Malaysian Journal of Civil Engineering 28(2):315-326 (2016)

TECHNICAL NOTE

DETERMINISTIC SEISMIC HAZARD ANALYSIS OF AMBIKAPUR DISTRICT HEADQUARTER OF CHHATTISGARH STATE [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 Probabilistic Seismic Hazard Analysis” (PSHA) and “The Deterministic Seismic Hazard Analysis” (DSHA). A sincere effort is made herein to perform seismic hazard analysis for Ambikapur District of Chattisgarh state using a Deterministic approach. The study broadly consists of two parts, the first part basically gives a detailed overview of the seismicity of the region and identification of various faults existing within the district with all their particulars and the second part includes DSHA analysis for the same. An effort was made to compile the occurrence of past and recent seismic activities within 300 km radius, around the District Headquarter Ambikapur. The main benchmark and indicator that needs to be involved in carrying out the hazard analysis which is the correctness and completeness of the data was attained to the utmost. The knowledge presented in this paper helps in evaluating the seismicity of the region around, District Headquarter Ambikapur after statistical analysis of the database. Finally the results are furnished in the form of peak ground acceleration (PGA) which can be used directly by engineers as fundamental considerations, for generating earthquake-resistant design of structures in and around District Headquarter Ambikapur.

Keywords: *Faults, PGA, DSHA, seismic hazard, attenuation*

1.0 Introduction

In the recent years, the interest of the scientific community regarding seismology and seismotectonic study has enhanced significantly in Peninsular India (PI), especially in the field related to seismic risk assessment, of urban seismic areas and its possible reduction measures. The hazard in this part of India is considered to be less critical than in the Himalayan plate boundary region. The fact that the Earthquakes in various parts of India, as compared to the Himalayan Plates are less severe is totally based on the relative occurrence of past tremors in the various regions. However as understood, intraplate earthquakes are rarer than plate boundary events but usually tend to be more harmful. India has experienced many great earthquakes in the past namely Rann of Kutch (June 16,1819; 8.2), Andaman Islands (December 31, 1881; magnitude 7.9), Shillong (June 12, 1897; magnitude 8.3), Kangra (April 04, 1905; magnitude 7.8), Bihar-Nepal earthquake (January 15, 1934; magnitude 8.3), Assam (August 15, 1950; magnitude 8.5), Koyna (December 11,1967; magnitude 6.5), Uttarkashi (October19, 1991; magnitude 7.0), Khillari (September 30,1993; magnitude 6.3), Jabalpur (May 22, 1997; magnitude 6.0), Chamoli earthquake (March 28, 1999; magnitude 6.8), Bhuj earthquake (January 26, 2001; magnitude 7.9) Nepal earthquake (April 25 & 26, 2015; magnitude 7.8, 6.6), Delhi (May 12, 2015; magnitude 7.3), and Dibrugarh, Assam (June 28, 2015; magnitude 5.6). Threat to human activity from earthquakes is significant. Hence, it is required to give a vital consideration while designing these kinds of structures and facilities. The main objective of earthquake resistant design is to produce a structure or facility that can withstand a certain level of shaking without excessive damage.

Figure 1: Chhattisgarh State

Figure 2: District Headquarter Ambikapur

The present study incorporates a Deterministic method of Analysis, for the Hazard investigation of Ambikapur District (23º 10' N, 83º 15' E), taking into consideration the location of Chhattisgarh as shown in Figure 1. In recent past, tremors from earthquakes have been felt, in neighbouring states, most notably in 1969 not forgetting seismic activities that have been recorded in the vicinity of Chiraikund and Muirpur along the border of Madhya Pradesh.

2.0 Methodology

2.1 Deterministic Seismic Hazard Assessment (DSHA)

In the early years of geotechnical earthquake engineering, the use of DSHA was prevalent. DSHA involves the development of a particular seismic scenario upon which a ground motion hazard evaluation is based. A typical DSHA can be described as a four-step process consisting of:

- Identification and characterization of all earthquake sources capable of producing significant ground motion at the site. Source characterization includes definition of each source's geometry and earthquake potential.
- Selection of a source-to-site distance parameter for each source zone. In most DSHAs, 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 hazard at the site is formally defined, usually in terms of the ground motions, produced at the site by the controlling earthquake.

