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Seismic Hazard Analysis of Low Seismic Regions, Durg & Rajnandgaon

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Abstract : *Seismic hazard assessment of low seismicity regions of the world is now-a-days becoming more common. The seismic hazard assessment involves the quantitative estimation of ground motion characteristics at a particular site. Seismic Hazard is a regional property. It can neither be prevented nor reduced. The only alternative is to quantify the Hazard and minimize the possible damages to the structures due to possible strong Ground Motion. Durg and Rajnandgaon sites are two District Headquarters of the state of Chhattisgarh. In the present study. Deterministic Seismic Hazard Assessment (DSHA) has been applied to these District Headquarters to assess the maximum Peak Ground Acceleration (PGA) at these sites. Beauro of Indian Standard has specified these sites in seismic Zone II. This fact has been verified in the present study.*

Keywords - *Deterministic Seismic Hazard, Fault Map, Earthquake, Peak Ground Acceleration, District Headquarters*

I. INTRODUCTION

A spate of Earthquakes in recent past, causing extensive damage has heightened the sensitivity of Engineers and Planners to the looming seismic risk in densely populated cities, major dams and important & historical places. Earthquakes are a global phenomenon and a global problem. It is not possible to prevent Earthquakes from occurring but it is possible to mitigate the effects of strong Earthquake shaking, to reduce loss of lives, injuries and damages. Occurrence of one or more Earthquakes at a project site is known as Seismic Hazard.

The Earthquakes in India occur in the plate boundary of the Himalayas region as well as in the intra-plate region of peninsular India (P I). Devastating events have occurred in P I in the recent past, which must be considered as a severe warning about the possibility of such Earthquake in the future. Engineering approaches to Earthquake resistant design will be successful to the extent that the forces due to future shocks are accurately estimated at location of a given structure. Earthquakes are low probability events, but with very high levels of risks to the society. Hence, either under estimation or over estimation of seismic hazard will prove dangerous or costly in the end Earthquakes present a threat to people and the facilities they design and build. Seismic hazard analysis (SHA) is the evaluation of potentially damaging earthquake related phenomenon to which a facility may be subjected during its useful lifetime. Seismic hazard analysis is done for some practical purpose, typically seismic-resistant design or retrofitting.

Seismic hazards may be analyzed deterministically as and when a particular earthquake scenario is assumed, or probabilistically, in which uncertainties in earthquake size, location, and time of occurrence are explicitly considered (Kramer 1996). In practice, DSHAs often assume that earthquakes of the largest possible magnitude occur at the shortest possible distance to the site within each source zone. The earthquake that produces the most severe site motion is then used to compute site –specific ground motion parameters. Deterministic method is the technique in which a single estimate of parameters is used to perform each analysis. To account for uncertainty, several analyses may be conducted with different parameters. For assessment of PGA, of District Headquarters Durg and Rajnandgaon have been considered for this study. The present study details of these District Headquarters sites are as follows:

Salient Features	Durg	Rajnandgaon
Latitude	21° 11' N	21° 05' N
Longitude	81° 05' E	81° 05' E

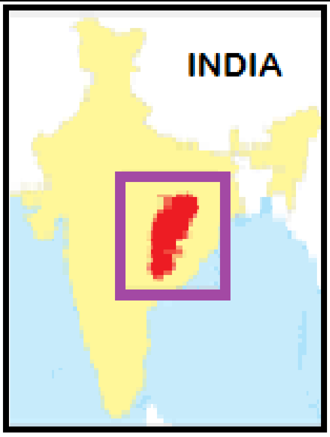

Figure1.1 (a) Chhattisgarh State

Figure1.1 (b) District Headquarters Durg and Rajnandgaon

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.

Seismic hazard analysis involves the quantitative estimation of ground shaking hazards at a particular area. The most important factors affecting seismic hazard at a location are:
1. Earthquake magnitude
2. The source-to-site Distance
3. Earthquake rate of Occurrence (return period)
4. Duration of Ground Shaking

II. DETERMINISTIC SEISMIC HAZARD ASSESSMENT (DSHA)

The DSHA can estimate in the following steps:
- Seismic Sources.
- Earthquake- recurrence- frequency.
- Deaggregation of Seismic Hazard.
- Ground motion attenuation.
- Estimation of PGA

2.1 Seismic Sources

- A circular region of 300 km radius has to be assumed around the site.
- Seismicity information has to be collected (i.e Epicenter, Magnitude) inside the 300 km radius.
- Different faults in this 300 Km. radius region have to be identified, length of the fault and their shortest distances from the site have to be worked out.

