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Assessment of Peak Ground Acceleration for South Chhattisgarh (India), with Local Site Parameters: A Deterministic Method

Ashish Kumar Parashar, Sohanlal Atmapoojya

Abstract*: Looking into the present scenario worldwide, it is obvious that there is rapid increase in construction activities hence, the vulnerability to calamities of areas leading to large loss potentials. So the researches all over the globe are basically focused over disaster management, to safeguard the life and properties. The district headquarters Dantewara, Jagdalpur and Kanker are located in the south of Chhattisgarh state (India), where high concentration of the tribal population and rapid infrastructure development is observed. In order to trim down vulnerability, precise microzonation studies are required to be a constituent of the master plan, for construction activities, of earthquake resistant structures in the south of Chhattisgarh region. In the present research, the Deterministic Seismic Hazard Analysis (DSHA) for district headquarters of south Chhattisgarh has been carried out. In order to estimate the seismic parameters, past earthquake data of district headquarters of south Chhattisgarh, with radius of 300kM around them has been analyzed. Thirteen, Twelve and Eighteen tectonic features have been identified as potential seismogenic source, from the seismotectonic atlas of India for Dantewara, Jagdalpur and Kanker respectively. The maximum magnitude has been assigned to each seismogenic source. To evaluate the hazard in the study region, Ground Motion Prediction Equation (GMPE) developed by Cornell (1976) and Raghukanth and Iyengar (2004) has been used. The Peak Ground Acceleration (PGA) values are estimated for district headquarters of Dantewara, Jagdalpur & Kanker around its adjoining areas. Maximum PGA value for return period of100 years at bed rock level is 0.05063g and 0.06378g for Dantewara region using Ground Motion Prediction Equation (GMPE) developed by Cornell (1976) and Raghukanth & Iyengar (2004). It has been reported from the study that the above values are found to be on the lower side as compared to the recommendation given by IS Code of practice (IS:1893 part I (2016).The outcome of present research can be directly implemented for design of earthquake resistant structures in south Chhattisgarh region. Thus the study accounts that south Chhattisgarh is safe from seismic risk.

Index Terms*: Deterministic Seismic Hazard Analysis, Faults, Maximum Magnitude, Peak Ground Acceleration.

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* Correspondence Author
Ashish Kumar Parashar*, Department of Civil Engineering, Faculty of SoS, E&T, GGV, Central University, Bilaspur, Chhattisgarh., India
Sohanlal Atmapoojya, Department of Civil Engineering, H.O.D., K.I.T.S. Ramtek, Maharashtra, India

I. INTRODUCTION

Overwhelming earthquakes have been experienced in India in the past, resulting in severe damages to property and loss of lives. The past major earthquakes that have occurred in India over the recent years – Uttarkashi (1991; ML 6.6), Latur (1993; Mw 6.1), Jabalpur (1997; Mw 5.8), Chamoli (1999; ML 6.8) Bhuj (2001; Mw 7.6) and Kashmir (2005; Mw 7.6),[1].The effects of earthquakes can be minimized by determining the seismic hazard and the strong motion that has been produced by earthquake events in various parts of the country and designing the structures accordingly. During an earthquake, the transmission of seismic waves and resulting ground displacement can be sensed even at far off places, but as per the observation of scientists, the damages caused are restricted to few hundred kilometers only, from the causative fault. It was much before the beginning of 20th Century that the quest for recording, understanding and characterizing the ground motion was initiated so as to make it amenable for structural design. Ground-motion or vibrations, produced by earthquakes cause immense structural damages and to reduce these damages, engineers demand the design ground-motion for designing of the structures. Thus in order to assure the safety of structures like building, bridges, power plants, dams etc. and decide the design ground-motion at a particular region, the knowledge of appropriate strong ground-motion is indispensable.

II. SEISMIC HAZARD ANALYSIS

Seismic Hazard Analysis is the quantitative evaluation of ground shaking hazard at an individual site through the identification and characterization of all potential sources of seismic activity, which may give rise to significant ground motions at the specific site [12]. There are two different approaches for seismic hazard analysis: a deterministic and a probabilistic one. The first attempt to evaluate the seismic hazard of Indian subcontinent based on deterministic techniques was done by Parvez et al. [14]. Deterministic seismic hazard analysis (DSHA) provides the worst scenario earthquake without considering its likelihood during the design life of the structure [2].The methodology for this analysis has involved four steps:

1. Identification and characterization of the earthquake sources which may cause ground motion in the study area.
2. Selection of the specific parameters for the earthquake source, such as hypocenter or epicenter distance, focal depth and magnitude.

3. Selection of relevant attenuation relationships and calculating the median value of the ground motion parameter as a function of the magnitude of the earthquake and distance from the hypocenter.
4. Evaluating the values for all the earthquake sources and selecting the largest value.