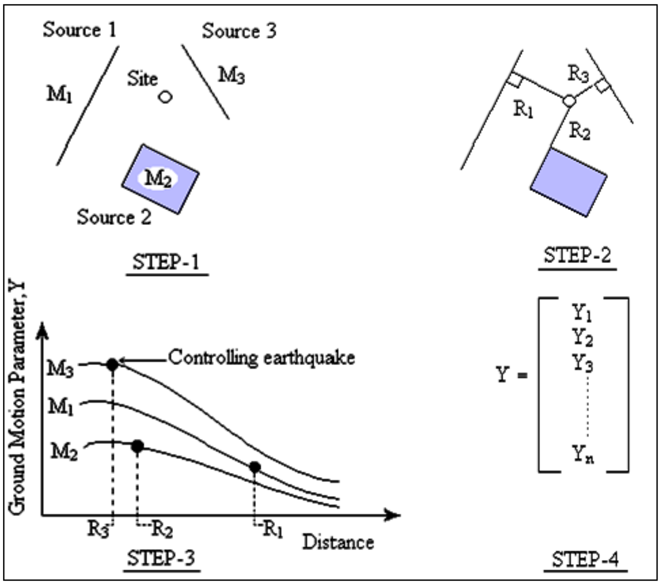

Figure 3: Steps for Deterministic Seismic Hazard Analysis (DSHA)

2.2 Identification and Characterization of Sources

In present study District Headquarter Ambikapur is selected as the target, including a control region within a radius of 300 km around the District Headquarter, having centre at 23º 10' N - 83º 15' E. The fault map of this circular region which was prepared in reference with the Seismo-tectonic Atlas of India is, as shown in Figure 4. Thus from Figure 4, it is obvious that, in recent years seismic activity appears to be concentrated along Bamhni-Chilpa Fault (140 km), Son Narmada South Fault (42 km), and Brahmani Fault (87km). A total of thirty three major faults, which influence seismic hazard at District Headquarter Ambikapur, were identified and shown in Figure 4.