2.1.1 Earthquake History of Study Area

Most of the earthquakes occurred in India are in northern part of Indian sub continent. These occurred due to the upward movement of Himalayan region. The earthquake data prior to 1827 is not available. The available data is from 1846- 2011. However, due to non availability of earthquake data United States Geological survey was collected with radial search of 300 Km. The collected earthquake data is as shown in Appendix I, for Durg and Rajnandgaon district headquarters. As per the past records the earthquake magnitudes Mw of 3 to 6.7 are available. A historical record of past Earthquakes, in a region, is the one of the most important tool as these records are useful to assess the region seismicity.

2.2. Earthquake Recurrence Frequency

Earthquake Recurrence relationship has to be worked in the following steps:
- Earthquake information for region has to be collected over a long period from various historical records.
- All the data has to be arranged as per the number of Earthquakes that exceeded various magnitude values (m=0, 1, 2, 3,)
- Suitable Earthquake Recurrence Relation has to be used, which appropriately characterizes the seismicity of the region.

2.3. Deaggregation of Seismic Hazard

1. In DSHA, the basic idea is to foreshadow on each of the causative fault, the magnitude of an Earthquake, which may be exceeded in say 100 years or 1000 years.
2. M100 has to be worked out for each fault.
3. Using the Regional Recurrence Relation, it is easy to find the above magnitudes for the region, but not for individual faults.
4. The potential of a fault to produce an Earthquake of a particular magnitude would depend on the length of the fault itself.
5. Ni (m0) on any individual fault may be proportional to the length of the fault itself.
Weightage Wi=Li / Σ Li.
6. The 'b' value of any fault is to be same as the regional 'b' value.
7. The value of mmax for each fault is to be fixed up by finding the most probable magnitude of the largest past event that can be associated with the fault. This value is increased by 0.5 and taken as m_{max}. In case, only the highest intensity value is known, the event magnitude is taken as m=2/3(I0)+1.

2.4. Ground Motion Attenuation

- Attenuation may be described as the way in which strong motion parameters decay with distance from the source.
- This depends on the source properties (M, focal depth, fault type and size), as well as on the regional properties (frequency dependent damping, layering, anisotropy etc.).
- The property of the site (hard rock, soft soil, valley and mountain) also influences the ground motion attenuation.

For the present study attenuation relationship5 suggested by R N Iyengar & S T G Raghukant, (Applicable for peninsular India, under bed rock condition) has been used.

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

Where,

C1= 1.6858, C2= 0.9241, C3= 0.0760, C4= 0.0057,

R= Hypo central distance, m= magnitude, ln ε = 0 (for DSHA).

2.5. Estimation of Peak Ground Acceleration (PGA)

The PGA, which exceedes with 50 % probability, is to be calculated from the attenuation equation. In DSHA, the maximum among these values is to be taken as the design basis acceleration depending on the acceptability of this value based on other seismological considerations. This PGA value could be a reference value for further work.

III. Application of DSHA

Deterministic seismic hazard analysis (DSHA) has been applied to Durg and Rajnandgaon sites using the following steps: A region of 300 km radius around both Durg and Rajnandgaon sites were considered and all the faults having ≥ 25 km length were marked. These regions are shown in Figure 3.1 and Figure 3.2 respectively

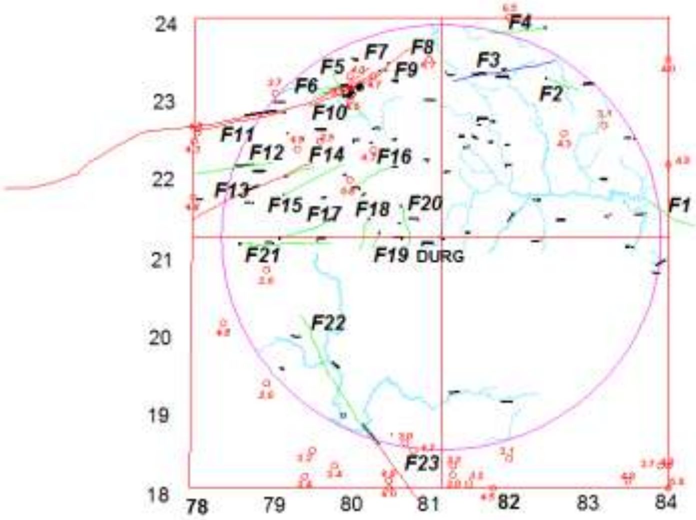

Figure 3.1 Fault considered for Deterministic Seismic Hazard Analysis of District Headquarter Durg