III. STUDY AREA

The district headquarters Dantewara, Jagdalpur and Kanker of south Chhattisgarh have been selected as study area.

Figure 1: Study Area for Seismic Hazard Analysis

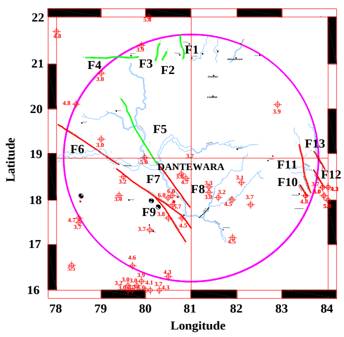
The object of present research is to apply the seismic hazard analysis and predict seismicity of south Chhattisgarh region.

IV. METHODOLOGY

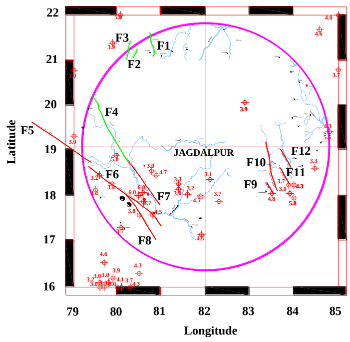
In view of all the potential seismogenic sources present in the seismic study area, were included and DSHA has been carried out. The methodology adopted for DSHA for South Chhattisgarh Region is based on the following steps:

A. Seismotectonic Maps for South Chhattisgarh Region

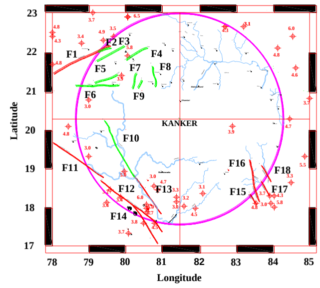
The Seismotectonic maps were prepared by scanning the Seismotectonic Atlas of India [15]. The tectonic features faults, that are likely to generate the significant ground motions in the study area have been identified and marked within 300 kM radius of circle having fault length (L_i) ≥ 25 kM and is shown in Figure 2. A total no. of 13, 12 and 18, potential seismogenic sources (Faults) for district headquarters Dantewara, Jagdalpur, and Kanker respectively, have been selected for DSHA.



(a) District Headquarter Dantewara



(b) District Headquarter Jagdalpur



(c) District Headquarter Kanker

Figure 2: Seismotectonic maps for District Headquarters of south Chhattisgarh [15]

B. Earthquake Catalogue and Recurrence Relation

Earthquake catalogues and databases are the most essential and important parameter for any kind of seismic hazard studies [7]. Earthquake data have been collected from USGS, NDMA and IMD; Delhi for a period of 188 years for district headquarters and the past earthquake data were collected from various catalogue, information center and departments for the study region is shown in Figure 2. For source to site distance parameters, Seismotectectonic Maps for district headquarters have been used. The minimum map distances of

Name of District Head Quarter	b Value From Stepp (1972)	b Value From Maximum Likelihood Estimation, Utsu. (1965)	b Value Considered for the Present Study
Dantewara	0.5460	0.4057	0.5460
Jagdalpur	0.5174	0.4081	0.5174
Kanker	0.7455	0.3546	0.7455

identified faults were measured and hypocentral distance was calculated for all the faults considered for Seismic Hazard Analysis. The above collected data were used to find out three parameters: the activity rate, the *b*-value of the Gutenberg-Richter (G-R) relationship and the observed maximum magnitude of earthquake near the fault [8]. The seismic parameters of district headquarters of south Chhattisgarh region have been evaluated using Stepp method (Linear Least-Square Fit) [9] and Maximum Likelihood Estimation. The seismic regional parameter "b" value for study area is tabulated in Table 1.

Table 1: Earthquake Catalogue Completeness for District Headquarters of South Chhattisgarh