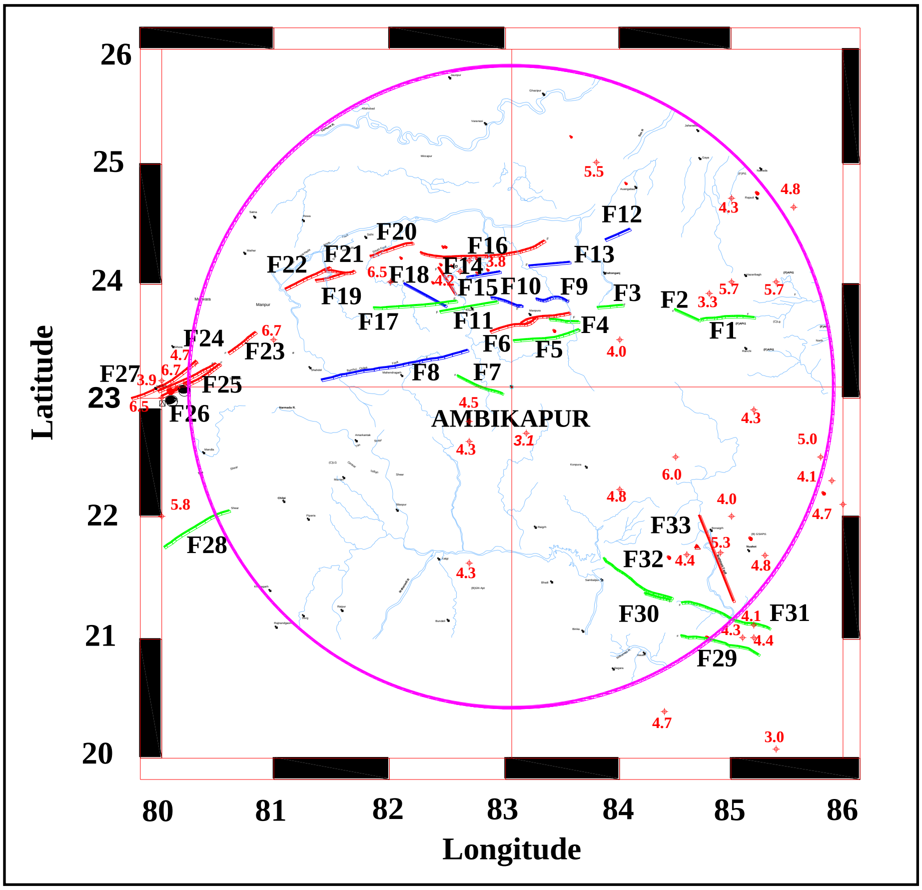

Figure 4: Seismotectonic Map of District Headquarter Ambikapur and Surroundings

The Fault details are tabulated in Table 1. After going through various available literatures and sources such as (Catalogue USGS, NIC), 43 Nos. of Earthquakes in the magnitude range 3< Mw <6.7 for District Headquarter Ambikapur, occurring over the period from 1846 to 2012 were identified.

Table 1: Faults Considered for Hazard Analysis around the District Headquarter Ambikapur

Fault No.	Fault length Li in km	Minimum map distance to the site D in km	Focal depth F in km	Hypo-central Distance R in km	Weightage of fault Wi=Li/∑Li
F1	51	187.930	10	188.196	0.0293
F2	26	168.987	10	169.283	0.0150
F3	25	109.264	10	109.721	0.0144
F4	28	72.365	10	73.053	0.0161
F5	62	42.811	10	43.964	0.0356
F6	77	54.527	10	55.437	0.0442
F7	46	10.313	10	14.366	0.0264
F8	140	52.428	10	53.374	0.0803
F9	30	85.253	10	85.838	0.0173
F10	30	76.252	10	76.905	0.0173
F11	55	80.224	10	80.845	0.0316
F12	25	163.025	10	163.332	0.0144
F13	39	114.003	10	114.441	0.0224
F14	32	110.007	10	110.461	0.0184
F15	30	76.746	10	77.395	0.0173
F16	117	140.112	10	140.469	0.0671
F17	78	94.476	10	95.004	0.0448
F18	45	96.485	10	97.002	0.0259
F19	28	188.293	10	188.559	0.0161
F20	42	162.243	10	162.551	0.0241
F21	28	181.449	10	181.725	0.0161
F22	47	201.765	10	202.013	0.027
F23	32	243.313	10	243.519	0.0184
F24	60	271.873	10	272.057	0.0345
F25	51	271.862	10	272.046	0.0293
F26	31	299.263	10	299.431	0.0178
F27	70	294.502	10	294.672	0.0402
F28	70	287.141	10	287.316	0.0402
F29	75	282.484	10	282.661	0.0431
F30	26	230.525	10	230.742	0.015
F31	86	258.063	10	258.257	0.0494
F32	75	182.619	10	182.893	0.0431
F33	87	213.349	10	213.584	0.0499

2.3 Estimation of Regional Seismicity Parameters

Seismic activity of a region, is usually characterized in terms of the Gutenberg–Richter frequency–magnitude recurrence relationship $\log_{10}(N) = a - b*Mw$, where N stands for the number of earthquakes greater than or equal to a particular magnitude M_w. Parameters (a, b) characterize the seismicity of the region. The simplest way to obtain (a, b) is through linear least square regression analysis.

Table 2: Activity Rate and Completeness for District Headquarter Ambikapur

Magnitude M_w	No. of Events $\geq M_w$	Complete in interval (year)	No. of Events per year $\geq M_w$
3.0	43	20	2.150
4.0	37	30	1.234
5.0	13	50	0.260
6.0	6	100	0.060

