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# Uncertainties and its Role in Seismic Hazard Analysis of District Headquarter Dantewara, Chhattisgarh, India

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***Abstract****—In the present paper, an attempt has been made to estimate seismic hazard at bedrock level in terms of PGA using state of art probabilistic seismic hazard analysis. A detailed catalogue of historical and recent seismicity within 300 km radius around the city has been compiled and new seismotectonic map has been generated for the region. The completeness of the data should be checked before carrying out hazard analysis. Finally earthquake data was analyzed statistically and the seismicity of the region around District Headquarter Dantewara of Chhattisgarh, India, has been evaluated by defining 'a' and 'b' parameters of Gutenberg- Richter recurrence relationship. The Regional Recurrence Relationship and "b" value, 0.6974 is obtained for District Headquarter Dantewara. The Maximum value of Peak Ground Acceleration (P.G.A.) for recurrence period of 100 years was found to be due to the Godavari Valley Fault which came out to be equal to 0.06211 for 50 Percentile and 09887 for 84 Percentile. The seismic hazard curve prepared, for district Headquarter can be furthered used to find out the PGA values for various return periods for different probabilities (2%, 10%, 50% ) of occurrence .*

***Keywords—Fault, Seismic Source Models, Attenuation, Peak Ground Acceleration, Seismic Hazard.***

## I. INTRODUCTION

India is highly vulnerable to earthquakes, with more than 60% of the land being prone to tremors of Richter Intensity 7.0 and greater, that can cause structural damages. Earthquakes continue to cause large-scale human fatalities, most of which are due to collapse of man-made structures. Recent earthquakes have revealed the under-preparedness of the country in facing its impacts. Since short- or mid-term prediction of earthquakes is difficult, seismic safety of built environments that will ensure that structures do not collapse forms an important cornerstone of earthquake disaster mitigation efforts. Poor people in developing countries are particularly vulnerable to disasters because of where they live. To evaluate the seismic hazards for a particular site or region, all possible sources of seismic activity must be identified and their potential for generating future strong ground motion needs to be evaluated. Identification of seismic sources requires some detective work, nature's clues, some of which are obvious and others quite obscure, must be observed and interpreted. This paper presumes that the primary aim of any seismic hazard analysis is to produce a defensible, unbiased estimate of the mean seismic hazard at a specified site. The mean seismic hazard is sensitive to uncertainties in the component pieces that together form the hazard model. As a result, the important sources of uncertainty must be explicitly included and evaluated as a part of a comprehensive probabilistic seismic hazard analysis (PSHA).

Dantewara District or Dakshin Bastar District lies in the Indian State of Chhattisgarh. The district is part of Bastar Division. Until 1998, the Dantewara District was a tehsil, of the larger Bastar District. Dantewara District has an area of 10,238.99 km². The district has a population of 719,065 (2001 census), of which 476,945 (66%) are tribal peoples. After declaration of district, in Dantewara the construction activities are suddenly increased. So it is essential to pay focus towards earthquake Disaster and its mitigation. Earthquakes are common phenomena which occur most often irrespective of time and place. They are most feared amongst all natural hazards as they strike suddenly without any prior indication and create devastation to life and property. They are as yet not predictable; hence prior warning to people is not possible. Earthquakes are not killer by themselves but houses in which people reside kill them. During an earthquake poorly designed and built houses on weak foundation collapse and sometimes associated fire hazards kill the residents. In the present study Seismic Hazard Analysis (SHA) has been used to assess Peak Ground Acceleration for District Headquarter Dantewara (18° 54' N- 81° 21' E ) of Chhattisgarh state.

## II. METHODOLOGY

DSHA seismic hazard is based on a single earthquake scenario whereas PSHA integrates the effects of all future earthquakes for all possible magnitudes, at all significant distances from the site. As a result, instead of discrete, single-valued event and model used in DSHA, PSHA allows the use of continuous, multi-valued events and models. The probabilistic analysis allows the use of multi-valued or continuous model parameters. The probability of different magnitude or intensity of earthquakes occurring is included in the analysis. Another advantage of probabilistic seismic hazard analysis is that it results in an estimate of the likelihood of earthquake ground motions or other damage measures, occurring at the location of interest. It allows for the more sophisticated incorporation of seismic hazard into seismic risk estimates. Probabilistic seismic hazard estimates can be expanded further, to define seismic risk.

