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SEISMIC HAZARD ANALYSIS OF SONDUR DAM SITE OF CHHATTISGARH STATE

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Abstract

Seismic vulnerability 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 Probablistic Seismic Hazard Analysis” (PSHA) and “The Deteminisntic Seismic Hazard Analysis” (DSHA). A sincere effort is made herein to do seismic hazard analysis for Sondur Dam site of Chhattisgarh state . The study consists of broadly two parts, the first part basically gives a detail overview of the seismicity of the region and identification of various faults existing within the Dam site with all their details and the second part includes DSHA analysis for the same. An attempt was made to compile the occurrence of past and recent seismic activities within 300 km radius, around the Sondur Dam site. 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. 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 Sondur Dam site.

Keywords: PGA, Dam, Seismic Hazard, Attenuation, DSHA

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, intra-plate earthquakes are rarer than plate boundary events but usually tend to be more harmful. Paucity of recorded ground motion data introduces uncertainties in predicting the nature of occurrence of future ground motions and the dynamic forces, which needs to be considered in the designing of manmade structures. The behavior of a building, dam or a power plant depends primarily on the local ground motion at the foundation level. A fairly accurate knowledge of such motions, pertaining to all possible sources in the influenced zone of about 300 km radius around the construction site, is the most sought information in engineering practices. The existing Indian code IS-1893 does not furnish any quantification of seismic hazard. Seismic hazard analysis plays an important role in generating earthquake-resistant design of structures by providing a rational value of input hazard parameters, like peak ground acceleration (PGA). Traditionally, PGA has been a popular hazard parameter, but it is often found to be poorly correlated with the damage potential of ground motion. All the existing researches, related to seismicity in India, have been made simply, in terms of the peak ground acceleration or by using the attenuation relations for some or the other parts of the world. In the present study Deterministic Seismic Hazard Analysis (DSHA) has been used to assess Peak Ground Acceleration at major dam site of state of Chhattisgarh. Sondur dam(N 20° 14′ - E 82° 06′) is located in Chhattisgarh in India. It was constructed in 1988 across sondur river. The catchment area of the sondur river up to the dam is 518 km^2. This is a major irrigation dam constructed across the Mahanadi River near village Sondur District Dhamtari.

Salient features of Dam:

Design flood.	5407 cumec	Gross storage.	6.99 TMC
Height of Dam	38.2 meter	Earthen Dam Portion	3176.75m
Masonry Portion	191.25 m	Irrigation.	12260.00 Hectare

Identification and Characterization of Sources:

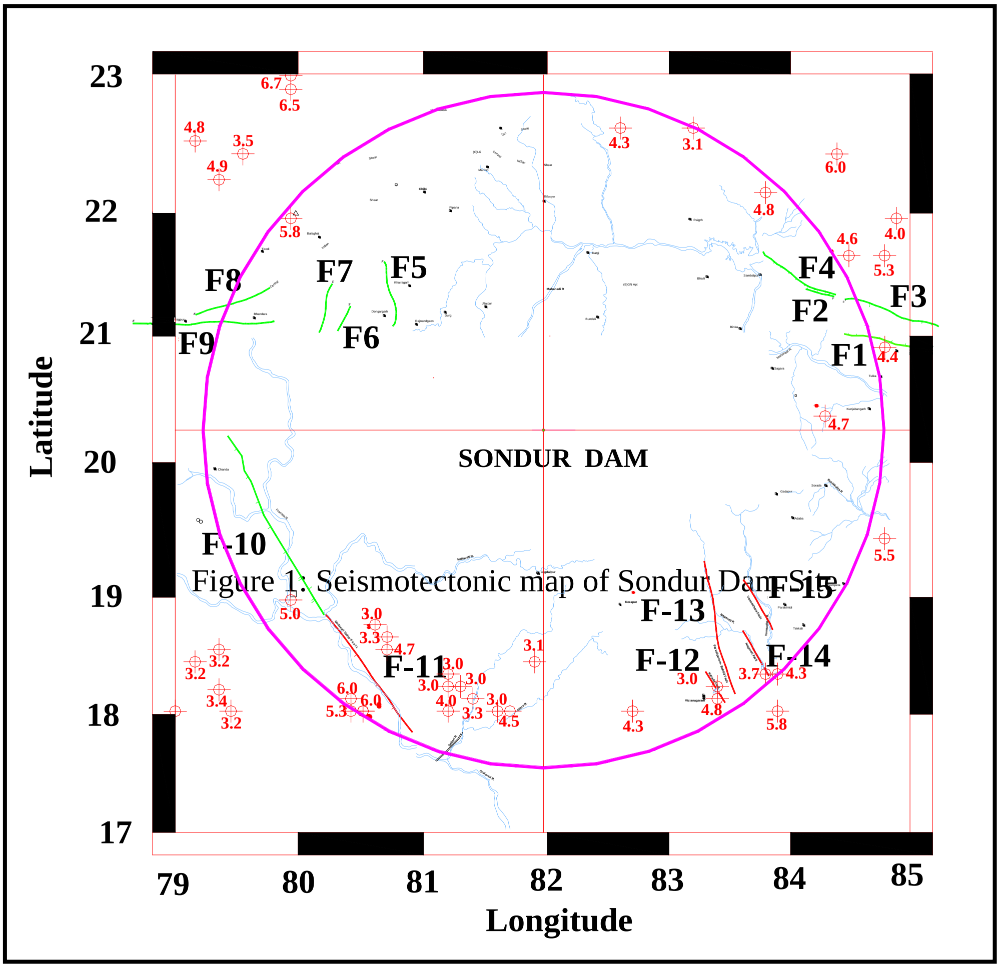

Figure 1: Seismotectonic map of Sondur Dam Site

Now coming back to the present study after a general introduction to the state, because Sondur Dam Site is selected as the target, including a control region of radius 300 km around the Sondur Dam Site, having centre at 20° 14′ N, 82° 06′ E, was considered for further investigation. The fault map of this circular region which was prepared in reference with the Seismo-tectonic Atlas of India, is as shown in Figure 1. From Figure 1, it is obvious that in recent years seismic activity appears to be concentrated along Godavari Valley fault. A total of fifteen major faults, which influence seismic hazard at Sondur Dam Site, were identified in the above map. Fault details are tabulated in Table 1. After going through various available literatures and sources such as (USGS, NIC), 77 Nos. of Earthquakes in the magnitude range 3< Mw <6.7 for Sondur Dam Site, occurring over the period from 1827 to 2012 were identified in the present study.

Table 1: Faults Considered for Hazard Analysis around the Sondur Dam Site

Fault no.	Length (kM)	Min. Map Distance (kM)	Focal Depth (kM)	Hypo Central Distance (kM)	Weightage	Maximum Magnitude (M)
F1	75	279.465	10	279.644	0.0655	4.9
F2	26	263.77	10	263.96	0.0228	5.1
F3	86	290.847	10	291.019	0.0752	5.1
F4	75	250.861	10	251.061	0.0655	5.1
F5	58	162.169	10	162.478	0.0507	6.3
F6	25	202.2	10	202.448	0.0219	6.3
F7	45	216.506	10	216.737	0.0393	6.3
F8	70	273.069	10	273.253	0.0612	6.3
F9	125	256.95	10	257.145	0.1092	6.3
F10	180	254.29	10	254.487	0.1572	5.5
F11	130	253.43	10	253.628	0.1136	6.5
F12	32	258.602	10	258.796	0.028	5.3
F13	121	184.02	10	184.292	0.1057	5.3
F14	46	251.03	10	251.23	0.0402	4.8
F15	51	221.462	10	221.688	0.0446	4.8

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) I_0 + 1] using the reported maximum MMI number. To avoid further confusion associated with different magnitude scales, all magnitudes were converted to moment magnitude M_w. Based on the nearness of epicenters to a particular fault, the maximum potential magnitude M of each fault was fixed, which were kept 0.5 units higher than the magnitude reported in the past as observed from Figure 1.

