RUPTURE BASED SEISMIC HAZARD ANALYSIS FOR FUTURE SEISMIC ZONATION- A CASE STUDY OF COIMBATORE

P. Anbazhagan, Department of Civil Engineering, Indian Institute of Science, Bangalore, anbazhagan2005@gmail.com
Prabhu Gajawada, Department of Civil Engineering, NIT Warangal, prabhugajawada@gmail.com
C V Smitha, Department of Civil Engineering, Indian Institute of Science, Bangalore, smithaprasad28@gmail.com

ABSTRACT: In this study presents ‘Rupture based seismic hazard analysis’ by identifying probable future earthquake zones. Seismotectonic map for Coimbatore has been generated using past earthquakes and seismic sources within 300 km radius around the city. The region has experienced a largest earthquake of moment magnitude 6.3 in 1900. Eight probable locations have been identified. Characteristic earthquake moment magnitude of 6.4 is estimated considering the regional rupture character of 5.2% of total length of source with additional 15% (i.e. 6%). The PGA due to the probable earthquake is calculated using the regional attenuation model. The final PGA map arrived is compared with that developed using DSHA. The probable earthquakes gave less PGA than that obtained using DSHA.

INTRODUCTION
Seismic hazard parameters are essential components of earthquake resistant design. Seismic hazard parameters are estimated and mapped in macro level and micro level based on study area. The process of estimating seismic hazard parameters is called seismic hazard analysis. Seismic hazard can be analyzed both in deterministic and in probabilistic ways. Seismic hazards can be analyzed deterministically as and when a particular earthquake scenario is assumed. The probabilistic approach is the other way of hazard analysis, in which uncertainties in earthquake size, location, and time of occurrence are explicitly considered [1]. Probabilistic seismic hazard analysis does not give a specific or unique choice but it gives infinite choices for the user [2]. Krinitzsky [3] comments on the problems in the application of probabilistic methods and gives an account on a deterministic alternative which highlights that Deterministic Seismic Hazard Analysis (DSHA) uses geology and seismic history to identify earthquake sources and to interpret the strongest earthquake each source is capable of producing regardless of time, because that earthquake might happen tomorrow. Those are the Maximum Credible Earthquakes (MCEs), the largest earthquakes that can reasonably be expected.

RaghuKanth and Iyengar [4] have pointed that the Indian Standard in current form does not provide a quantified seismic hazard for each region but lumps large parts of the country into unstructured regions of equal hazard. The current hazard zoning map adopted by Indian Standards prescribes lower hazard for regions without significant record of historical earthquakes [5]. A seismotectonic map of Coimbatore city has been generated in this paper and areas of reported damaging earthquake and area of little or no seismic activity in the past have been identified. Subsurface rupture length of past earthquakes were estimated and used to establish rupture character of the region. According to energy release theory, earthquakes relive the strain energy that builds up on faults; they should be more likely to occur in areas where little or no seismic activity has been observed for some time [1]. Potential seismogenic sources are identified and these locations are called as probable earthquake zones for the region. Eight such probable places are identified in and around Coimbatore. Maximum characteristic earthquake magnitude is estimated by considering regional rupture character and length of seismogenic source close to zone. Coimbatore is divided into grids and hypocentral distances from these eight locations to each grid point are calculated. PGA at each grid is estimated by considering hypocentral distance and maximum credible earthquake at eight locations by using regional attenuation model. The maximum PGA value among eight PGA values from eight probable zones is considered as the hazard value for each grid and these values are mapped. Then conventional deterministic hazard analysis has been carried out and PGAs are estimated. PGA arrived from the DSHA is compared with that obtained in proposed rupture based analysis.

STUDY AREA OF COIMBATORE
The city of Coimbatore located between 10° 10’ and 11° 30’ of the northern latitude and 76° 40’ and 77° 30’ of eastern longitude in the extreme west of Tamil Nadu near Kerala state at an elevation of 432 meters from the sea level. Its geographic location is mean valued to 11.01° N 76.96° E as shown in Fig. 1. Coimbatore falls under Seismic Zone III as per IS 1893 [6], and has experienced an earthquake moment magnitude 6.3 in the past. This earthquake was reported at 10.80° N, 76.80° E on 8th of February 1900. The city is surrounded by mountains on west and northern side with reserve forests and river basin (Nilgiri Biosphere Reserve), the eastern side of the district starting from the city is predominantly dry. The entire western and northern part of the district borders with Western Ghat with Nilgiri biosphere, Annamalai and Munnar range with a western
pass

REGIONAL ATTENUATION MODEL
Seismic hazard analysis of particular region needs ground motion predictive equation/ attenuation models. Coimbatore, South India has almost no strong motion records for moderate to larger earthquakes. Therefore, there is no ground motion predictive equation/attenuation model developed considering the recorded earthquake data. For the area having poor seismic record, synthetic ground motion models is the alternative. There was no ground motion predictive equation before 2004 for Peninsular India, in particular, South India. Iyengar and RaghuKanth [7] have developed first ground motion attenuation relation based on the statistically simulated seismological model. In this study, PGA at rock sites has been estimated considering relation given by Iyengar and RaghuKanth [7], which is given below:

\[
\ln y = c_1 + c_2 (M - 6) + c_3 (M - 6)^2 - \ln R - c_4 R + \ln \varepsilon \quad (1)
\]

Where \( y \), \( M \) and \( R \) refer to PGA (g), moment magnitude and hypocentral distance respectively.