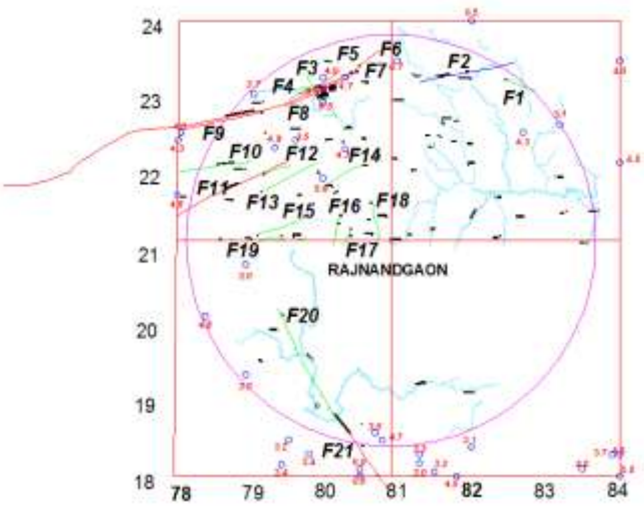

Figure 3.2 Fault considered for Deterministic Seismic Hazard Analysis of District Headquarter Rajnandgaon

With the help of different literature available and websites 55 Nos. of Earthquakes in the magnitude range 3≥ Mw to Mw ≤ 6.7 for Durg and Rajnandgaon sites over the period from 1846 to 2012 (166) years have been collected. The same is presented at Appendix I.

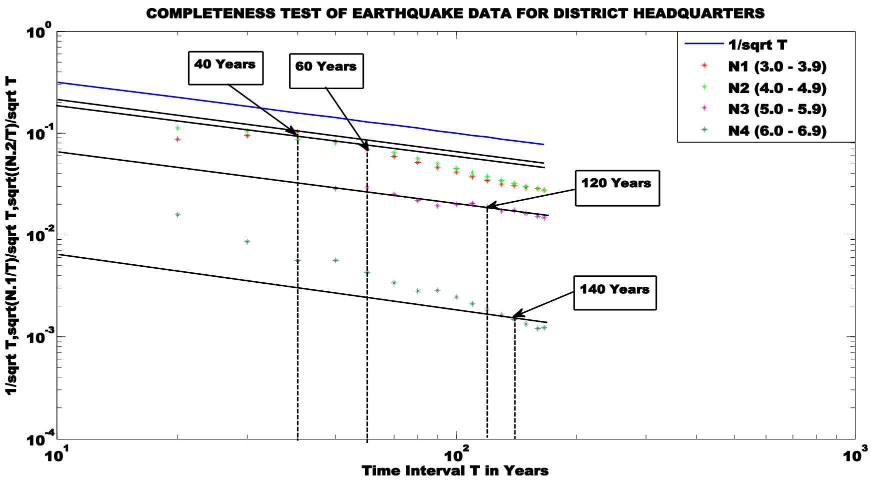

Figure 3.3 Completeness Test of Earthquake Data for District Headquarters

The completeness analysis for District Headquarters sites has been performed and as shown in Figure 3.3. Earthquakes data for completeness test for Durg and Rajnandgaon sites have been presented in Table 2.3 (Appendix II) respectively. Completeness test of Earthquakes data for Durg and Rajnandgaon sites has been shown in Figure 3.3. It has been observed for Durg and Rajnandgaon (from the Table 3.1 below) that 3.0 magnitude will be completed in 40 years time interval while 6.7 magnitude will complete in 140.

Table No.3.1 Activity Rate and Interval of Completeness at District Headquarters

Magnitude Mw	No. of Events ≥ Mw	Complete in interval	No. of Events per year
3.0	55	40	1.3750
4.0	34	60	0.5667
5.0	13	120	0.1084
6.7	3	140	0.0214

Using completeness analysis, Regional Recurrence Relationship has been obtained for: District Headquarters