### *A. Seismic source characterization*

In present study District Headquarter Dantewara is selected as the target, including a control region of radius 300 km around the District Headquarter, having centre at 18° 54′ N - 81° 21′ E, and was considered for further investigation. The fault map of this circular region which was prepared in reference with the Seismo-tectonic Atlas of India (2000), is as shown in Fig. 1.

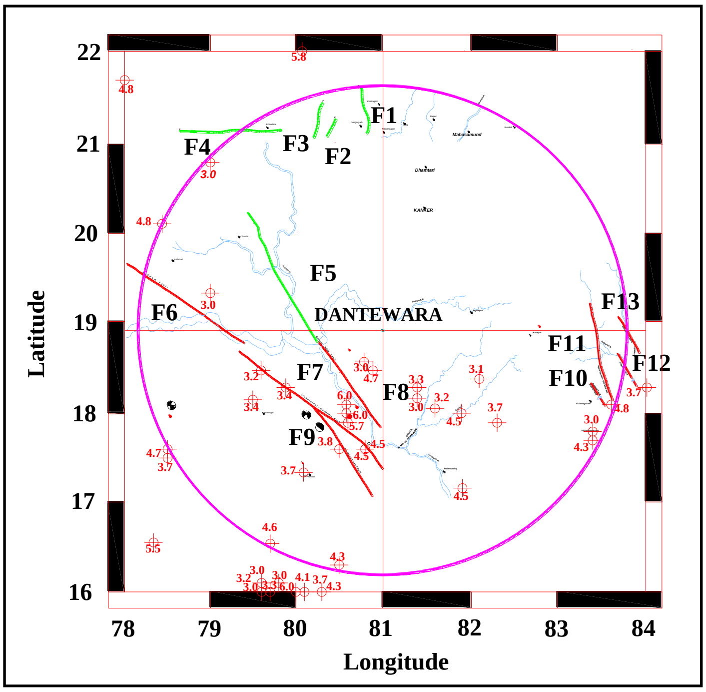


*Fig. 1 Fault Map for District Headquarter Dantewara*

Fault map for District Headquarter Dantewara *Fig.2*, shows that in recent years seismic activity appears to be concentrated along Kaddam Fault (174 km), Kinnerasani – Godavari Fault (228 km), Godavari Valley Fault(130 km), Kolleru Lake Fault (129 km), Kanada Fault (32 km), Parvatipuram- Bobbili Fault (121 km), Nagavali Fault (46 km) and Vamsadhara Fault (51km). A total of Thirteen (13) major faults, which influence seismic hazard at District Headquarter Dantewara, were identified. Fault details are tabulated in TableI.

TABLE I
DISTRICT HEADQUARTER DANTEWARA FAULTS CONSIDERED FOR HAZARD ANALYSIS

| **Fault no.** | **Length Li (kM)** | **Fault Name** | **Min. Map Distance (kM)** | **Focal Depth (kM)** | **Hypo Central Distance (kM)** | **Weightage Wi=Li/∑Li** |
|---|---|---|---|---|---|---|
| F1 | 58 | ---- | 242.975 | 10 | 243.181 | 0.0432 |
| F2 | 25 | ----- | 247.616 | 10 | 247.818 | 0.0187 |
| F3 | 45 | ----- | 251.265 | 10 | 251.464 | 0.0335 |
| F4 | 125 | ----- | 276.012 | 10 | 276.194 | 0.0931 |
| F5 | 180 | ----- | 81.862 | 10 | 82.471 | 0.1340 |
| F6 | 174 | Kaddam Fault | 170.93 | 10 | 171.223 | 0.1295 |
| F7 | 228 | Kinnerasani - Godavari Fault | 126.727 | 10 | 127.121 | 0.1697 |
| F8 | 130 | Godavari Valley Fault | 71.588 | 10 | 72.284 | 0.0968 |
| F9 | 129 | Kolleru Lake Fault | 128.103 | 10 | 128.493 | 0.0960 |
| F10 | 32 | Kanada Fault | 265.117 | 10 | 265.306 | 0.0239 |
| F11 | 121 | Parvatipuram- Bobbili Fault | 257.837 | 10 | 258.031 | 0.0901 |
| F12 | 46 | Nagavali Fault | 291.139 | 10 | 291.311 | 0.0343 |
| F13 | 51 | Vamsadhara Fault | 290.698 | 10 | 290.87 | 0.0380 |