Fault No.	Fault Length	Min. Map Distance (kM)	Estimation of Maximum Magnitude		M_{max}
			Method (i)	Method (ii)	
(a) District Headquarter Dantewara					
F1	58	242.975	4.7	6.3	6.3
F2	25	247.616	4.1	4.4	4.4
F3	45	251.265	4.6	4.4	4.6
F4	125	276.012	5.3	4.4	5.3
F5	180	81.862	5.6	5.5	5.6
F6	174	170.93	5.6	3.5	5.6
F7	228	126.727	5.8	5.0	5.8
F8	130	71.3150	5.4	6.5	6.5
F9	129	128.103	5.3	4.3	5.3
F10	32	265.117	4.3	5.3	5.3
F11	121	257.837	5.3	5.3	5.3
F12	46	291.139	4.6	4.2	4.6
F13	51	290.698	4.6	4.8	4.8
(b) District Headquarter Jagdalpur					
F1	58	255.303	4.8	6.3	6.3
F2	25	279.779	4.1	4.4	4.4
F3	45	289.365	4.6	4.4	4.6
F4	180	193.089	5.6	5.5	5.6
F5	174	281.810	5.6	3.5	5.6
F6	228	221.100	5.8	5.0	5.8
F7	130	173.013	5.4	6.5	6.5
F8	129	226.563	5.4	4.3	5.4
F9	32	171.604	4.3	5.3	5.3
F10	121	147.031	5.3	5.3	5.3
F11	46	187.611	4.6	4.2	4.6
F12	51	181.203	4.7	4.8	4.8
(c) District Headquarter Kanker					
F1	182	289.122	5.6	5.4	5.6
F2	38	283.721	4.4	5.4	5.4
F3	91	261.459	5.1	6.3	6.3
F4	71	222.399	4.9	6.3	6.3
F5	70	291.522	4.9	4.4	4.9
F6	125	200.507	5.3	4.4	5.3
F7	45	161.198	4.6	4.4	4.6
F8	58	116.039	4.8	6.3	6.3
F9	25	148.451	4.1	4.4	4.4
F10	180	198.459	5.6	5.5	5.6
F11	174	277.406	5.6	3.5	5.6
F12	228	288.384	5.8	5.0	5.8
F13	130	210.941	5.4	6.5	6.5
F14	129	282.015	5.4	4.3	5.4
F15	32	298.074	4.3	5.3	5.3
F16	121	235.618	5.3	5.3	5.3
F17	46	298.307	4.6	4.2	4.6
F18	51	273.877	4.7	4.8	4.8

C. Maximum Magnitude Potential Seismogenic Sources

The magnitude is a number that distinguishes the relative size of an earthquake. The seismograph record specified the dependence of Magnitude on evaluation of the maximum motion. Though the moment magnitude (Mw) scale, which is based on the concept of seismic moment is more difficult to compute as compared to the other types, but is uniformly applicable to all sizes of earthquakes. Mostly the seismologists, geologists, engineers, risk analysts, economists, social scientists and government officials use methods (i) Wells and Coppersmith (1994) [5] and (ii) Gupta (2002)[6] for estimation of Table 2 Values of M_{max} Corresponding to Various Seismogenic Sources of District Headquarters of South Chhattisgarh [10]

M_{max}. In Wells and Coppersmith (1994) method a relation between M_w and Surface Rupture Length (SRL) was developed, using reliable source parameters and this is further applicable for all types of faults, shallow earthquakes and interplate or intraplate earthquakes.

Log (SRL) = 0.57Mw − 2.33 ---------------(1)

The above equation was used to estimate M_{max} for all sources of district headquarters of south Chhattisgarh region.

In Gupta's method (2002), the M_{max} was estimated after adding an incremental unit. In this method for estimation of M_{max} an increment of 0.5 is added to the observed maximum magnitude. This incremental technique has been used by various researchers to estimate the seismic hazard in India. The M_{max} was calculated by equation (2) as given below:

$M_{max}= M_{obs}+0.5$ -------------------------(2)

M_{max}(M)= Maximum Magnitude

M_{obs}(Mw)= Moment Magnitude

After comparing the outcome of the two methods, maximum magnitude M_{max} values have been tabulated in Table 2 for calculating Peak Ground Acceleration.

D. Estimation of Peak Ground Acceleration

For predicting the peak ground acceleration for a particular site, the absolute Ground Motion Prediction Equation (GMPE) model or attenuation relationship plays a vital role.

The level of shaking is to be effectively characterized by the peak horizontal acceleration. An appropriate attenuation relationship can be used to select the controlling earthquake. Cornell et al. (1979), [4] has developed Ground Motion Prediction Equation (GMPE) model or attenuation relationship for western United States. This model or attenuation relationship is generally region specific. The region specific GMPEs have been developed for PI (Peninsular India) by Iyengar and Raghu kanth (2004). Iyengar and Raghu Kanth (2004) developed a statistically simulated ground motions for Peninsular India using a well-known stochastic seismological model and regional seismotectonic parameters. This GMPE model was validated by comparing the PGA from instrumented data of two strong earthquakes, in Peninsular India namely Koyna (December 11, 1967) and Bhuj (January 26, 2001). The magnitude M_{100} was estimated by using Matlab program. The M_{100} means the magnitude estimated at 100 years returned periods.

(i) Cornell et al. (1979), Ground-Motion Model

The attenuation relationship as given by Cornell et al. (1979) [4] is as follows:

ln PHA(gals) = 6.74 + 0.859*M-1.80*ln(R+25) -----(3)
where PHA, M, and R refer to PGA(g), moment magnitude, and Minimum Map Distance to the site in kM respectively.