$$\text{Log } 10\ (N) = 1.99 - 0.5478Mw \text{---------}(3.1)$$

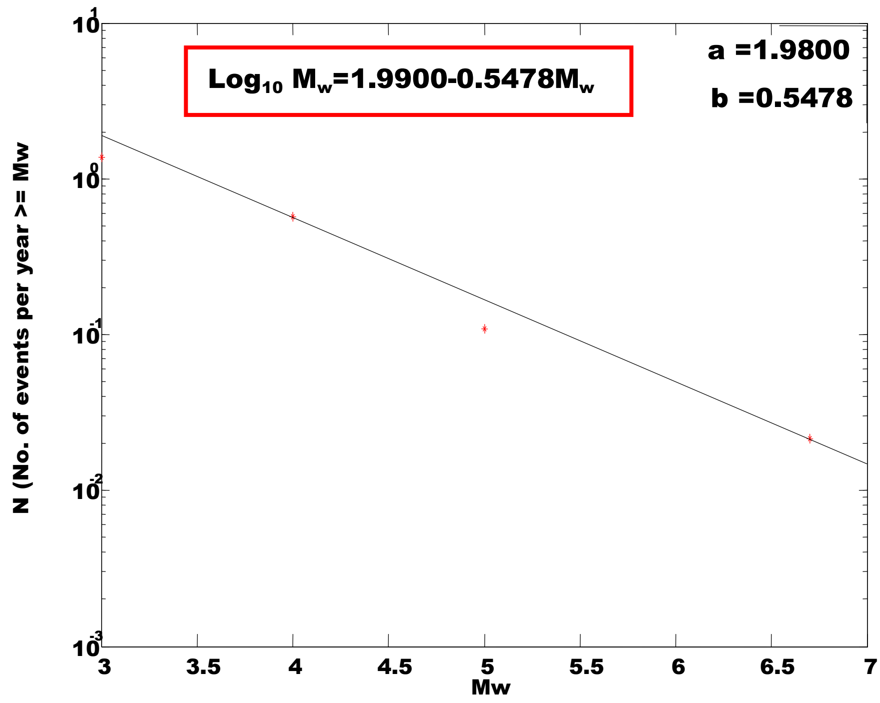

Figure 3.4 Regional Recurrence Relationships for District Headquarters

The Hypo-central distance (by considering the focal depth as 10 km), weightage and maximum potential magnitude (Mu) is obtained for each fault having length ≥25 km and has been presented in Table 2.4 for Durg and in Table 2.5 (Appendix II) for Rajnandgaon.

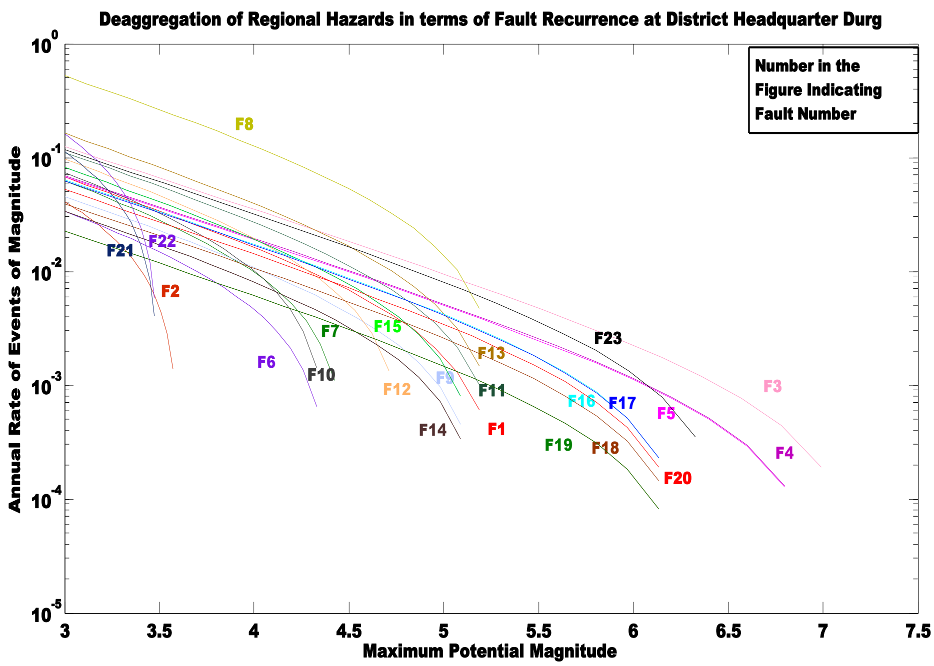

Figure 3.5 Deaggregation of Regional Hazards in terms of Fault Recurrence at District Headquarter Durg