### *B. Frequency–Magnitude Recurrence Relationship*

Seismic activity of a region, is usually characterized in terms of the Gutenberg–Richter frequency–magnitude recurrence relationship $\log_{10}$ (N) = a – b*M, where N stands for the number of earthquakes greater than or equal to a particular magnitude M. Parameters (a, b) characterize the seismicity of the region. The simplest way to obtain (a, b) is through least square regression, but due to the incompleteness of the database, such an approach may lead to erroneous results.
After going through various available literatures and sources such as (USGS, NIC), 66 Nos. of Earthquakes in the magnitude range 3< Mw <6 for District Headquarter Dantewara, occurring over the period from 1827 to 1898 were identified in the present study and stepp method is used for find out seismic parameters (a,b) for site.

Log 10 (N) = 3.8591- 0.6974 Mw-----------(1)

Norm of residuals ($R^2$ ) = 0.80361 b (Regional Seismicity Parameter) = 0.6974

### *C. Estimation of Maximum Magnitude*

To determine the maximum magnitude of a fault or source, Wells and Coppersmith (1994) proposed some empirical equations based on the subsurface fault rupture characteristics such as length, area and slip rate of the fault with the moment magnitude. These empirical equations were developed by standard statistical regression, using a global database of the events. These relations are given based on tectonic regime characteristics such as strike-slip, reverse, and normal faulting and also the average relation for all slip types are developed, to be appropriate for most application in general (if the fault type is unknown). In this work, the length of faults was estimated from the seismotectonic atlas (SEISAT-2000) of India published by GSI (Geological Survey of India) and some of the faults were extracted from the literature. The relation proposed by Wells and Coppersmith (1994) to estimate expected moment magnitude of a linear fault is given below:

Log (SRL) = 0.57Mw − 2.33------------(2)

In places where the magnitude of any event was not available in the previous reports, they were derived using the approximate empirical relation [m = (2/3) I0 + 1] using the reported maximum MMI number. To avoid further confusion associated with different magnitude scales, all moment magnitude Mw were converted to Maximum Magnitude (M). In this method to estimate $M_{max}$, an increment of 0.5 is added to the observed maximum magnitude (Gupta 2002). Well-Coppersmith (1994) Method -A and Gupta (2002) Method -B, were used to find out the maximum magnitude for the sources around the site within the 300m diameter. In Gupta‘s method for gating maximum value for seismic liner source fault to give increment of 0.5 in observed Moment magnitude (Mw).The maximum value of moment among above mention method two method is consider for seismic hazard analysis. Fault no. F1, F2, F3 have reported $M_{max}$ as 6.3 where on the other-hand fault F12 & F13 have $M_{axm}$ as 4.8 as depicted in Table III.

TABLE III
ESTIMATION OF MAXIMUM MAGNITUDE FOR FAULTS/LINEAMENTS FOR DISTRICT HEADQUARTER DANTEWARA

| **Fault No.** | **Fault Length (km)** | **Mw Observed in the Fault** | **Method A (Well and Coppersmith 1994)** | | **Method –B $M_{max}$ by incremental value (Gupta 2002)** | **$M_{max}$ Considered for the present study (M)** |
|---|---|---|---|---|---|---|
| | | | **SRL 3.8% of Total Fault Length (km)** | **$M_{max}$** | | |
| F1 | 58 | 5.8 | 2.204 | 4.7 | 6.3 | 6.3 |
| F2 | 25 | 5.8 | 0.950 | 4.1 | 6.3 | 6.3 |
| F3 | 45 | 5.8 | 1.710 | 4.5 | 6.3 | 6.3 |
| F4 | 125 | 3.0 | 4.750 | 5.3 | 3.5 | 5.3 |
| F5 | 180 | 3.0 | 6.840 | 5.6 | 3.5 | 5.6 |
| F6 | 174 | 3.0 | 6.612 | 5.6 | 3.5 | 5.6 |
| F7 | 228 | 4.5 | 8.664 | 5.8 | 5.0 | 5.8 |
| F8 | 130 | 6.0 | 4.940 | 5.4 | 6.5 | 6.5 |
| F9 | 129 | 3.8 | 4.902 | 5.3 | 4.3 | 5.3 |
| F10 | 32 | 4.8 | 1.216 | 4.3 | 5.3 | 5.3 |
| F11 | 121 | 4.8 | 4.598 | 5.3 | 5.3 | 5.3 |
| F12 | 46 | 4.3 | 1.748 | 4.6 | 4.8 | 4.8 |
| F13 | 51 | 4.3 | 1.938 | 4.6 | 4.8 | 4.8 |

