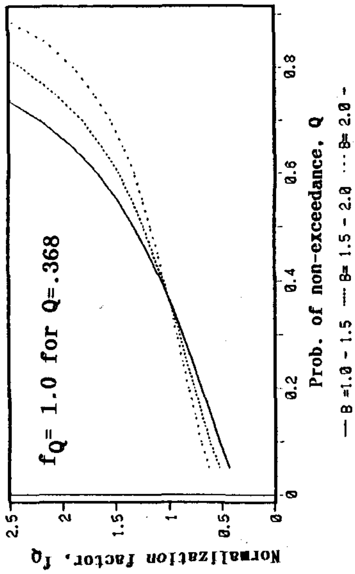

Fig. 6 Variation of PGA with probability of non-exceedance (Q)

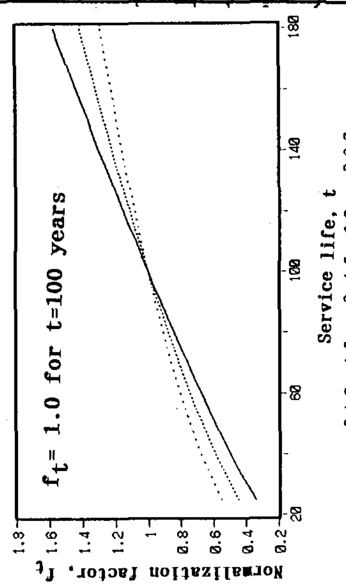

Fig. 7 Variation of PGA with service life (t)

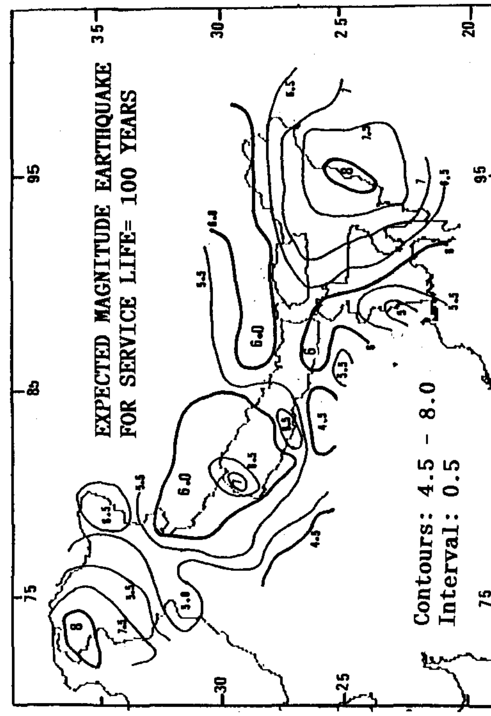

Fig. 8 Expected magnitude map

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