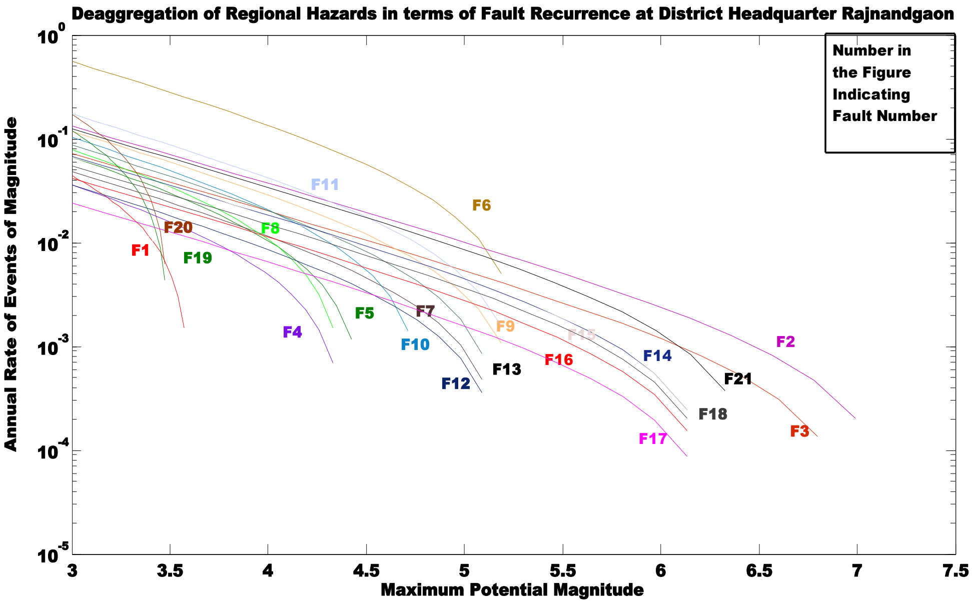

Figure 3.6 Deaggregaton of regional hazards in terms of fault recurrence at District Headquarter Rajnandgaon

M100 has been obtained by generating the fault deaggregation record. In this study all the faults having ≥ 25 km lengths are considered. Fault deaggregation for Durg and Rajnandgaon have been shown in Figure 3.5 and Figure 3.6 respectively.

IV. RESULT & CONCLUSION

Regional Recurrence Relationship obtained for Durg and Rajnandgaon sites have been presented in Equation No 3.1 Obtained "b" value 0.5478 respectively. Hence, the both the sites are situated in less seismic active zone. Deterministic Seismic Hazard Analysis has been applied to the District Headquarters Durg and Rajnandgaon sites, Values of P.G.A. for M100 Earthquakes have been presented in Table No.2.6 & Table No.2.7 (Appendix II) respectively. Maximum values of Peak Ground Acceleration (P.G.A.) for Durg Site has been obtained due to fault No. 20 (length 58 km, Distance 48.093km) is equal to 0.01385g. and Maximum value of Peak Ground Acceleration (P. G. A.) for Rajnandgaon. Site has been obtained due to fault No. 18 (length 58 km, Distance 21.245 km) is equal to 0.03433g. As per IS 1893:2002(Part-1) the District Headquarters region have been categorized as zone II and corresponding P.G.A. is equal to 0.1g. Hence, this fact has also been verified from the present study.

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APPENDIX 1

Listing of Earthquake Events around District Head Quarters

S.No.	Name of Head Quarter	Location of HQ		Latitude		Longitude	
		Latitude	Longitude				
1	Durg	21° 11' N	81° 21' E	18° 0'	24° 0'	78° 0'	84° 0'
2	Rajnandgaon	21° 05' N	81° 05' E	18° 0'	24° 0'	78° 0'	84° 0'

S No.	Year	Month	Date	Latitude	Longitude	Int	Ms	Mb	Mw	Depth	Source
1	1846	5	27	23	80	Vi			6.5		OLD, NEIC, UKOLD
2	1858	10	12	18.3	84	V			4.3		OLD, NEIC
3	1859	8	24	18.1	83.5	V			3.7		OLD, NEIC, UKGSI
4	1861	11	13	18.11	83.5	Iii			3		UGS
5	1871	9	27	18.3	83.9	Iii			3		UGS
6	1872	11	22	18.86	80	Vi			5		UGS
7	1878	12	10	18.3	83.9	Iv			3.7		UGS
8	1903	5	17	23	80		5		5.5		TRI, NEIC, UKTRI
9	1917	4	17	18	84		5.5		5.8		ISS, NEIC, UKIMD
10	1927	6	2	23.5	81		6.5	6	6.7		GR
11	1927	6	2	24	82				6.5		NEIC, UKCH
12	1954	1	5	18	81.8		4		4.5		IMD
13	1954	1	5	18	81.3				4		NEIC, UKIMD
14	1957	8	25	22	80		5.5	5.5	5.8		SHL, NEIC, UKSHL
15	1959	8	9	18.1	83.5		4.1		4.7		RAO, UKRAO
16	1959	12	23	18.1	83.5		4.3		4.8		RAO, UKRAO
17	1965	4	29	23.5	84				4		NEIC
18	1968	11	14	21.8	78		4.2		4.8		IMD, NEIC, UKHYB
19	1969	4	14	18	80.5			5.2	5.3		IMD
20	1969	4	15	18	80.7			4.6	4.6	33	ISC
21	1969	4	14	18.1	80.5				6		UKTS
22	1969	3	26	22.6	78.1		4.2		4.8		IMD
23	1969	4	14	18	80.5				6		USC
24	1969	4	14	18	80.5	Vi			5.7	33	USC
25	1973	7	12	23.2	80		4		4.6		IMD
26	1973	7	12	23.1	79				3.7		NEIC, UKHYB
27	1975	4	24	18.7	80.7		3		3		INR, NEIC, UKHYB
28	1975	7	3	18	79.5		3.2		3.2		INR
29	1975	9	15	18.4	79.2		3.2		3.2		INR, NEIC, UKHYB
30	1975	7	3	18.5	79.5				3.2		UKHYB
31	1977	9	30	18.08	81.5		3.3		3.3		GBA
32	1979	8	29	18.24	81.3		3		3		GBA
33	1979	4	22	18.5	80.8		3.5		4.7		INR
34	1981	12	4	18.16	81.4		3		3		GBA
35	1981	12	16	18.57	80.7		3.3		3.3		GBA
36	1983	4	8	18.17	81.3		3		3		GBA
37	1984	4	24	18.27	78.8		3.4		3.4		GBA
38	1984	4	27	18.16	79.4		3.4		3.4		GBA
39	1984	6	20	20.4	78.5		3.7		4.3		GBA

