Seismic Hazard Maps of Yangon and Its Surrounding Areas

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Abstract The purpose of this study is to develop probabilistic seismic hazard maps for Yangon and its surrounding areas including ‘Peak Ground Acceleration’ values for 2% and 10% probability of the exceedance in 50 years at rock sites. The present study area is situated between the latitudes of N 13°37′ and N 20°2′ and the longitudes of E 93°35′ and E 99°5′. The study areas are focused on nine source zones centered around Yangon with the radius of about 200 km. The probabilistic seismic hazard maps are created by ArcGIS-9.3 software.

Keywords seismic hazard; peak ground acceleration; Yangon

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Introduction

Myanmar is located at a long active tectonic belt extending from the Himalayas to the Sunda Trench.[1] Historically, Myanmar has experienced many earthquakes.[2,3] Yangon is situated in the southern part of the Central Lowland, which is one of three major tectonic provinces of Myanmar. The Taungnio Range of the Gyophyu catchments area of Taikkyi District, north of Yangon, through the Thalyn Ridge, south of Yangon forming a series of isolated hills is probably resulted from the progressive deformation[4] of the Upper Miocene rocks as the eastern continuation of the subduction or stretching and compression along the southern part of the Central Basin and regional uplifting of the Bago Yoma. The Sagaing Fault, which is located about 40 km east of the Shwedagon Pagoda, is a regional right hand strike-slip fault trending in the north-south direction.[5]

The purpose of this study is to provide seismic hazard curves and hazard maps for the study area in terms of ‘Peak Ground Acceleration’ for 2% and 10% probability of the exceedance in 50 years and site classifications in rock type. The peak ground acceleration values are calculated based on the attenuation relationship.[6]

The highest hazard levels have been observed at the source zone 1 (longitude 93.33° and latitude...
18.18°) and source zone 6 (longitude 95.45° and latitude 16.37°). The lowest hazard level has been observed in the source zone 4 (longitude 96.44° and latitude 16.21°) and source zone 7 (longitude 96.10° and latitude 17.37°). These hazard levels are very useful and recommended for building the codes of Yangon and its surrounding areas.

1 Earthquake catalogue

The present study area is centered around Yangon with the radius of about 200 km. The seismicity of the area bordered by 13°37’ N−20°2’ N and 93°35’ E−99°5’ is mainly compiled from the catalogues for Yangon and its surrounding areas. The level of seismicity in the region is quite low, and the historical record is 31 years (in Fig.1, cited from http://www.usgs.gov.eq/). The geological data such as paleoseismic recurrence intervals and slip rates are expected to provide the primary basis for recurrence characterization of the faults.

![Distribution of earthquake events (1975–2006 August 31)](Fig.1)

2 Probabilistic seismic hazard assessments

We performed probabilistic seismic hazard assessments (PSHA), using a method that deduces the causative sources, characteristics, and ground motions for future earthquakes. This method was first put forward by Cornell, and it has had broad applications since then. The analysis methodology is based on the concept that the seismic hazard at a site is a function of three basic elements: an earthquake source, a controlling earthquake of specified size, and a parameter of hazard definition such as “the peak ground acceleration” at the considered distance to the site of interest.

By taking into account the entire available database on seismicity, tectonics, geology and attenuation characteristics of the seismic waves in an area of interest, the seismic hazard analysis is used to provide an estimate of the site-specific design ground motion at the site of a structure. One important application of hazard analysis is the preparation of the seismic zoning maps for generalized applications.

