EARTHQUAKE HAZARD SCENARIO IN GREATER SYLHET REGION

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Introduction

For Bangladesh, earthquake hazard constitutes a constant threat to human life and property. The first step in reducing the risk of the society from earthquake hazard is an assessment of the hazard itself. Both the seismic hazard analysis and the establishment of seismic hazard maps were made difficult in Bangladesh due to the lack of homogeneous, accurate and complete data. Today, after the re-evaluation of the seismicity of Bangladesh and adjacent regions (Sharfuddin, 2000), it became possible to produce these maps. Among all the areas of Bangladesh greater Sylhet region, north-east of capital Dhaka is the most earthquake prone area. Recently three major earthquakes have affected Bangladesh, one of which was in the Sylhet region that have caused extensive damage to brick masonry structures (police station, school buildings, markets etc.). For this purpose, this paper intends to assess the seismic hazard and to produce earthquake hazard maps for greater Sylhet region of Bangladesh. An earthquake-zoning map for engineering purposes is a map that specifies the levels of the maximum ground motions (forces) for earthquake-resistant design. Seismic hazard maps are practical tools in seismic design of structures because they provide important guidance when it is not feasible to do the earthquake hazard assessment at particular sites. These maps give a good indication on the areal extent of expected strong shaking for large earthquakes. This paper proposes earthquake magnitude and peak ground acceleration (PGA) values for greater Sylhet region that is to be considered for return periods of 50, 100, 200 years. Also a return period seismic hazard map for $PGA \geq 150$ cm/s^2 is presented. These information will be useful for seismic design of structures in the region.

Zone under Investigation

In this study, an attempt is made to assess the seismicity of greater Sylhet area (24-26 north latitude and 91-93 east longitude), as shown in Fig. 1. The region under study has similar geological process and similar historical development. Similarities in population settlements, building stock characteristics and socio-economic and demographic conditions, etc., are very important parameters in the whole process of seismic hazard studies in the region.

Seismic Hazard Analysis Methodology

For earthquake hazard assessment in a given site numerous methods are available today. Lomnitz and Epstein (1966) employed the Poisson process for the occurrence of large earthquakes which is still used. Cornell (1968) and Esteva (1968) derived the general basis for the most complete analysis of the whole seismic hazard problem with the inclusion of the propagation mechanism of the ground motion. Shah and Vagliente (1972) used the Markov model of earthquake prediction in seismic hazard analysis. A methodology for seismic hazard estimation based on historical earthquake occurrences is presented in detail in Tomatsu and Katayama (1988) and Molas and Yamazaki (1994). The seismic hazard evaluation at a specified site depends upon the definition of the following four conditions:

(a) *An earthquake source model.* It is based on geological evidence, seismic sources are identified and modelled as a point, line, area or dipping plane. In this study, an annular source model is used.

(b) *A seismicity model.* The seismicity of each of the modelled sources is first determined from past data available. The recurrence relationship relating the size of the past events in terms of Peak Ground Acceleration (PGA) is derived. The seismicity model used in Tomatsu and Katayama (1988) and Molas and Yamazaki (1994) is usually taken as

$$\log(v) = a + b\log(y) \qquad (1)$$

where y is the peak ground acceleration, n is its occurrence rate and a and b are regression constants. This relation can be written as

$$\log(y) = (-\log(T) - a)/b \qquad (2)$$

where $T (=1/v)$ is the return period of T yr. Thus, Eq (2) represents the peak ground acceleration with a return period of T yr.

(c) *An attenuation model of ground motion information.* This describes the transfer of ground motions from the source to a particular site as a function of magnitude, distance and soil conditions. Here, the peak ground acceleration is used to characterize the ground motion; the attenuation law is in the form

$$\log(y) = b_1 + b_2 (Ms) - b_3 \log(r) - b_4 (r) \qquad (3)$$

where $r^2 = d^2 + h^2$, r is the hypocentral distance (km), d is the epicentral distance (km), h is the focal depth (km), y is the peak ground acceleration, and Ms is the surface-wave magnitude. This attenuation law is required to determine the regression constants a and b. Then, a linear regression fitting is carried out at each given site within the region under consideration.