40	1985	1	6	20.22	78.4		4.2		4.8		GBA
41	1985	9	27	19.39	78.9		3		3		GBA
42	1986	4	9	18.34	82		3.1		3.1		GBA
43	1987	4	18	22.53	79.2			4.8	4.8	20	ISC
44	1987	4	18	22.35	79.3			4.9	4.9	33	GSPDE, UKHYB
45	1990	6	9	18.1	80.5		4		4.6		CVR
46	1996	2	12	22.62	82.7				4.3	33	MLDMIV, UKHYB
47	1997	5	21	23.07	80			6	6.7	36	CGS
48	1997	5	21	23.08	80			6	6.7	36	NEIC, GS
49	1997	6	4	23.14	80				3.9	33	MDHYR, PDE, NEIC
50	1998	3	9	22.49	78			4.3	4.3	10	GSPDE, NEIC
51	2000	10	10	23.8	82.7			4.5	4.5	33	GSPDE, NEIC
52	2000	10	16	23.28	80.3			4.7	4.7	33	GSPDE, NEIC
53	2001	6	12	22.22	83.9			4.8	4.8	33	GSPDE, NEIC
54	2007	4	13	22.70	83.2				3.1	10	RAIG., IMD
55	2011	2	8	22.5	79.6				3.5	12	SEONI,MP,IMD

APPENDIX I1

Table 2.1Magnitude-Frequency Data of District Headquarters Durg and Rajnandgaon
Observation Period– 166 years [1846-2012]

S.No.	Moment Magnitude Mw	No. of Earthquake ≥ Mw	No. of Earthquake ≥ Mw per year
1	3.0	55	0.331320
2	3.1	48	0.289152
3	3.2	46	0.277104
4	3.3	43	0.259032
5	3.4	41	0.246984
6	3.5	39	0.234936
7	3.6	38	0.228912
8	3.7	38	0.228912
9	3.8	35	0.210840
10	3.9	35	0.210840
11	4.0	34	0.204816
12	4.1	32	0.192768
13	4.2	32	0.192768
14	4.3	32	0.192768
15	4.4	28	0.168672
16	4.5	28	0.168672
17	4.6	26	0.156624
18	4.7	23	0.138552
19	4.8	20	0.120480
20	4.9	14	0.084336
21	5.0	13	0.078312
22	5.1	12	0.072288
23	5.2	12	0.072288
24	5.3	12	0.072288
25	5.4	11	0.066264
26	5.5	11	0.066264
27	5.6	10	0.060240

28	5.7	10	0.060240
29	5.8	9	0.054216
30	5.9	7	0.042168
31	6.0	7	0.042168
32	6.1	5	0.030120
33	6.2	5	0.030120
34	6.3	5	0.030120
35	6.4	5	0.030120
36	6.5	5	0.030120
37	6.6	3	0.018072
38	6.7	3	0.018072

Table 2.2 Earthquake Distribution by Time and Magnitude for District Headquarters