SUB SURFACE RUPTURE CHARACTER OF THE REGION
The tectonic features of region should refer to various faults, folds, shear zones and lineaments with associated past earthquakes and future seismicity be expected to occur [8]. Seismotectonic parameters are also useful to build knowledge on the rupture character of earthquakes in the region and to foresee the seismic hazard parameters. The knowledge of the maximum size of fault ruptures in the region helps one to estimate the maximum earthquake magnitude that may occur in the region. Best established are the relationships between moment magnitude \( M_w \) and subsurface rupture length (RLD) and is valid for the magnitude range of 4.8 to 8.1 and length/width range of 1.1 to 350 km, which is as follows.

\[
\log(\text{RLD}) = 0.59 M_w - 2.44 \quad (2)
\]

Wells and Coppersmith [9] equations are widely used to estimate source parameters and magnitudes [7] and [10]. Wells and Coppersmith [9] have also considered the magnitude and source parameters from Indian earthquake data [11]. Rupture character of the region has been established by carrying out parametric studies between subsurface rupture length and earthquake magnitude.

PROBABLE FUTURE RUPTURE ZONES
Most of the hazard analyses/zonations are being carried out considering past earthquake location, size and rate of occurrence of earthquakes on the fault or in the region for future design of structures. Moderate to major earthquakes need sufficient energy to rupture the faults. Time required to buildup the required energy to create moderate to major earthquakes is a region specific. So, interval between two consecutive earthquakes in the same location is considerable, but it is accounted poorly in the hazard analysis and future seismic zonation. Based on the average return period of earthquakes in the region, one can assess the potential location for future earthquake for seismic zonation considering past earthquake and seismogetic activity of region. Let the place/source having earthquake magnitude, \( M \) with average return period, \( T \) be ruptured by an amount, \( R \). Average maximum magnitude reported in the region is \( M_{\text{max}} \). If \( M \) and \( M_{\text{max}} \) are relatively comparable the possibility of occurrence of the same \( M \) or \( M_{\text{max}} \) in the
same location is rare up to period T. Hence probable seismic source location for future seismic zonation for a period less than T, the past earthquake locations can be omitted or considered as areas of limited potential for occurrence near future earthquake.

Considering this Anbazhagan et al. [11] attempted ‘Rupture Based Seismic Hazard Analysis’ (RBSHA) for future zonation. Steps are RBSHA with case study can be found in Anbazhagan et al. [11]. In this study, total earthquake data are divided into two categories. The first category includes the earthquakes of moment magnitude 5.0 and above i.e., damaging earthquakes. Here, damaging earthquake (Mw of 5 and above). The second category includes all earthquakes of moment magnitude is less than 5.0 (minor earthquakes). Eight probable earthquake zones have been identified in the proposed method considering seismic sources and the divided earthquakes. Fig. 2 shows identified probable locations with seismotectonic details. The probable future earthquake zones identified in this paper are compared with the recent seismogenic sources mapped by Ramasamy [12] and Gupta [8]. These comparisons are discussed in detail in Anbazhagan et al., [11].

The PGA at each grid point due to earthquake at each of the eight zones are calculated and mapped. The PGA map of Coimbatore due to earthquake at zone 1 is shown in Fig. 3. Similarly, the PGA maps of Coimbatore due to earthquakes at other seven probable zones are also mapped and presented in Anbazhagan et al [11]. The maximum PGA value among eight PGA values from eight probable zones is considered as the hazard value for each grid and these values are mapped. The final PGA map is shown in Fig.4 which serves as the new seismic zonation map of Coimbatore for future seismic activity. The PGA is calculated by carrying out conventional Deterministic Seismic hazard analysis and is mapped. Seismotectonic map in Fig. 2 shows that many minor to damaging earthquakes are reported within the radius of 100 km around Coimbatore city. There were three damaging earthquakes, i.e. Mw greater than 5.0 namely, Mw 6.3 and 5.7 at 10.80°N 76.80°E, Mw 5.7 at 11.46°N 76.7°E and Mw 5.3 at11N 77E. These three earthquakes and associated sources have been considered for PGA estimation. MCE has been estimated by increasing 0.5 units to past earthquake similar to...
previous study in the region. The PGA for every grid point in Coimbatore is calculated for this earthquake and the PGA map is plotted. Fig 5 shows PGA distribution in Coimbatore city by DSHA approach. The maximum PGA in Coimbatore is found to be 0.44 g and is observed at south western part of the city. The minimum PGA is found to be 0.29 g and is observed at North eastern part of Coimbatore city. By comparing Fig. 4 and 5, it can be easily observed that DSHA PGA values and distribution pattern completely differ from those of proposed rupture based analysis.

Fig. 5 Seismic zonation map of Coimbatore based on deterministic seismic hazard analysis

CONCLUSIONS
Seismic hazard values of PGA are conventionally mapped considering past earthquake and its recurrence interval. Most of the time, earthquakes may not occur in the same zone because it needs time to store strain energy, particularly in intraplate regions. In this paper a new attempt has been made to locate future probable earthquake zones considering subsurface rupture phenomena and hazard values are estimated at rock level considering proposed approach. Ruptured seismic sources are delineated by drawing influence circles considering subsurface length of the damaging earthquakes. These locations are considered as limited probable locations for future earthquake for a period of 50 to 100 year, because the average return period of intraplate damaging earthquakes is about 200 to 500 years. Eight probable earthquakes zones are identified for near future earthquakes. These eight zones identified in this study match well with the seismogenic sources in the region identified by other researchers and away from past major earthquakes. PGA values arrived from new approach are more than that of previous studies in the region and are comparable with recent studies. PGA values arrived from new method are compared to conventional deterministic approach. Conventional approach gives higher PGA values when compared to proposed approach. Proposed approach is found to be more appropriate for future zonation and microzonation for disaster management as the seismic zones are well defined and are not associated with past damaging earthquake locations.

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REFERENCES