(d) *A recurrence forecasting model.* Various statistical models have been tested in research papers; however, for practical purposes, earthquakes are considered to be random events, and the Poisson process is used, which implies assumptions of stability and independence over time.

Earthquake Source Data

The results of any study based mainly on an inventory of data available from different sources is subject to the quality and completeness of the information. The newly compiled earthquake catalogue for Bangladesh (Sharfuddin, 2000) is used in this research work. This catalogue is as homogeneous, complete and accurate as the available macroseismic and instrumental data allow. The earthquake data set used in this work has been re-evaluated with a consistent process and is considered to be reliable in both homogeneity and completeness. It is of interest to mention that the seismicity of Bangladesh goes back well before 1900; for this study, the earthquake data are collected between 1869 to 1995 by reviewing instrumental data and macroseismic information retrieved from various sources. The geographical distribution of epicentres of this earthquake catalogue for greater Sylhet region is shown in Fig. 2.

This catalogue was analysed for completeness using the method proposed by Stepp (1971). This method determines the time period in which the estimate of the occurrence rate of a certain magnitude class is stable. The Bangladesh earthquake catalogue was found to be complete for $Ms \geq 3.0$ from 1964; $Ms \geq 4.0$, from 1964; $Ms \geq 5.0$, from 1923; $Ms \geq 6.0$, from 1927; $Ms \geq 7.0$ from 1869. It is needed to mention that to establish the occurrence rates of the peak ground acceleration, only the earthquakes whose magnitudes are within the class of completeness for the specific period are used.

Attenuation Law of Peak Ground Acceleration

The quantitative assessment of seismic hazard at any particular site within a region requires an attenuation law for the Peak Ground Acceleration (PGA). The maximum ground motion to be expected in the site constitutes a crucial problem in earthquake engineering. For Bangladesh, as in many other parts of the world, no PGA attenuation law has been developed, due mainly to the shortage of strong motion data. However, in order to assess the seismic hazard in this region, we have to adopt an attenuation law from the literature. A great amount of PGA attenuation relationships, predicting strong ground motions in terms of magnitudes, distance, site geology, and in some cases other factors, using various models and data sets are established for different parts of the world. Reviews of these laws are presented in Campbell (1985) and Joyner and

Boore (1988). In this study, the attenuation law for alluvial soil proposed by McGuire (1978) has been used. This equation is presented below:

$$y = 0.0306 e^{0.89M} r^{-1.17} e^{-0.2} \quad (4)$$

where M is the magnitude and r is the hypocentral distance (km) and y is the PGA (cm/s^2). For this calculation h is assumed to be 30 km and $r = \sqrt{h^2+d^2}$ (d is the epicentral distance).

Results of Earthquake Hazard Mapping

In order to estimate the seismic hazard within a given region with a certain degree of reliability, the whole region is subdivided into a large enough number of grids of which the intersections constitute the sites where the selected seismic hazard parameters (e.g. PGA, Intensity, Return Period) are calculated. Then contour lines are drawn, linking all different sites with equal seismic hazard. This contour lines map is known as an earthquake hazard map for the region considered.

Selection of Earthquakes around the Site

To estimate the seismic hazard in any particular site within a region requires a selection of earthquakes which affect significantly the value of the hazard output. However, there is no strict rule for selecting the maximum epicentral distance to the site. A sensitivity study for different maximum epicentral distances, for three sites in the region considered, was carried out to show the influence on the seismic hazard evaluation, as shown in Fig. 3. A small area around the site results in a smaller number of earthquakes to be considered and some events outside the zone considered may affect the hazard in the site. This, naturally, will decrease the data set for regression. On the other hand, a too large area may include earthquakes which do not affect the seismic hazard in the site and are thus useless. The findings show that for an epicentral distance of 200 km and beyond, the b-coefficient of the Gutenberg-Richter formula is relatively stable. Thus, it is assumed that significantly earthquakes are equally likely to occur anywhere in the area of 200 km in radius surrounding the sites under consideration. Figure 4 shows the regression curve fitting for a site. The evaluation of seismic hazard at a site is carried out only if the number of earthquakes in the area considered (200 km radius) is larger than 10 and the surface-wave magnitude is equal to or greater than 4.0.