Time	Time Interval T in years	No. of Cumulative Earthquakes occurred in the time interval T				Rate of occurrence of Earthquake /year for the Magnitude			
		3-3.9 M_w	4-4.9 M_w	5-5.9 M_w	6-6.9 M_w	3-3.9 M_w(N1)	4-4.9 M_w(N2)	5-5.9 M_w(N3)	6-6.9 M_w(N4)
2002-2012	10	2	0	0	0	0.2	0	0	0
1992-2012	20	3	5	0	2	0.15	0.25	0	0.1
1982-2012	30	8	10	0	2	0.2667	0.3333	0	0.0667
1972-2012	40	17	12	0	2	0.425	0.3	0	0.05
1962-2012	50	17	16	2	4	0.34	0.32	0.04	0.08
1952-2012	60	17	20	3	4	0.2833	0.3333	0.05	0.0667
1942-2012	70	17	20	3	4	0.2429	0.2857	0.0429	0.0571
1932-2012	80	17	20	3	4	0.2125	0.25	0.0375	0.05
1922-2012	90	17	20	3	6	0.1889	0.2222	0.0333	0.0667
1912-2012	100	17	20	4	6	0.17	0.2	0.04	0.06
1902-2012	110	17	20	5	6	0.1545	0.1818	0.0455	0.0545
1892-2012	120	17	20	5	6	0.1417	0.1667	0.0417	0.05
1882-2012	130	17	20	5	6	0.1308	0.1538	0.0385	0.0462
1872-2012	140	18	20	6	6	0.1286	0.1429	0.0429	0.0429
1862-2012	150	19	20	6	6	0.1267	0.1333	0.04	0.04
1852-2012	160	21	21	6	6	0.1313	0.1313	0.0375	0.0375
1846-2012	166	21	21	6	7	0.1265	0.1265	0.0361	0.0422

Table 2.3 Rate of Occurrence of Magnitude of District Headquarters Durg and Rajnandgaon

Time Interval T in year	$\frac{1}{\sqrt{T}}$	$\frac{\sqrt{(N_1/T)}}{\sqrt{T}}$	$\frac{\sqrt{(N_2/T)}}{\sqrt{T}}$	$\frac{\sqrt{(N_3/T)}}{\sqrt{T}}$	$\frac{\sqrt{(N_4/T)}}{\sqrt{T}}$
10	0.3162	0.1414	0.0000	0.0000	0
20	0.2236	0.0866	0.1118	0.0000	0.015811
30	0.1826	0.0943	0.1054	0.0000	0.008607
40	0.1581	0.1031	0.0866	0.0000	0.00559
50	0.1414	0.0825	0.0800	0.0283	0.005657
60	0.1291	0.0687	0.0745	0.0289	0.004303
70	0.1195	0.0589	0.0639	0.0247	0.003415
80	0.1118	0.0515	0.0559	0.0217	0.002795

90	0.1054	0.0458	0.0497	0.0192	0.002869
100	0.1000	0.0412	0.0447	0.0200	0.002449
110	0.0953	0.0375	0.0407	0.0203	0.002123
120	0.0913	0.0344	0.0373	0.0186	0.001863
130	0.0877	0.0317	0.0344	0.0172	0.001653
140	0.0845	0.0303	0.0319	0.0175	0.001479
150	0.0816	0.0291	0.0298	0.0163	0.001333
160	0.0791	0.0286	0.0286	0.0153	0.00121
166	0.0776	0.0276	0.0276	0.0148	0.001237

Table 2.4 Faults Considered for Hazard Analysis around the District Headquarter Durg

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 W_i	Maximum potential magnitude M_u
F1	75	285.995	10	286.17	0.0302	5.3
F2	46	267.067	10	267.26	0.0185	3.6
F3	140	221.310	10	221.54	0.0563	7.2
F4	78	295.772	10	295.95	0.0314	7.0
F5	76	198.402	10	198.66	0.0306	7.0
F6	38	257.176	10	257.38	0.0153	4.4
F7	70	258.658	10	258.86	0.0282	4.5
F8	585	269.231	10	269.42	0.2352	5.3
F9	51	242.429	10	242.64	0.0205	5.2
F10	83	258.855	10	259.05	0.0334	4.4
F11	124	279.578	10	279.76	0.0499	5.3
F12	108	253.582	10	253.78	0.0435	4.8
F13	182	204.697	10	204.95	0.0732	5.3
F14	38	200.335	10	200.59	0.0153	5.2
F15	91	169.963	10	170.26	0.0366	5.2
F16	71	119.711	10	120.13	0.0286	6.3
F17	70	156.865	10	157.19	0.0282	6.3
F18	44	103.318	10	103.81	0.0177	6.3
F19	25	84.162	10	84.76	0.0101	6.3
F20	58	48.093	10	49.13	0.0234	6.3
F21	125	151.865	10	152.2	0.0503	3.5
F22	180	222.259	10	222.49	0.0724	3.5
F23	130	289.363	10	289.54	0.0523	6.5
Total= 2488						