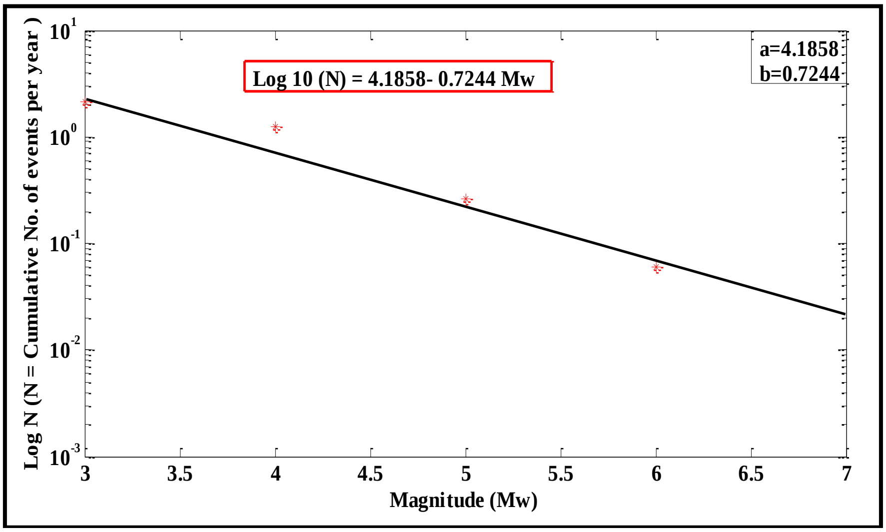

Figure 5: Frequency-Magnitude Relationship for District Headquarter Ambikapur

The present study incorporates the earthquake data of the samples, for past 167 years around District Headquarter Ambikapur, which was first evaluated for its degree of completeness. The analysis is shown in (Table 2), that all the data is complete in a statistical sense, in the following fashion: (3.0 ≤ Mw < 4) is complete in 20 years; (4.0 ≤ Mw < 5) is complete in 30 years; (5.0 ≤ Mw < 6) is complete in 50 years; and (6.0 ≤

Mw < 7) is complete in 100 years. Regional Recurrence Relationship District Headquarter Ambikapur is given by

$$\text{Log } 10\ (N) = 4.1858 - 0.7244\ M_w \quad (1)$$
$$\text{Norm of residuals } (R^2) = 0.40345$$

2.4 Estimation of Maximum Magnitude

In seismic hazard analysis, the knowledge of estimating the maximum magnitude is important and used as one of the key input parameters in the seismic design. The maximum magnitude indicates the highest potential of accumulated strain energy to be released in the region or a seismic source/fault. Alternatively, the M_{max} is an upper limit or the largest possible earthquake that may produce the highest seismic hazard scenarios for the region. However, in the study region, very limited amount of data is available for the last few decades, which do not sufficiently reveal the full seismic potential characteristics of any seismic source/fault with confidence. Following are the proposed methods for estimation of maximum magnitude for faults/lineaments; Kijko and Sellevoll (1989), Wells and Coppersmith (1994) and Gupta (2002).

2.4.1 Method-A: Wells and Coppersmith (1994)

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.

$$\text{Log (SRL)} = 0.57M_w - 2.33 \quad (2)$$

The 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. Using this equation along with a parametric study, it is observed that the subsurface fault rupture length of about 3.8% of the total fault length provides moment magnitude values closely matching those of the past earthquakes.

2.4.2 Method-B: Gupta (2002)

This method has been proposed by Gupta (2002) after adding an incremental unit. In this method to estimate 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. But in present study M_{max} was chosen by maximum value among both above methods as tabulated in Table 3.

Table 3: Estimation of Maximum Magnitude for Faults of District Headquarter Ambikapur

Fault No.	Fault length Li in km	Mw Observed for Fault	Method A (Well and Coppersmith) 1994-M_{max}	Method –B (Gupta 2002) M_{max}	M_{max} Considered for the study
F1	51	3.3	4.7	3.8	4.7
F2	26	4.0	4.1	4.5	4.5
F3	25	4.0	4.1	4.5	4.5
F4	28	4.0	4.2	4.5	4.5
F5	62	4.0	4.8	4.5	4.8
F6	77	4.0	5.0	4.5	5.0
F7	46	4.5	4.6	5.0	5.0
F8	140	6.7	5.4	7.2	7.2
F9	30	4.2	4.3	4.7	4.7
F10	30	4.2	4.3	4.7	4.7
F11	55	4.2	4.7	4.7	4.7
F12	25	5.5	4.1	6.0	6.0
F13	39	4.2	4.4	4.7	4.7
F14	32	4.2	4.3	4.7	4.7
F15	30	4.2	4.3	4.7	4.7
F16	117	3.8	5.3	4.3	5.3
F17	78	6.5	5.0	7.0	7.0
F18	45	6.5	4.6	7.0	7.0
F19	28	6.5	4.2	7.0	7.0
F20	42	6.5	4.5	7.0	7.0
F21	28	6.5	4.2	7.0	7.0
F22	47	6.5	4.6	7.0	7.0
F23	32	6.7	4.3	7.2	7.2
F24	60	6.7	4.8	7.2	7.2
F25	51	6.7	4.7	7.2	7.2
F26	31	6.7	4.3	7.2	7.2
F27	70	6.7	4.9	7.2	7.2
F28	70	5.8	4.9	6.3	6.3
F29	75	4.4	4.9	4.9	4.9
F30	26	4.4	4.1	4.9	4.9
F31	86	4.4	5.0	4.9	5.0
F32	75	4.4	4.9	4.9	4.9
F33	87	5.3	5.1	5.8	5.8