### *D. Ground Motion Attenuation and Estimation of Peak Ground Acceleration (PGA)*

For the present study attenuation relationship suggested by R N Iyengar & S T G Raghukant, (Applicable for peninsular India, under bed rock condition) has been used.

$$\text{In }(PGA/g) = C1+C2(m-6)+C3(m-6)^2-\ln(R)-C4(R)+\ln\varepsilon \text{ ---------------------(3)}$$

Where, C1= 1.6858, C2= 0.9241, C3= 0.0760, C4= 0.0057,
R= Hypo central distance,
m= magnitude, ε = 0 (for DSHA) 50 Percentile, ln ε = 0.4648(for DSHA) 84 Percentile

Table IV
Deterministic PGA Values at District Headquarter Dantewara

| **Fault No.** | **Fault Length** | **Hypocentral Distance R in Km** | **100 years Recurrence M100** | **PGA for Site ** [Peninsular India]** | |
|---|---|---|---|---|---|
| | | | | **50 Percentile** | **84 Percentile** |
| F1 | 58 | 243.181 | 5.947 | 0.00528 | 0.00841 |
| F2 | 25 | 247.818 | 5.653 | 0.00381 | 0.00607 |
| F3 | 45 | 251.464 | 5.861 | 0.00450 | 0.00715 |
| F4 | 125 | 276.194 | 5.259 | 0.00196 | 0.00312 |
| F5 | 180 | 82.471 | 5.553 | 0.02665 | 0.04242 |
| F6 | 174 | 171.223 | 5.548 | 0.00770 | 0.01226 |
| F7 | 228 | 127.121 | 5.747 | 0.01620 | 0.02579 |
| F8 | 130 | 72.284 | 6.252 | 0.06211 | 0.09887 |
| F9 | 129 | 128.493 | 5.256 | 0.00973 | 0.01549 |
| F10 | 32 | 265.306 | 5.141 | 0.00192 | 0.00305 |
| F11 | 121 | 258.031 | 5.256 | 0.00232 | 0.00369 |
| F12 | 46 | 291.311 | 4.75 | 0.00098 | 0.00157 |
| F13 | 51 | 290.87 | 4.753 | 0.00099 | 0.00158 |

Using above attenuation relationship, PGA values for different faults were calculated with the maximum values highlighted in the table IV. The PGA contour map for 50 Percentile and 84 Percentile for District Headquarter Dantewara were prepared as shown in Fig. 2& Fig. 3 respectively.

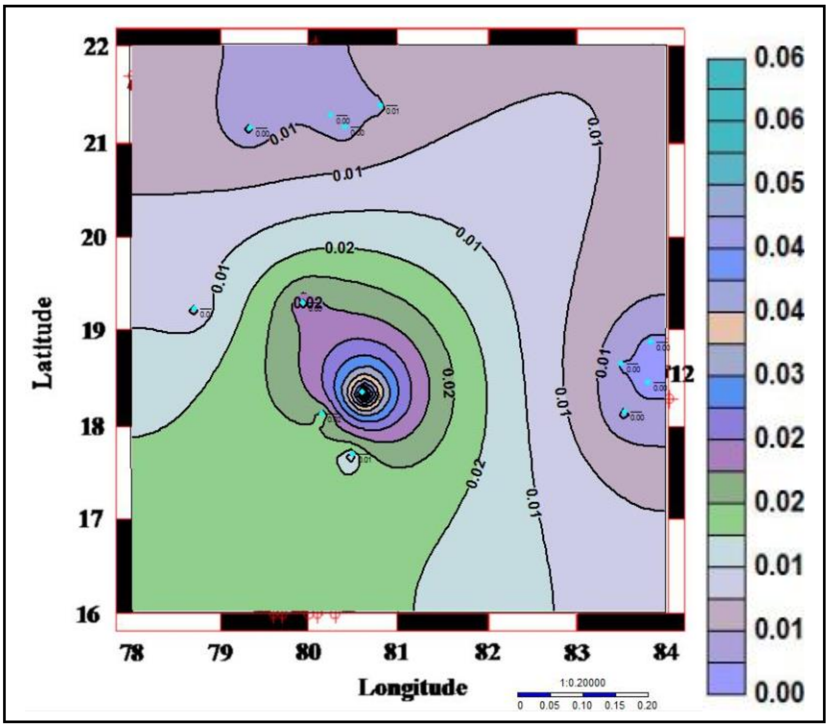


*Fig. 2 M100 PGA* Contour Map for District Headquarter Dantewara [50 Percentile]*

