Fuzzy-Logic Tree Approach for Seismic Hazard Analysis

Prasad Hiremath
M.Tech Student
Department of Geotechnical Engineering
NIT Warangal
Warangal, India

G. Kalyan Kumar
Assistant Professor
Department of Geotechnical Engineering
NIT Warangal
Warangal, India

Abstract- **This study presents an approach for seismic hazard analysis based on logic tree and fuzzy sets theory. To accomplish seismic hazard analysis in the framework of fuzzy sets theory, all of the variables are first converted into fuzzy sets using α-cut method. Calculations are made for various combinations of them and also applying logic tree approach. Extracted output in the framework of fuzzy are defuzzified using mean of maxima method. The method is applied to Warangal district of Telangana, where the hazard curve is already obtained using Probabilistic seismic hazard analysis (PSHA). Outcomes of this study would contribute for the quick and better estimation of the seismic design of structures.**

Keywords: Fuzzy method, logic tree, probabilistic approach, seismic hazard analysis

I. INTRODUCTION

Indian peninsular shield, which was once considered to be seismically stable, has shown that it is becoming active. In the last three decades large earthquakes have caused massive loss of lives and extensive physical destruction throughout the world Seismic activity of India is clearly evident from these recent earthquakes within the intra plate and also along the boundaries of Indo-Australian Plate and Eurasian Plate. The recent seismicity has revealed that the Indian peninsular shield is no longer considered to be a stable land or seismically inactive region. Seismicity zone map of India shows Warangal district comes under zone II and Zone III. Warangal is the second largest city in Telangana state, after Hyderabad. Warangal in the Deccan plateau is home to the very classic and brilliant Kakatiyaart. The seismic hazard assessment of this region is of great importance to minimize the seismic risk and to predict earthquakes accurately. Seismic hazard may be analyzed using an empirical-statistical approach, which is based on historical data, or a deterministic approach, when a particular scenario is assumed, or a probabilistic approach, in which uncertainties in earthquake size, location, and time of occurrence are explicitly considered.Seismic hazard analyses involve the quantitative estimation of ground-shaking hazards at a particular site (Kramer, 1996).
Based on, logic tree approach and fuzzy set theory, the present study analysis the seismic hazard for the Warangal District and peak ground acceleration over bedrock are estimated for it.

II. SEISMICITY OF THE STUDY AREA

The study area selected for the present study is a circular area of 350 km radius, with NIT Warangal at its center. The geographical co-ordinates of the NIT Warangal are 17.98^0N Latitude and 79.53^oE Longitude.In order to understand the seismic characteristics of the study area, earthquake catalogue compiled by Chandra (1977) and Rao and Rao (1984) for the Peninsular India were used which span from 1800 to 1983 A.D (Fig. 1). The current earthquake catalogue for Warangal includes 337 earthquakes with $Mw \geq 3.0$ from 1800 to 2014(Fig. 2). Totally 19 earthquake events have been reported with magnitude greater than 5.0, with a maximum of Mw 6.5.

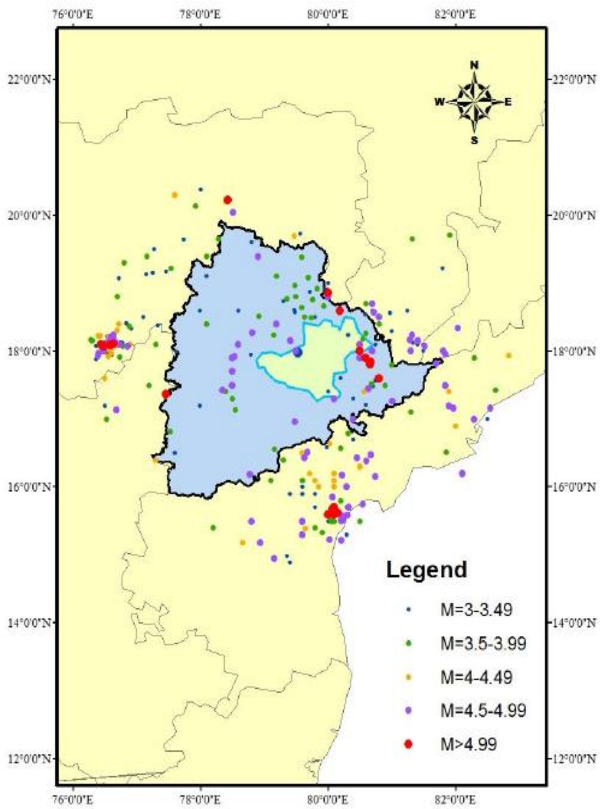

Fig. 1: Seismicity of the study area (1800-2014 A. D.)