(ii) Iyengar and Raghu Kanth (2004), Ground-Motion Model

A comprehensive predictive attenuation relationship as given by Iyengar and Raghu Kanth (2004)[11] proposed for Peninsular India is as follows:

$\ln Y = C1 + C2 (M-6) + C3 (M-6)^2 - \ln(R) - C4 (R) + \ln(\varepsilon)$---------------(4)

where Y, M, and R refer to PGA(g), moment magnitude, and hypocentral distance, respectively . Peninsular India Region: C1=1.6858,
C2= 0.9241, C3=-0.0760,
C4 = 0.0057, Focal depth =10 kM σ (ln ε) taken as zero "0" because it is very small [13].

Table 3 Peak Ground Acceleration (PGA) for Faults for District Headquarters of South Chhattisgarh

Fault No.	Fault Length	Hypo-Central Distance	100 years Recurrence M_{100}	PGA(g) Cornell	PGA(g) Iyengar & Raghu Kanth
(a) District Headquarter Dantewara					
F1	58	243.181	5.934	0.00602	0.00522
F2	25	247.818	4.322	0.00146	0.00091
F3	45	251.464	4.541	0.00173	0.00113
F4	125	276.194	5.242	0.0027	0.00192
F5	180	82.471	5.54	0.02243	0.02631
F6	174	171.223	5.543	0.00756	0.00766
F7	228	127.121	5.741	0.01419	0.01611
F8	130	72.284	6.276	0.05063	0.06378
F9	129	128.493	5.245	0.00912	0.00962
F10	32	265.306	5.104	0.00256	0.00184
F11	121	258.031	5.242	0.00302	0.00228
F12	46	291.311	4.542	0.00136	0.00078
F13	51	290.87	4.732	0.0016	0.00097
(b) District Headquarter Jagdalpur					
F1	58	255.499	5.963	0.00569	0.00476
F2	25	279.958	4.317	0.00119	0.00067
F3	45	289.538	4.539	0.00137	0.00079
F4	180	193.348	5.545	0.00624	0.00599
F5	174	281.988	5.543	0.00337	0.00247
F6	228	221.327	5.741	0.00594	0.00541
F7	130	173.302	6.119	0.01408	0.01506
F8	129	226.784	5.34	0.00405	0.00343
F9	32	171.896	5.098	0.00513	0.00481
F10	121	147.371	5.24	0.00736	0.0075
F11	46	187.878	4.541	0.00276	0.00217
F12	51	181.479	4.73	0.00343	0.00289
(c) District Headquarter Kanker					
F1	182	289.295	5.54	0.00323	0.00231
F2	38	283.898	5.215	0.00252	0.00175
F3	91	261.651	5.986	0.00558	0.00459
F4	71	222.624	5.911	0.00681	0.00628
F5	70	291.694	4.853	0.00177	0.0011
F6	125	200.757	5.247	0.00455	0.00409
F7	45	161.508	4.558	0.00356	0.003
F8	58	116.47	5.854	0.01783	0.02082
F9	25	148.788	4.348	0.00337	0.00275
F10	180	198.711	5.538	0.00594	0.00562
F11	174	277.587	5.538	0.00345	0.00257
F12	228	288.558	5.733	0.00382	0.00281
F13	130	211.178	6.189	0.00942	0.00911
F14	129	282.193	5.34	0.00283	0.00202
F15	32	298.242	5.11	0.00212	0.00137
F16	121	235.831	5.245	0.0035	0.00285
F17	46	298.475	4.558	0.00132	0.00075
F18	51	274.06	4.75	0.00179	0.00116

The computer program developed in Excel, are used to calculate the PGA values for both GMPE.

V. CONCLUSIONS

For the estimation of PGA for district headquarters Dantewara, Jagdalpur and Kanker of south Chhattisgarh the DSHA methodology is used, with two Ground Motion Prediction Models. First model developed by Cornell et al. (1979) is universally accepted and other model developed by Iyengar and Raghu Kanth (2004) is region specific (Peninsular India). The result of present study is that, the highest value of PGA at bed rock level for return period of 100 years, from Cornell et al. (1979) and Iyengar and Raghu Kanth (2004) models were found as 0.05063g & 0.06378g for seismic source F8 respectively due to minimum map distance 71.3150 kM for Dantewara district. On the other hand, minimum value was found for seismic source F7 as 0.01408g & 0.01506g respectively for Jagdalpur district for having minimum map distance as 173.013 kM. For Kanker district the PGA values were found to be 0.01783g & 0.02082g respectively for seismic source F8, having minimum map distance 116.039 kM which lies in between the above stated values of Dantewara and Jagdalpur. On comparing the two Ground Motion Prediction Models the present study outcome thus highlights the fact that in the district headquarters Dantewara, Jagdalpur and Kanker the highest PGA values are found to be less than 0.1g. Hence it reflects that the south Chhattisgarh region comes under seismic zone II.

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