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# Deterministic Seismic Hazard Approach for Low Seismic Region, Jagdalpur, Chhattisgarh, India

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**Abstract**

Seismic hazard analysis, an approach to get an estimate of the strong ground-motions at any particular site, is mainly intended for earthquake resistant designs or for seismic safety assessments. The hazard analysis usually attempts to analyze two different kinds of anticipated ground motions, "The Deterministic Seismic Hazard Analysis" (DSHA) and "The Probabilistic Seismic Hazard Analysis" (PSHA). A sincere effort is made herein to carry out, Deterministic Seismic Hazard Analysis, for Jagdalpur District of Chattisgarh state. In this paper, previous earthquake history of the region was considered to generate earthquake recurrence relation. An attempt was made to compile the occurrence of past and recent seismic activities within 300 km radius, around the District Headquarter Jagdalpur. Further the seismic hazard analysis was carried out at substratum level in terms of PGA using (DSHA), deterministic seismic hazard analysis technique The main benchmark and indicator involved in carrying out the hazard analysis is the correctness and completeness of the data which needs to be attained. From the present investigation the values of peak ground acceleration varies from 0.00762g to 0.01213g for 50 percentile and 84 percentile respectively.

***Keywords:*** *Fault, Fault Map, DSHA, Moment Magnitude, PGA, Attenuation,* Deaggregation *, Hazard.*

## 1. Introduction

Earthquakes are natural disasters and result in huge loss to mankind and assets. In India, large numbers of earthquakes took place with low to high magnitudes. Some areas earlier considered stable have experienced severe damages caused by earthquakes. Noticeable earthquakes happened in India in various places such as Latur in Maharashtra, Bhuj in Gujarat and Jabalpur in Madhya Pradesh. Jagdalpur is a city in Bastar district in the Indian state of Chhattisgarh. Jagdalpur is the administrative headquarters of Bastar District and was the capital of the erstwhile princely state of Bastar. It is well known for its lush green mountains, deep valleys, dense forests, streams, waterfalls, caves, natural parks, monuments, natural resources, herbs, exuberant festivity and peaceful solitude. Other tourist attractions relate to Bastar's royal past and its tribes. Currently two steel plants are being built near Jagdalpur by NMDC and Tata Steel Plant. After completion these projects will be Jagdalpur city's industrial hubs. The city's demography is changing rapidly and it has the fastest-growing population in Chhattisgarh state. Jagdalpur is located at 19.07°N 82.03°E. It has an average elevation of 552 metres (1811 feet). The city is located on the south bank of the Indravati River.


Fig. 1. Location Map of District Headquarter Jagdalpur

Chhattisgarh has very low rates of seismic activity. In recent years, tremors from earthquakes in neighbouring states have been felt, most notably in 1969. Minor seismic activity has been recorded in the vicinity of Chiraikund and Muirpur along the border with Madhya Pradesh.

## 2. Methodology

The literature review reveals the information regarding different parameters for assessment of seismic hazard. Seismic hazard analysis can be classified as Deterministic and Probabilistic. The hazard at the site is defined in terms of ground motion, induced at the site due to the earthquake that can occur on the already identified sources. Different values of ground motion will be obtained from different sources at the site under investigation. Deterministic Seismic Hazard Analysis is the earliest approach taken to Seismic Hazard Analysis originated in nuclear power industry applications and also used for structures. It provides a base for Probabilistic Seismic Hazard Analysis of earthquake. A deterministic seismic hazard analysis involves the development of a particular seismic scenario upon which a ground motion hazard evaluation is based. The scenario consists of the postulated occurrence of an earthquake of a specified size occurring at a specified location. A typical Deterministic Seismic Hazard Analysis can be described as a four-step process (Reiter) consisting of followings:

- Identification and characterization of all earthquake sources capable of producing significant ground motion at the site.
- Selection of a source to site distance parameter for each source zone. In most Deterministic Seismic Hazard Assessments, the shortest distance between the source zone and the site of interest is selected.
- Selection of the controlling earthquake (i.e. the earthquake that is expected to produce the strongest level of shaking), generally expressed in terms of some ground motion parameter, at the site.
- The controlling earthquake is described in terms of its size (usually expressed as magnitude) and distance from the site.