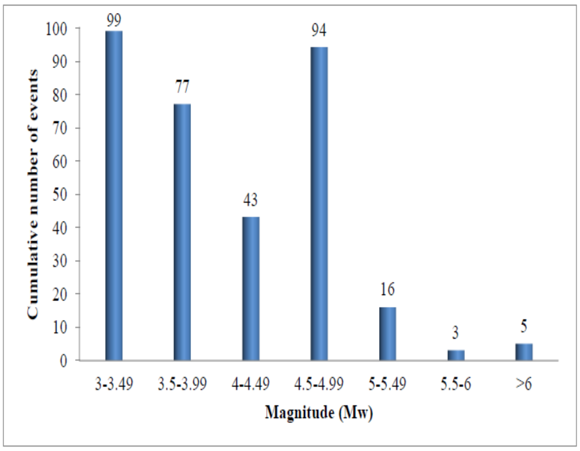

Fig. 2: Statistics of Warangal Earthquake Catalogue

III. SEISMIC SOURCE ZONING

A preliminary step in seismic hazard assessment is the definition of potential seismic sources that affect the site at which the hazard is estimated. This process, known as seismogenic zoning, is perhaps the most critical part of a hazard analysis, for which there are no general rules available yet to implement in a systematic manner. Seismic source zones have been drawn based on the information provided by the seismotectonics of the study area and historical seismic catalogue. Faults and Lineaments in the study area are digitized to identify possible sources of future earthquakes in the region as shown in Figure 3 and important faults and lineaments in the study area are listed in Table 1.

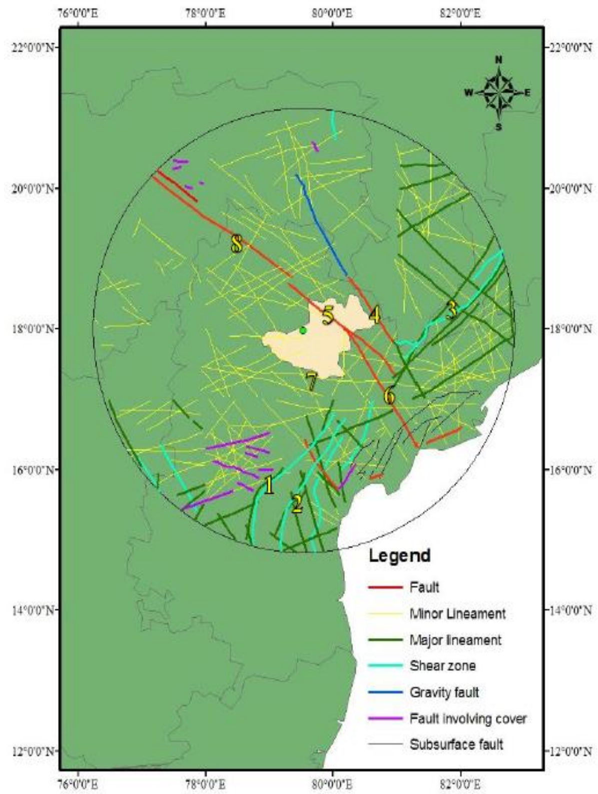

Fig. 3:Digitized faults and lineaments in the study area

Table 1: List of important faults and lineaments in the study area

Identification	Name of fault/lineament
1	Nallamalai Shear Zone
2	Cuddapah Eastern Margin Shear Zone
3	Sileru Shear Zone
4	Godavari Valley Fault
5	Kinnerasani Godavari Fault
6	Kolleru Lake Fault
7	Musi Lineament
8	Kaddam Fault

IV. ATTENUATION RELATIONSHIP

Since the attenuation relationship highly influences the results of seismic hazard analysis, the choice of a ground motion attenuation model is of great importance. However, because of inadequacy of usable data, there is not a well-constrained attenuation relationship for Indian peninsula. Therefore, four attenuation relationships are used in this study. PGA is the most commonly used ground motion parameter for the seismic hazard studies. The present study involved use of the following attenuation relationships developed by Raghu Kanth and Iyengar (2007), Abrahamson and Silva (1997), Campbell (2003) and Boore and Atikson (2008).