2.1 Seismic sources

The study areas of nine source zones are centered around Yangon with the radius of about 200 km, see Table 1.

| Source zone | Latitude (°N) | Longitude (°E) |
|-------------|--------------|----------------|
| 1           | 18.18        | 96.33          |
| 2           | 17.79        | 96.97          |
| 3           | 17.00        | 96.61          |
| 4           | 16.21        | 96.44          |
| 5           | 15.00        | 96.42          |
| 6           | 16.37        | 95.45          |
| 7           | 17.37        | 96.10          |
| 8           | 17.47        | 95.61          |
| 9           | 18.53        | 95.56          |

2.2 Attenuation relationship

The following equations provide the ground motion in terms of moment magnitude, distance, and site conditions for strike-slip faulting mechanism:

\[
\ln Y = b_1 + b_2 (M_w - 6) + b_3 (M_w - 6)^2 + b_4 \ln r + b_5 \ln(V_s / V_d)
\]

where \(Y\) is the ground-motion parameter (peak horizontal acceleration or pseudo-acceleration response in g), \(M_w\) is the moment magnitude, \(V_s\) is the average shear-wave velocity up to the depth of 30 m (in m/sec), \(b_i (i = 1, 2, 3, 5)\), \(h\), and \(V_d\) are the coeffi-
cient to be determined, \( r \) is the distance in km, determined by
\[
r = \sqrt{r_{bh}^2 + h^2}
\]
(2)

\( r_{bh} \) is the closest horizontal distance to the surface projection of the rupture plane (km).

3 Seismic hazard calculations and probabilistic seismic hazard maps

Peak ground acceleration (PGA) is the strong ground motion parameter for which the calculations were performed. The empirical predictive relations that were used are the ones proposed by Skarlatoudis et al.\[18\]. For the selected site at Yangon and its surrounding areas, the annual frequencies of the exceedance for a number of ground motion levels were calculated by the equation of Reiter.

\[
E(z) = \sum_{i=1}^{N} \alpha_i \int_{m_0}^{m_u} f_i(m) \left[ \int f_j(r) P(Z > z/m, r) dr \right] dm
\]

where \( E(z) \) is the expected number of the exceedances of ground motion level \( z \) during a specified period of time \( t \), \( N \) is the number of earthquake sources, \( \alpha_i \) is the mean rate of occurrence of earthquakes between lower and upper bound magnitudes \( (m_0 \text{ and } m_u) \) in the \( i \)th source, \( f_i(m) \) is the probability density distribution of magnitude (recurrence relationship) within source \( i \), \( f_j(r) \) is the probability density distribution of site to source distances and \( P(Z > z/m, r) \) is the probability that a given earthquake of magnitude \( m \) and distance \( r \) will exceed ground motion level \( z \).

The seismic hazard curves for the rock site have been developed and figured out for the attenuation relationship of Boore et al.\[6\]. After the estimation of the maximum acceleration levels expected to be exceeded in 50 years, with a chance of 2% and 10%, the probabilistic seismic hazard maps for rock site at the intersections of grid lines were developed. These maps represent the levels of peak ground acceleration (PGA) with return periods of 2475 years (2% probability of exceedance in 50 years) and 475 years (10% probability of exceedance in 50 years) are shown in Fig.3 through Fig.6 for ‘rock’ sites. The MATLAB program was used in our calculations. The probabilistic seismic hazard maps (Figs.3, 4, 5 and 6) have been created by using ArcGIS-9.3 software.

Therefore, for Yangon and its surrounding areas, the probabilistic seismic hazard maps or iso-PGA contours developed by the attenuation relationship\[6\] for 2% and 10% probability of exceedance in 50 years. The 0.2 second spectral acceleration value (0.2 SA) is often selected to represent the short-period range of the response spectra for use in defining a uniform hazard response spectrum for various building codes. In general, the 0.2 SA represents the upper bound in spectral accelerations. The long-period range of the response spectra often selected for use in defining a uniform hazard response spectrum for various building codes is the 1-second spectral acceleration (1.0 SA).

![Fig 2: Hazard curves with 0.2s and 1s spectral periods based on Boore et al. (1997) attenuation relationship at rock sites for all sources](image-url)
4 Conclusion

The hazard maps and curves of mean annual rate of the exceedance for peak ground acceleration and spectral acceleration have also been generated at rock level. The seismic hazard maps for the study area has been developed by the attenuation relationship of Boore et al.\(^6\) for 2% and 10% probability of the exceedance in 50 years. The highest hazard levels have been observed at the source zones 1 and 6. The lowest hazard levels have been observed in the source zones 4 and 7. These results are significant in building the codes of Yangon and its surrounding areas for further usage.

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