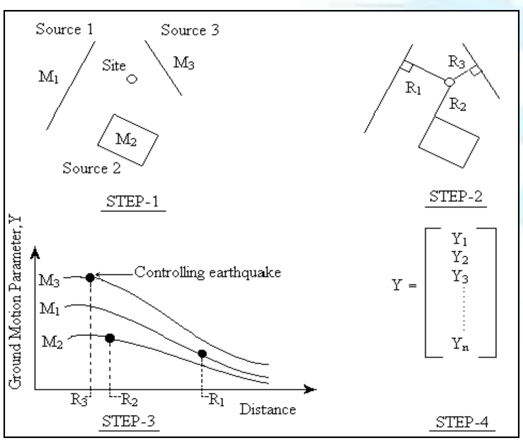


Fig. 2 Steps of Deterministic Seismic Hazard Analysis

## 2.1 Identification and Characterization of Sources

The present study uses a Deterministic method of Analysis for the Hazard Analysis of Jagdalpur District taking into consideration the location of Chhattisgarh, it is found to be located in the zone where the occurrence of seismic activity is found to be very low. For Identification of seismic sources, District Headquarter Jagdalpur is selected as the target. A control region of radius 300 km around the District Headquarter, having centre at19.07°N 82.03°E, was considered for numbering of fault 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. 2. A total of twelve major faults, which influence seismic hazard at District

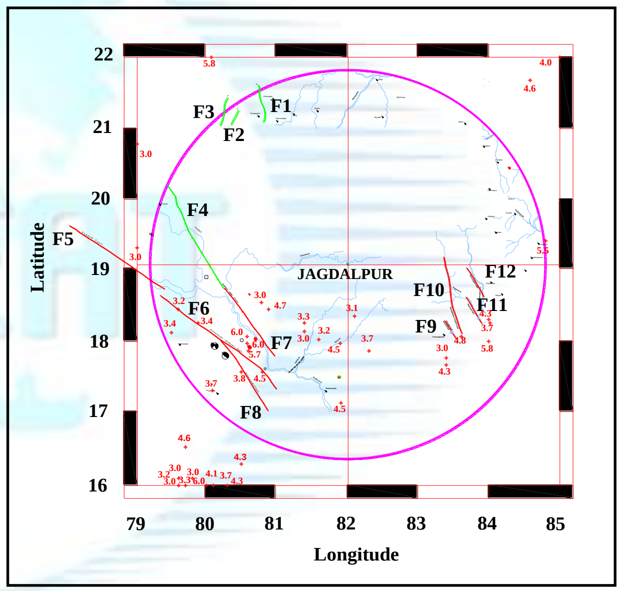


Fig. 3. Fault Map for District Headquarter Jagdalpur

Headquarter Jagdalpur , were identified in the above map. Fault details are tabulated in Table 1, Appendix -1. After going through various available literatures and sources such as (USGS, NIC), 60 Nos. of Earthquakes in the magnitude range 3< Mw <6.7 for Jagdalpur District Headquarter, occurring over the period from 1827 to 1998 were identified in the present study.

## 2.2 Regional Recurrence

Seismic activity of a region, is usually characterized in terms of the Gutenberg–Richter frequency–magnitude recurrence relationship log10 (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

| *Magnitude Mw* | *No of Events ≥ Mw* | *Complete in interval (year)* | *No. of Events per year ≥ Mw* |
|---|---|---|---|
| 3 | 60 | 30 | 3.0000 |
| 4 | 31 | 60 | 0.5167 |
| 5 | 10 | 100 | 0.1000 |
| 6 | 3 | 140 | 0.0215 |

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. Stepp has proposed a reliable statistical method to address the issue of incompleteness of earthquake catalogues. They classified the database into two groups, called the extreme part and the complete part. The extreme part consists of a long time period where information related to only large historical events is consistently available. The complete part further represents the data related to the recent decades during which information on both large and small magnitude earthquakes is available