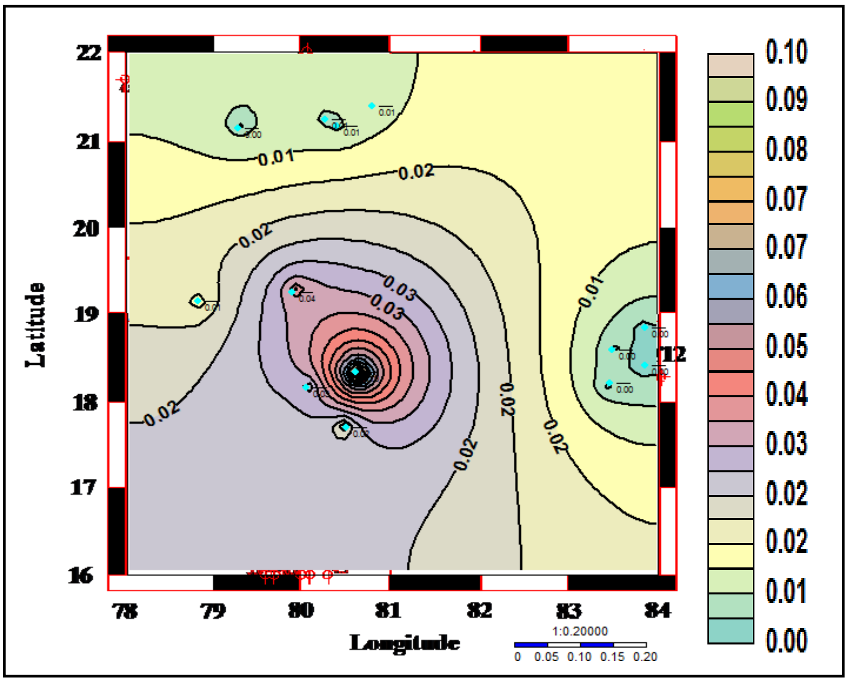


*Fig. 3 M100 PGA* Contour Map for District Headquarter Dantewara [84 Percentile]*

## III. UNCERTAINTIES

### *E. Uncertainty in the Sources to Site Distance*

In the PSHA, the uncertainty involved is, the distance of each source to the site. In a seismogenic source, each segment of the source can rupture and generate an earthquake. The geometries of seismic sources, depend on the tectonic processes involved in their formation. Earthquakes are usually assumed to be uniformly distributed with in a particular fault or lineaments. A uniform distribution of source to site distance is expressed in groundmotion parameter in terms of some measure of source to site distance; the uncertainty must be described with respect to the appropriate distance parameter. The uncertainty involved in the source to site distance is described by a probability density function. Thus the relative orientation of each source with respect to the site becomes important. The shortest and longest distance of the sources from the site and the hypocentral distances has been evaluated by considering focal depth of 10km. The probability distribution for the hypocentral distance, from any site to earthquake rupture on the source, is computed conditionally for the earthquake magnitude. Generally, the rupture length is a function of magnitude. The conditional probability distribution function of the hypocentral distance R for on earthquake magnitude M=m for a ruptured segment, is assumed to be uniformly distributed along a fault. Since predictive relationships express ground motion parameters in terms of some measure of source-to-site distance, the spatial uncertainty must be described with respect to the appropriate distance parameter. The uncertainty in source-to-site distance can be described by a probability density function. For the linear source of Fig. 4 the probability that an earthquake occurs on the small segment of the fault between L=l and L=l+dl is the same as the probability that it occurs between R = r and R = r+dr; that is, If earthquakes are assumed to be uniformly distributed over the length of the fault, since the probability density function of R is given by

$$f_R(r) = \frac{r}{L_f\sqrt{r^2 - r^2_{\min}}} \quad \text{--------------------(4)}$$