Table 2.5 Faults Considered for Hazard Analysis around the District Headquarter Rajnandgaon

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 W_i	Maximum potential magnitude M_u
F1	46	290.209	10	290.39	0.0198	3.6
F2	140	235.267	10	235.48	0.06	7.2
F3	76	196.07	10	196.33	0.0326	7.0
F4	38	253.602	10	253.8	0.0163	4.4
F5	70	252.993	10	253.2	0.03	4.5
F6	585	277.013	10	277.2	0.2506	5.3

F7	51	240.641	10	240.85	0.0219	5.2
F8	83	244.212	10	244.42	0.0356	4.4
F9	124	267.844	10	268.04	0.0532	5.3
F10	108	235.807	10	236.02	0.0463	4.8
F11	182	189.664	10	189.93	0.078	5.3
F12	38	184.814	10	185.09	0.0163	5.2
F13	91	158.214	10	158.53	0.039	5.2
F14	71	117.218	10	117.65	0.0305	6.3
F15	70	134.031	10	134.41	0.03	6.3
F16	44	83.09	10	83.69	0.0189	6.3
F17	25	60.86	10	61.68	0.0108	6.3
F18	58	21.245	10	23.49	0.0249	6.3
F19	125	126.175	10	126.58	0.0536	3.5
F20	180	194.317	10	194.58	0.0771	3.5
F21	130	270.773	10	270.96	0.0557	6.5
Total= 2335						

Table 2.6 PGA for M_{100} Earthquakes at District Headquarter Durg

Fault No.	Fault length L_i in km	Minimum map distance to the site D in km	Focal depth F in km	Hypo central distance R in km	100 years recurrence M_{100}	PGA * of Site
F1	75	285.995	10	286.17	4.26	0.00059
F2	46	267.067	10	267.26	3.42	0.00024
F3	140	221.310	10	221.54	5.10	0.00282
F4	78	295.772	10	295.95	4.60	0.00080
F5	76	198.402	10	198.66	4.50	0.00184
F6	38	257.176	10	257.38	3.70	0.00039
F7	70	258.658	10	258.86	4.00	0.00055
F8	585	269.231	10	269.42	4.15	0.00060
F9	51	242.429	10	242.64	4.10	0.00073
F10	83	258.855	10	259.05	4.00	0.00055
F11	124	279.578	10	279.76	4.61	0.00094
F12	108	253.582	10	253.78	4.30	0.00084
F13	182	204.697	10	204.95	4.73	0.00224
F14	38	200.335	10	200.59	3.88	0.00086
F15	91	169.963	10	170.26	4.43	0.00233
F16	71	119.711	10	120.13	4.48	0.00466
F17	70	156.865	10	157.19	4.48	0.00289
F18	44	103.318	10	103.81	4.10	0.00378
F19	25	84.162	10	84.76	3.66	0.00298
F20	58	48.093	10	49.13	4.30	0.01385
F21	125	151.865	10	152.2	3.44	0.00085
F22	180	222.259	10	222.49	3.45	0.00039
F23	130	289.363	10	289.54	4.80	0.00106

Table 2.7 PGA for M_{100} Earthquakes at District Headquarter Rajnandgaon

Fault No.	Fault length L_i in km	Minimum map distance to the site D in km	Focal depth F in km	Hypo central distance R in km	100 years recurrence M_{100}	PGA * of Site
F1	46	290.209	10	290.39	3.42	0.00020*
F2	140	235.267	10	235.48	5.00	0.00220
F3	76	196.070	10	196.33	4.55	0.00200
F4	38	253.602	10	253.8	3.70	0.00040
F5	70	252.993	10	253.2	4.05	0.00062
F6	585	277.013	10	277.2	4.90	0.00132
F7	51	240.641	10	240.85	4.10	0.00075
F8	83	244.212	10	244.42	4.05	0.00068
F9	124	267.844	10	268.04	4.60	0.00103
F10	108	235.807	10	236.02	4.30	0.00099
F11	182	189.664	10	189.93	4.40	0.00181
F12	38	184.814	10	185.09	3.90	0.00104
F13	91	158.214	10	158.53	4.42	0.00265
F14	71	117.218	10	117.65	4.60	0.00554
F15	70	134.031	10	134.41	4.50	0.00393
F16	44	83.090	10	83.69	4.10	0.00526
F17	25	60.86	10	61.68	3.70	0.00492
F18	58	21.245	10	23.49	4.32	0.03433*
F19	125	126.175	10	126.58	3.45	0.00120
F20	180	194.317	10	194.58	3.48	0.00055
F21	130	270.773	10	270.96	4.92	0.00143