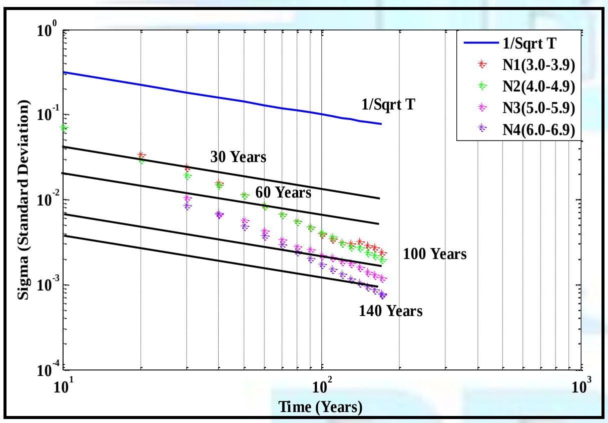


Fig.4 Completeness Test of Earthquake Data for District Headquarter Jagdalpur

As it is very clear that, in hazard analysis one would not be interested in events below a threshold level, say $m_0$ = 3. Again, there will be an upper limit on the potential of a fault, but it may be difficult to know the actual precision of the faults from the catalogues, thus the above stated method, suited to engineering requirements, which can easily estimate such doubly truncated Gutenberg–Richter relationship, with statistical errors in values of the magnitude that have occurred in the past. The present study, incorporates the earthquake data of the samples, of past 166 years around District Headquarter Jagdalpur, was first evaluated for its degree of completeness. The analysis is shown in (Table 2), that data are complete, in a statistical sense, in the following fashion: (3.0 ≤ M < 4) is complete in 20 years; (4.0 ≤ M <5) is complete in 30 years; (5.0 ≤ M < 6) is complete in 50 years; and (6.0 ≤ M < 7) is complete in 100 years.

Table 2. Activity Rate and Completeness for District Headquarter Jagdalpur

Regional Recurrence Relationship District Headquarter Jagdalpur is given by

Log 10 (N) = 3.5181- 0.6352 M--------(1)

Norm of Residuals ($R^2$)= 0.72104

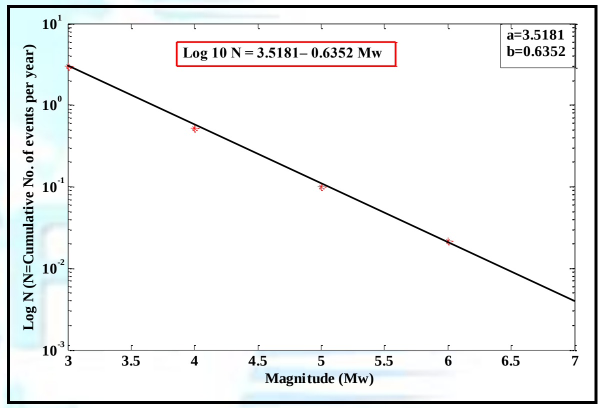


Fig. 5 Frequency-Magnitude Relationship for District Headquarter Jagdalpur

## 2.3 Deaggregation of Seismic Sources

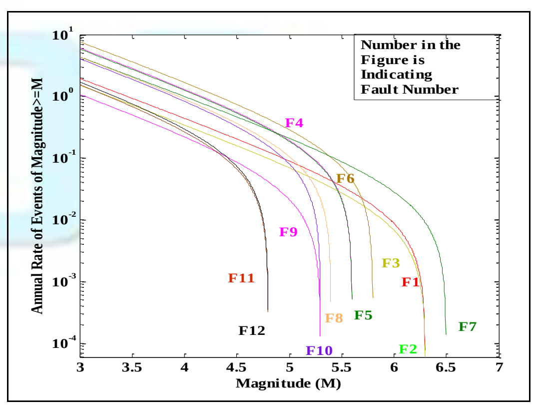


Fig.6 Deaggregation of Seismic Sources for District Headquarter Jagdalpur

The maximum possible earthquake magnitude for each of the seismic sources within the area was then estimated.