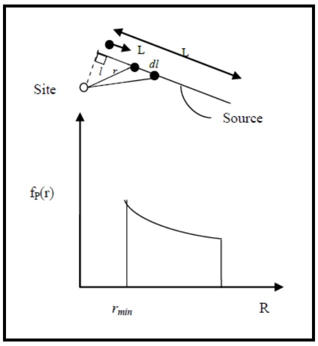
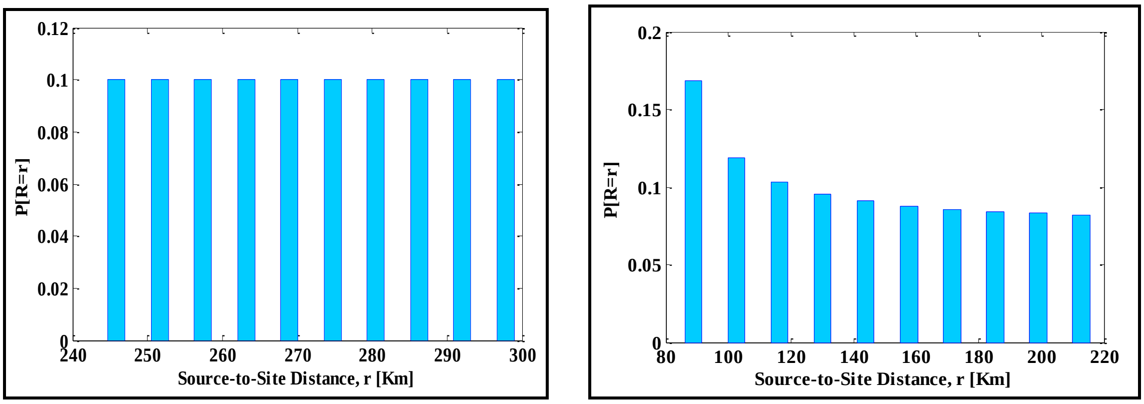
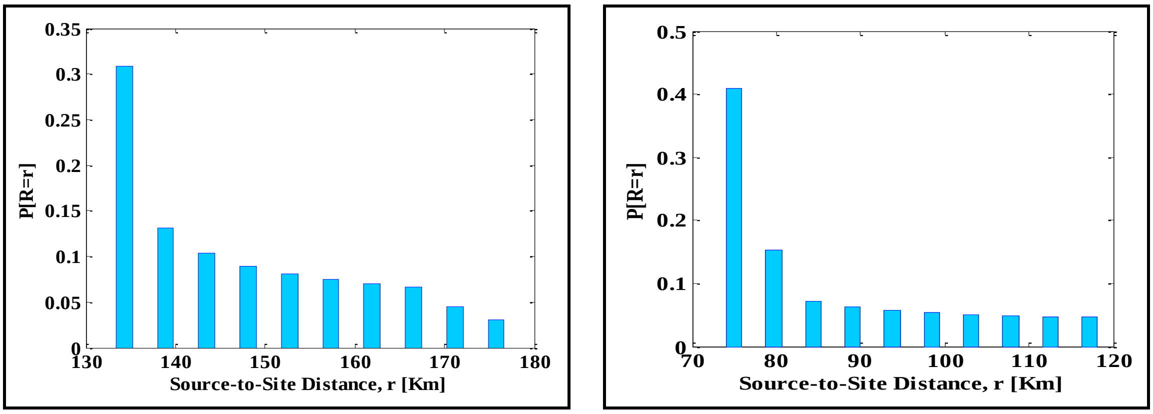


*Fig.4 Uncertainty in Sources to Site Distance*

Histogram for the typical faults were prepared, depicted (Fig. 5) as under indicating that with the increase in the distance the probability density function values decreases.



*Fault F1* *Fault F5*



*Fault F7* *Fault F8*

*Fig. 5 Probability Distribution for Source-to-Site Distance for sources (Fault 1,Fault 4, Fault 7&Fault 8) of District Headquarter Dantewara*