Earthquake Hazard Maps

Greater Sylhet region, as defined in Fig. 1, has been first divided into a number of grids. Earthquake hazard is estimated in terms of (1) expected peak

ground horizontal accelerations for 50, 100 and 200 year return periods, and (2) return period in years for PGA≥150 cm/s^2 which is considered as an important value in engineering purposes. Figures 5 to 7 show the geographical distribution of the expected peak ground acceleration for a return period of 50, 100 and 200 years respectively using McGuire's horizontal attenuation law. In greater Sylhet region, the highest seismic hazards are found to be in the areas which were struck by several damaging earthquakes during the last and the current centuries which are 1869 Cachar earthquake, 1897 Great Bengal earthquake and 1918 Srimangal earthquake. Figure 8 shows a seismic hazard assessment in Bangladesh in terms of return period in years for PGA≥150 cm/s^2, using McGuire's horizontal attenuation law.

Conclusions and Recommendations

The seismic hazard maps for greater Sylhet region are constructed in terms of expected peak ground accelerations and return period in years for PGA≥150 cm/s^2 which should be of great use in the social and economic development strategies of the region under study. It is of interest to mention that every 10 to 15 year, while more data on earthquakes are accumulated and seismological understanding improved, these maps should be renewed. Due to the lack of a seismotectonic map in the region under consideration, in order to make a probabilistic (source based) hazard analysis we used a catalogue-based earthquake hazard mapping. This scenario is very common for many developing countries and this methodology will benefit many who are most affected by earthquake disasters. These seismic hazard maps are addressed to a broad range of users, including high-level government officials, administrators, civil engineers, architects, earth scientists, seismologists, planners, technical experts and researchers in all these disciplines.

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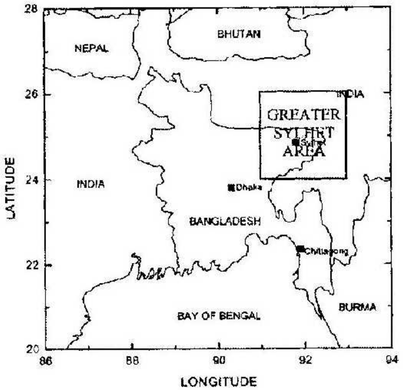

Figure 1: Map showing the limits of Bangladesh and adjacent region

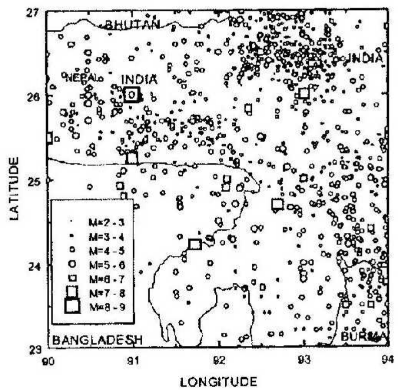

Figure 2 : Geographical distribution of seismicity of Greater Sylhet

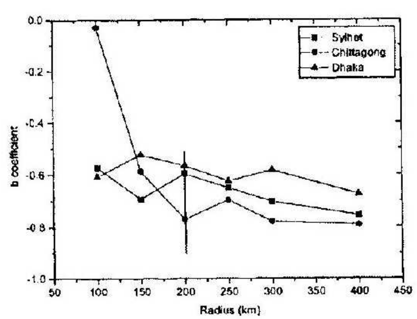

Figure 3 : Sensitivity of b-coefficient to the increase in radius

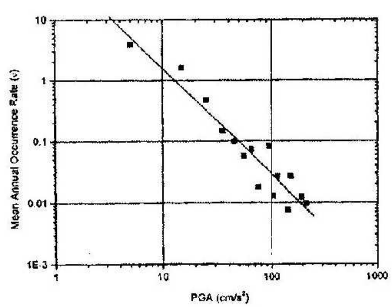

Figure 4:PGA versus mean occurrence rate for Sylhet (91.80 E and 24.85 N)