Shortest distance to each source and site of interest was evaluated and taken as major input for performing DHSA. In the present investigation truncated exponential recurrence model developed by Mcguire and Arabasz (1990) was used and is given by following expression;

$$\lambda_m = N_i(m_0)*\upsilon*\frac{\exp[-\beta(m-m_0)]-\exp[-\beta(m_{max}-m_0)]}{1-\exp[-\beta(m_{max}-m_0)]}$$

-(2)

Where $\upsilon=\exp(\alpha-\beta*m_0)$ α=2.303*a, β=2.303*b and Ni(m0) is the weightage factor for a particular source based on recurrence. The threshold value having a magnitude 3.0, was adopted in the study.

## 2.4 Ground Motion Attenuation

Attenuation relationship developed by Iyenger and Raghukanth (2004) was considered for the analysis and PGA was calculated. Maximum value of PGA has been taken, amongst the PGA calculated, by various source at each point.

In (PGA/g) = C1+C2 (M-6)+C3 (M-6) 2-ln(R)-C4(R) +ln ε------ (3)

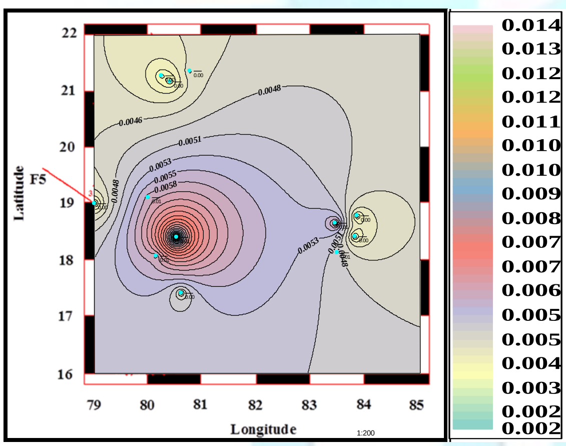


Fig. 7 PGA Contour Map for District Headquarter Jagdalpur Percentile 50

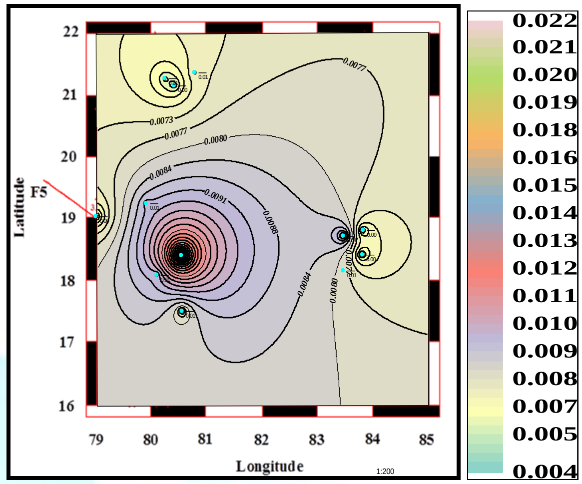


Fig. 8 PGA Contour Map for District Headquarter Jagdalpur Percentile 84

Where, C1= 1.6858, C2= 0.9241, C3= 0.0760, C4= 0.0057, R= Hypo central distance, M= magnitude = M100, ln ε = 0 (for DSHA). Finally the Deterministic Seismic Hazard Analysis (DHSA), was carried out for District Headquarter Jagdalpur considering the seismic events and Seismotectonic sources from the newly developed seismotectonic model for the region, 300 km around the District Headquarter. The above attenuation relationships (Raghu Kanth and Iyengar, 2007) was used to estimate the peak ground acceleration, for 100 years of return period. In the present paper the contour map of peak ground acceleration [PGA*], for 100 years of return period for 50 Percentile and 84 Percentile where prepared and shown in Fig.7 & Fig.(8).