V. FUZZY SETS

Seismic hazard assessment like many other problems in seismology is a complicated problem, owing to the variety of parameters affecting the occurrence of earthquake. Uncertainty, which is a result of vagueness and incompleteness of the data, should be considered in a rationale way. Herein, fuzzy set theory is used to take into account the inherent uncertainty in the seismic hazard analysis. Fuzzy sets are groups whose components have grades of membership. It was first presented by Zadeh [6] who extended the classical concept of sets. Information is obtained from data, measurements, or past knowledge; approximations must often be made which in turn introduce uncertainties. Fuzzy sets signify vague information which required in the analysis. The data are fuzzy numbers, i.e., fuzzy variables defined on a real line in a fuzzy environment.

A. A- Cut Technique

Zadeh [6] presented α-cut or α-level set, which is one of the most significant concepts established as a link between fuzzy set theory and traditional set theory. Let *X* be a non-empty set, *F*(*X*) represents the set of all fuzzy sets of X. A is a fuzzy set in *X*, where, $A \in F(X)$ and $\alpha \in [0, 1]$. Then the non-fuzzy or crisp set:

$$A_\alpha = \{x \in X \mid \mu_A(x) \geq \alpha\} \qquad (1)$$

is called the α-cut or α-level set of *A*. If above equation is replaced by:

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A□ = {x ϵ X | □□□x) > α□ (2)

then is called a strong -cut. Any fuzzy set can be collected from a family of nested crisp sets satisfying equation (2), and the problems in the context of fuzzy sets such as decision making could be solved by transforming these fuzzy sets into their families of nested α-cuts and determining solutions to each of them using traditional techniques. Then all the partial results derived in this way are merged reconstructing a solution to the problem in its original fuzzy set based formulation.
In this study four of the input parameters including *d*, *ß*, *λ* and *M* are fuzzily defined by the discrete membership functions μ(d), μ(*ß*), μ(*λ*) and μ(*M*), respectively.

VI. LOGIC TREE

Input parameters to seismic hazard analysis (SHA) such as fault dimensions, recurrence rates, maximummagnitudes, attenuation relationships, etc. Often has to be estimated from limited data or determined by subjective judgment. Logic tree is a popular tool used to compensate forthe uncertainty in SHA. Logic tree reflects uncertainty byallowing the analyst to assign each parameter a range of values, along with an assessment of the probabilities thateach of these is the correct value [7]. The final result of thisprocess is a logic tree in which each of the value forms a branch. Fig. 4 shows the logic tree that considered the uncertainty in attenuation relationships and sources.

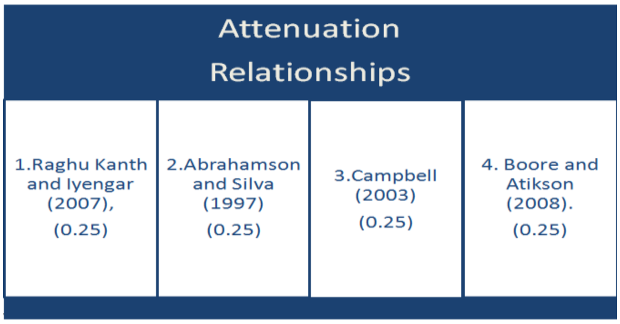

Fig. 4: Elements of logic trees in our SHA scheme and the assigned weights.

Each branch is weighted by the product of the weight assigned to it. Seismic hazard can then be assessed at each end nod. The reason for using the four different attenuation relationships rather than a single one in this paper is that available data does not have the required accuracy.

VII. CONCLUSION

In this study, we apply logic tree approach and fuzzy set theory to analysis seismic hazard of Warangal District. Calculations have been made for various combinations of variables with applying both fuzzy set theory and logic tree approach. The extracted outputs in the framework of fuzzy are defuzzified using mean of maxima method. Peak ground accelerations (Fig. 5) are estimated for 10% and 63% probability of exceedance in 50-year.

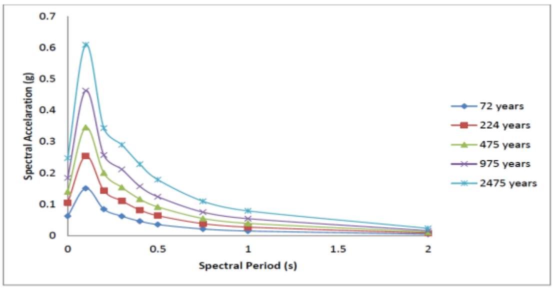

Fig. 5 Uniform Hazard Spectra for different return periods.

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