2.5 Fault Recurrence Relation

In the present investigation truncated exponential recurrence model developed by Mcguire and Arabasz (1990) is used and is given by following expression:

$$\lambda_m = N_i(m_0) * \upsilon * \frac{\exp[-\beta(m-m_0)] - \exp[-\beta(m_{max}-m_0)]}{1-\exp[-\beta(m_{max}-m_0)]} \text{---------}(3)$$

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

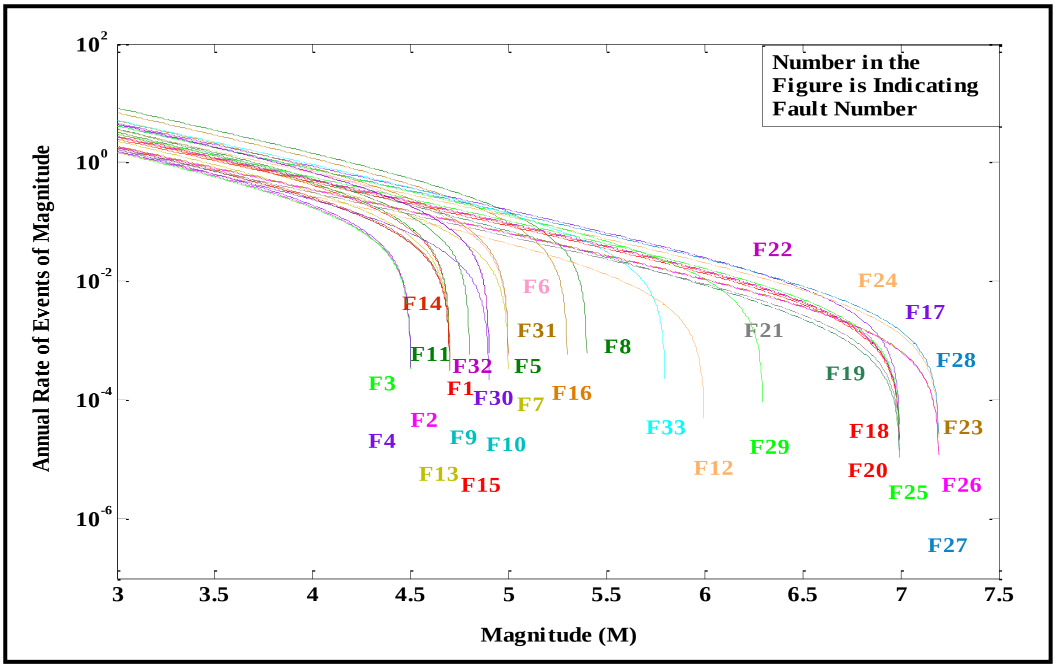

Figure 6: Deaggregation Regional Hazards in terms of Fault Recurrence for District Headquarter Ambikapur

2.6 Ground Motion Attenuation & Estimation of PGA

The Deterministic Seismic Hazard Analysis (DSHA) was carried out for District Headquarter Ambikapur considering the seismic events and Seismotectonic sources from the newly developed seismotectonic model for the region, 300 km around the District Headquarter. 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 DSHA. The attenuation relationship developed by Iyengar and Raghukanth (2004 & 2006) was considered for the analysis. Maximum value of PGA has been taken amongst the PGA calculated by various source at each point.

$$\text{In}\ (PGA/g) = C1+C2\ (M-6) + C3\ (M-6)^2 - \ln(R) - C4(R) + \ln\varepsilon \qquad (4)$$

Where, C1= 1.6858, C2= 0.9241, C3= 0.0760, C4= 0.0057,
R= Hypo central distance, M= Magnitude = M100, lnε = 0 (for DSHA).