## 3. Conclusions

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The present research, the seismic hazard analysis carried out, for the establishment of PGA at substratum level for District Headquarter Jagdalpur, was based on deterministic approach. 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 Jagdalpur, as depicted in Equation 1, shows the obtained "b" value as 0.6352. The Values of P.G.A. for M100 Earthquakes have been shown in Table 2. Appendix-1.The Maximum value of Peak Ground Acceleration (P.G.A.) for recurrence period of 100 years for District Headquarter Jagdalpur, was found to be due to the fault No. 10 (Fault length 121 km, Min. Map Distance 147.031 km) which came out to be equal to 0.01213g, for 84 percentile. The study results, outlined in this paper can be directly be implemented for designing of earthquake-resistant structures, in and around District Headquarter Jagdalpur. The District Headquarter Jagdalpur comes under very low seismic area.

**Appendix-1**

Table 1 District Headquarter Jagdalpur Faults Considered for Hazard Analysis

| ***Fault No.*** | ***Fault Length*** | ***Fault Name*** | ***Hypo Central Distance R in Km*** | ***MagnitudeM100 [100 years Recurrence Period]*** | ***PGA Values (g) (100Years)*** | |
|---|---|---|---|---|---|---|
| | | | | | ***50 Percentile*** | ***84 Percentile*** |
| F1 | 58 | ---- | 255.499 | 5.963 | 0.00476 | 0.00757 |
| F2 | 25 | ----- | 279.958 | 5.686 | 0.00290 | 0.00462 |
| F3 | 45 | ----- | 289.538 | 5.901 | 0.00326 | 0.00519 |
| F4 | 180 | ----- | 193.348 | 5.553 | 0.00604 | 0.00962 |
| F5 | 174 | Kaddam Fault | 281.988 | 5.551 | 0.00249 | 0.00397 |
| F6 | 228 | Kinnerasani - Godavari Fault | 221.327 | 5.747 | 0.00544 | 0.00866 |
| F7 | 130 | Godavari Valley Fault | 180.253 | 6.279 | 0.01379 | 0.02194 |
| F8 | 129 | Kolleru Lake Fault | 226.784 | 5.35 | 0.00347 | 0.00552 |
| F9 | 32 | Kanada Fault | 171.896 | 5.137 | 0.00502 | 0.00798 |
| F10 | 121 | Parvatipuram- Bobbili Fault | 147.371 | 5.256 | 0.00762 | 0.01213 |
| F11 | 46 | Nagavali Fault | 187.878 | 4.746 | 0.00274 | 0.00436 |
| F12 | 51 | Vamsadhara Fault | 181.479 | 4.75 | 0.00296 | 0.00471 |

Table 2 Deterministic PGA Values at District Headquarter Jagdalpur

| ***Fault no.*** | ***Length (kM)*** | ***Min. Map Distance (kM)*** | ***Focal Depth (kM)*** | ***Hypo Central Distance (kM)*** | ***Weightage*** | ***Maximum Magnitude (M)*** |
|---|---|---|---|---|---|---|
| F1 | 58 | 255.303 | 10 | 255.499 | 0.0476 | 6.3 |
| F2 | 25 | 279.779 | 10 | 279.958 | 0.0206 | 6.3 |
| F3 | 45 | 289.365 | 10 | 289.538 | 0.0370 | 6.3 |
| F4 | 180 | 193.089 | 10 | 193.348 | 0.1477 | 5.6 |
| F5 | 174 | 281.810 | 10 | 281.988 | 0.1428 | 5.6 |
| F6 | 228 | 221.100 | 10 | 221.327 | 0.1871 | 5.8 |
| F7 | 130 | 179.975 | 10 | 180.253 | 0.1067 | 6.5 |
| F8 | 129 | 226.563 | 10 | 226.784 | 0.1059 | 5.4 |
| F9 | 32 | 171.604 | 10 | 171.896 | 0.0263 | 5.3 |
| F10 | 121 | 147.031 | 10 | 147.371 | 0.0993 | 5.3 |
| F11 | 46 | 187.611 | 10 | 187.878 | 0.0378 | 4.8 |
| F12 | 51 | 181.203 | 10 | 181.479 | 0.0419 | 4.8 |

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