### *F. Uncertainty in Magnitude*

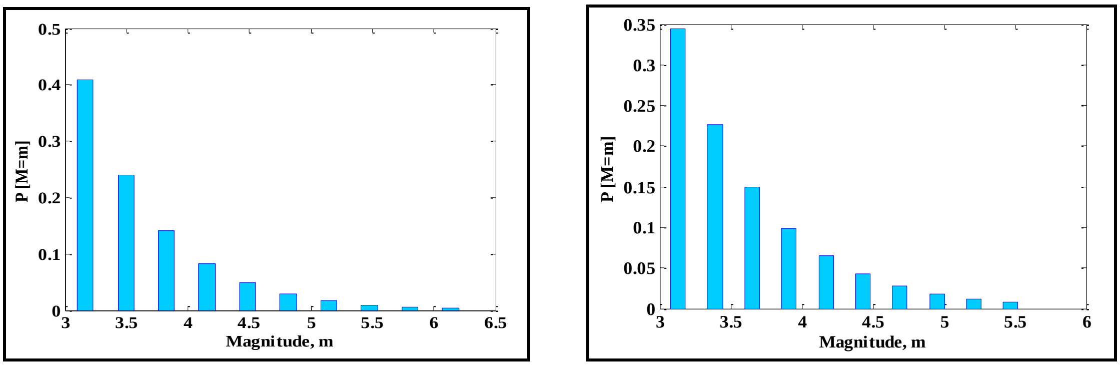
The source can experience an earthquake of any magnitude within the predicted minimum and maximum range for the particular source. This uncertainty in the magnitude of the earthquake is accounted by, the probability of occurrence of a particular magnitude in the given range. All source zones have a maximum earthquake magnitude that cannot be exceeded; in general, the source zone will produce earthquakes of different sizes up to the maximum earthquake, with smaller earthquakes occurring more frequently than larger ones. A basic assumption of PSHA is that, the recurrence law obtained from past seismicity is appropriate for the prediction of future seismicity. In most PSHA's, the lower threshold magnitude is set at values from about 3.0 to 7.0. For each source, the probability of occurrence of an earthquake of a particular magnitude is obtained using the probability density function of the magnitude. The distribution with an upper bound magnitude is given by:

$$f_M(m) = \frac{\beta e^{-\beta(m-m_{\min})}}{[1-e^{-\beta(m_{\max}-m_{\min})}]} \qquad m_{\min} \le m \le m_{\max}$$

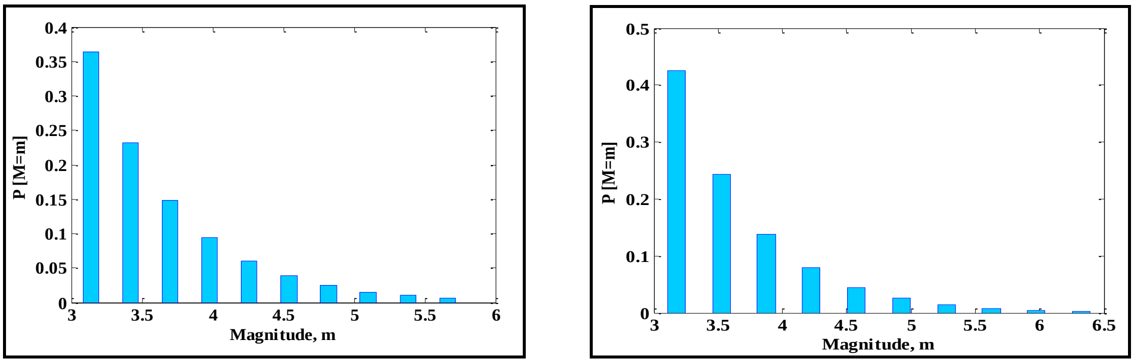
$$P[m_1 < m < m_2] = \int_{m_1}^{m_2} f_M(m)dm \approx f_M(\frac{m_1+m_2}{2})x(m_2-m_1)$$

--------------(5)

Histogram for the typical faults were prepared, depicted (Fig. 6) as above indicating that with the increase in the distance the probability density function for magnitude values decreases.



*Fault F1* *Fault F5*



*Fault F7* *Fault F8*

*Fig. 6 Probability Distribution for Magnitude for sources (Fault 1, Fault 4, Fault 7&Fault 8) of District Headquarter Dantewara*

### G. Seismic Hazard Curve

In the estimation of ground motion parameters at the site of interest, there are inherent uncertainties which must be accounted for, in the computation of seismic hazards. The ground motion parameters are usually assumed to be longnormally distributed meaning that the logarithm of the parameters is normally distributed. For accounting this uncertainty in the seismic hazard analysis, the probability distribution of the ground motion parameter Y must be estimated as a function of earthquake source properties (magnitude) and the location of the rupture with respect to the site of interest. The probability of exceedance of Y from a certain value y*, for a particular source-to-site distance, r and an earthquake of magnitude, m is expressed (Kramer 1996) as:
Effects -P[Y > y*| m,r] = 1- Fy(y*) Attenuation Relationship
Where Fy(y) is the CDF of Y at m and r.
Timing P = 1 - e-$^{\lambda}$t -Poisson model
If the site of interest is subjected to shaking from more than one source (say Ns sources), then

$$\lambda_{y^*}=\sum_{i=1}^{N_s}\nu_i\int\int P[Y>y^*\mid m,r]\,f_{Mi}(m)\,f_{Ri}(r)\,dm\,dr$$