3.0 Results and Discussion

The seismic hazard analysis carried out, for the establishment of PGA at substratum level for District Headquarter Ambikapur, was based on deterministic approach. An attempt was also made to evaluate the seismic hazard in terms of PGA at the same level. The Regional Recurrence Relationship obtained for District Headquarter Ambikapur as depicted in Equation 1 shows, the obtained “b” value as 0.7244. The Values of P.G.A. for M100 Earthquakes have been presented in Table 4. The Maximum value of Peak Ground Acceleration (P.G.A.) for recurrence period of 100 years for District Headquarter Ambikapur was found to be due to the fault No. 7 (Fault length 46 km, Min. Map Distance 10.313 km) which came out to be equal to 0.1199 for 50 percentile and 0.1908 for 84 percentile. The Indian Seismic code as per IS: 1893 (Part1)-2002, the Chhattisgarh comes under low seismic region-Zone II and Seismic Intensity (PGA) for it is given as 0.10g, but for District Headquarter Ambikapur the PGA value comes as 0.1199g for 50 percentile, so the value of PGA is exceeding from recommended value of as per IS: 1893 (Part 1)-2002.So it is essential to design the civil engineering structures seismic resistant to safe guard the public infrastructures and human properties.

Table 4: Deterministic PGA Values at District Headquarter Ambikapur

Fault No.	Fault length Li in km	Fault Name	Hypo-Central Distance R in Km	Magnitude M100 [100 years Recurrence Period	PGA Values (g) (100Years)	
					50 Percentile	84 Percentile
F1	51	--	188.197	4.669	0.0026	0.004
F2	26	--	169.283	4.458	0.0025	0.0039
F3	25	--	109.722	4.455	0.0053	0.0084
F4	28	--	73.0530	4.461	0.0099	0.0157
F5	62	--	43.964	4.771	0.0274	0.0436
F6	77	--	55.437	4.966	0.0252	0.0401
F7	46	Bamhni - Chilpa Fault	14.366	4.944	0.1199	0.1908
F8	140	--	53.374	5.362	0.0402	0.0639
F9	30	--	85.839	4.649	0.0097	0.0154
F10	30	--	76.906	4.649	0.0114	0.018
F11	55	--	80.845	4.671	0.0108	0.0172
F12	25	--	163.333	5.595	0.0089	0.0141
F13	39	--	114.441	4.661	0.0063	0.0099
F14	32	--	108.345	4.652	0.0068	0.0108
F15	30	--	101.339	4.649	0.0075	0.0119
F16	117	--	140.470	5.263	0.0084	0.0134
F17	78	--	95.004	6.416	0.0480	0.0763
F18	45	--	96.767	6.164	0.0374	0.0594
F19	28	Son Narmada South Fault	188.56	5.932	0.0092	0.0146
F20	42	--	162.653	6.148	0.0151	0.0240
F21	28	--	181.726	5.964	0.0102	0.0163
F22	47	--	202.013	6.212	0.0103	0.0163
F23	32	--	243.519	6.049	0.0058	0.0093
F24	60	--	276.160	6.368	0.0057	0.0090
F25	51	--	272.046	6.232	0.0052	0.0083
F26	31	--	299.432	6.041	0.0034	0.0055
F27	70	--	294.673	6.423	0.0050	0.0080
F28	70	--	287.316	6.026	0.0038	0.0060
F29	75	--	282.662	4.870	0.0013	0.0020
F30	26	--	230.742	4.816	0.0019	0.0031
F31	86	--	182.893	4.970	0.0038	0.0059
F32	75	Brahmani Fault	258.258	4.870	0.0016	0.0025
F33	87	--	213.585	5.688	0.0056	0.0089

4.0 Conclusions

The study results outlined in this paper can directly be implemented for designing of earthquake-resistant structures in and around District Headquarter Ambikapur. It will also help municipal authorities and other Government Agencies to enforce suitable by-laws in land use Planning and Construction Activity and create awareness among the public to safeguard their properties.

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