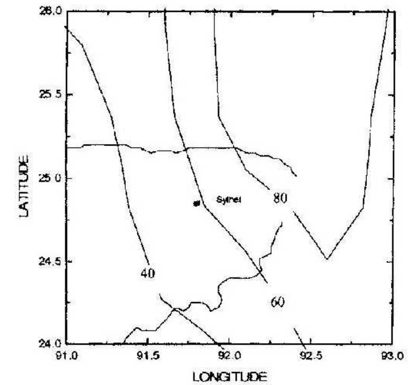

Figure 5: 50-Year PGA (cm/s^2) using McGuire attenuation law

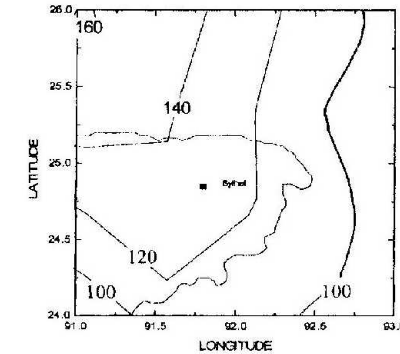

Figure 6: 100-Year PGA (cm/s^2) using McGuire attenuation law

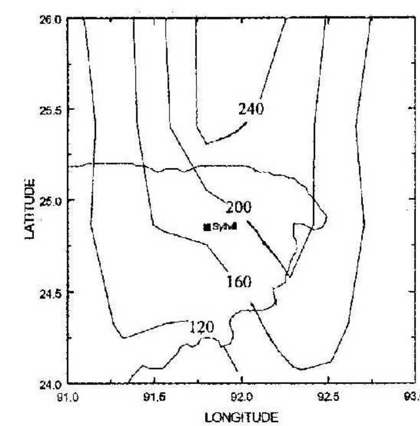

Figure 7. 200-year PGA (cm/s^2) using McGuire attenuation law

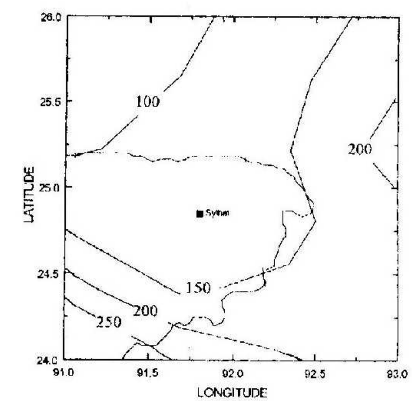

Figure 8. Seismic hazard in terms of return period in years for PGA≥150 cm/s^2 using McGuire attenuation law

References

Campbell, K.W. (1985). "Strong motion attenuation relations: a ten year perspective". *Earthquake spectra*, 1, 759-804.

Cornell, C.A. (1968). "Engineering seismic risk analysis". *Bull seism. soc. Am.* 58, 1583-1606.

Esteva, L. (1968). "Bases para la formulacion de decisiones de diseno sismico". Instituto de Inginiera, No. 182, Universidad Nacional Autonoma de Mexico.

Joyner, W.B. and D. W. Boore (1988). "Measurement, characterization and prediction of strong ground motion". *Proc. ASCE conf. earthquake eng. soil dyn.*, Park City, Utah, 43-102.

Lomnitz, C. and B. Epstein (1966). "A model for occurrences of large earthquakes". *Nature* 211, 954-956.

McGuire, R.K. (1978). "Seismic Ground Motion Parameter Relations". *Journal of Geotechnical Engg. Division, ASCE*, 104, 481-490.

Molas, G.L. and F. Yamazaki (1994). "Seismic microzonation of Philippine based on seismic hazard analysis". *Structural eng. earthquake eng.*, 2(1), 33-43.

Shah, H.C. and V. N. Vagliente (1972). "Forecasting the risk inherent in earthquake resistant design". *Proc. int conf. on microzonation*, Vol. 2.

Sharfuddin, M. (2000). *Earthquake Hazard Analysis for Bangladesh*. M.Sc. Engineering Thesis, Department of Civil Engineering, BUET, Dhaka, Bangladesh.

Stepp, J.C. (1971). "An investigation of earthquake risk in the Puget sound area by use of the type I distribution of large extremes". Ph.D. Thesis, Pennsylvania State university, State College, USA.

Tomatsu, Y. and T. Katayama (1988). "An online graphic computer program [ERISA-G] and its application to seismic macrozonation of Japan". *Proc. 9th world conf. on earthquake eng.*, Tokyo-Kyoto, Japan Vol. 2, 181-186.