For realistic cases, PDF's for M (Magnitude) and R (Source to Site Distance) are too complicated to integrate analytically. Therefore, we do it numerically. Dividing the range of possible magnitudes and distances into NM and NR increments, respectively and given by

$$\lambda_{y^*}=\sum_{i=1}^{N_S}\sum_{j=1}^{N_M}\sum_{k=1}^{N_R}\nu_i\int\int P[Y>y^*\mid m_j,r_k]\,f_{Mi}(m_j)\,f_{Ri}(r_k)\Delta m\Delta r$$

Where Δr and Δm is given by Δr = (rmax - rmin)/ Nm , Δm = (mmax - mmin)/ Nr

Final PSHA Equation is given by

$$\lambda_{y^*}=\sum_{i=1}^{N_S}\sum_{j=1}^{N_M}\sum_{k=1}^{N_R}\nu_i\int\int P[Y>y^*\mid m_j,r_k]P[M=m_j]P[R=r_k]$$

Many researchers have adopted this methodology for evaluating hazard and recently this method has been adopted by Iyengar and Ghosh (2004), Raghu Kanth and Iyengar (2006), Ambazhagan et al. (2008), and Vipin et al. (2009) for the probabilistic seismic hazard analysis of Delhi, Mumbai, Bangalore and Peninsular India respectively. The summation of all the probabilities is termed as hazard curve, which is plotted as the mean annual rate of exceedance (and its reciprocal is defined return period) versus the corresponding ground motion. The mean annual rate of exceedance has been calculated for all the Faults for district headquarter Dantewara of Chhattisgarh state, separately and summation of these representing the cumulative hazard curves.

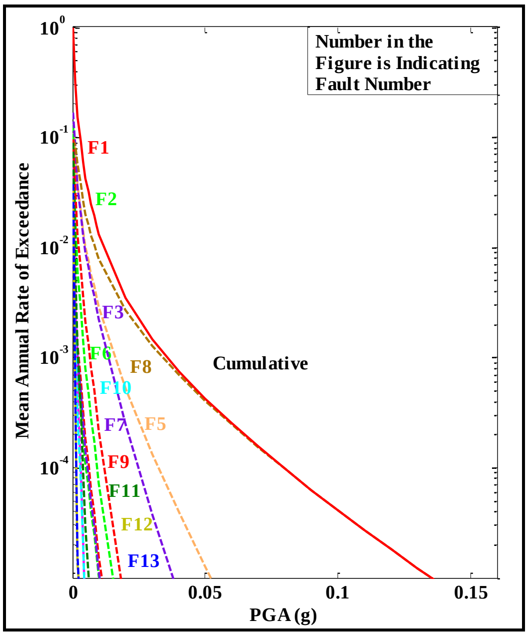


*Fig. 7 Seismic Hazard Curve for District Headquarter Dantewara*

## IV. CONCLUSIONS

In the present research, the seismic hazard analysis is carried out, for the establishment of PGA at substratum level for District Headquarter Dantewara, An attempt has also been made to evaluate the seismic hazard in terms of PGA at the same level. The Regional Recurrence Relationship obtained for District Headquarter Dantewara as given in the equation (1) and obtained “b” value is 0.6974. The Values of P.G.A. for $M_{100}$ Earthquakes have been shown in Table No.IV. The Maximum value of Peak Ground Acceleration (P.G.A.) for recurrence period of 100 years for District Headquarter Dantewara was found to be due to the Godavari Valley Fault (Fault No. 8, Fault length 130 km, Min. Map Distance 72.588 km) which came out to be equal to 0.06211 for 50 Percentile and 09887 for 84 Percentile. The seismic hazard curve prepared, for district Headquarter can be furthered used to find out the PGA values for various return periods for different probabilities (2%, 10% and 50%). The study results outlined in this paper can be directly implemented for designing of earthquake-resistant structures, in and around District Headquarter Dantewara. Furthermore, the endless potential for future for earthquake resistant design is unlimited.

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