Regional recurrence

Seismic activity of a region, is usually characterized in terms of the Gutenberg–Richter frequency–magnitude recurrence relationship $\log_{10}(N) = a - b*M_w$, 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 least square regression, but due to the incompleteness of the database, such an approach may lead to erroneous results. Kijko and Sellevoll have 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. 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 186 years around Sondur Dam Site. This was first evaluated for its degree of completeness. The analysis is shown in (Figure 2) that, data are complete in a statistical sense in the following fashion: ($3.0 \leq M < 4$) is complete in 20 years; ($4.0 \leq M < 5$) is complete in 30 years; ($5.0 \leq M < 6$) is complete in 50 years; and ($6.0 \leq M < 7$) is complete in 100 years.

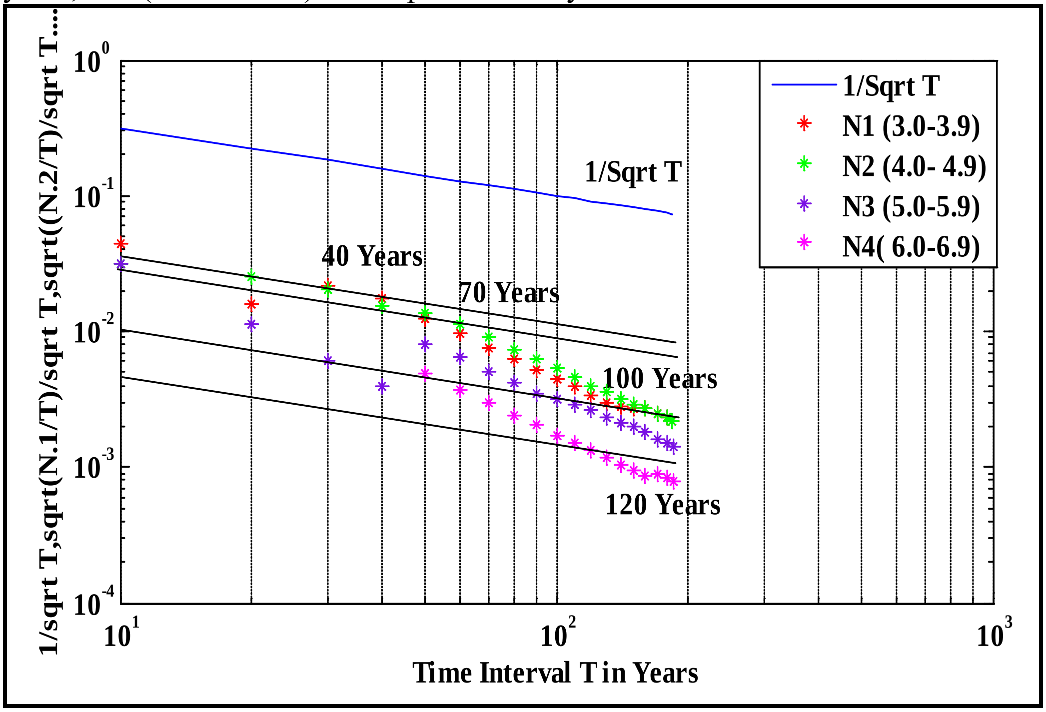

Figure 2:Completeness Test of Earthquake Data for Sondur Dam Site

Table 2: Activity Rate and Completeness for Sondur Dam Site

Magnitude M_w	No of Events $\geq M_w$	Complete in interval (year)	No. of Events per year $\geq M_w$
3.0	77	40	1.925
4.0	47	70	0.671
5.0	16	100	0.160
6.0	4	120	0.034

Regional Recurrence Relationship Sondur Dam Site is given by

$$\text{Log}_{10}(N) = 3.4803 - 0.6184\, Mw \text{-------}(1)$$

Norm of residuals (R^2)= 0.56965 b(Regional Seismicity Parameter) = 0.6184

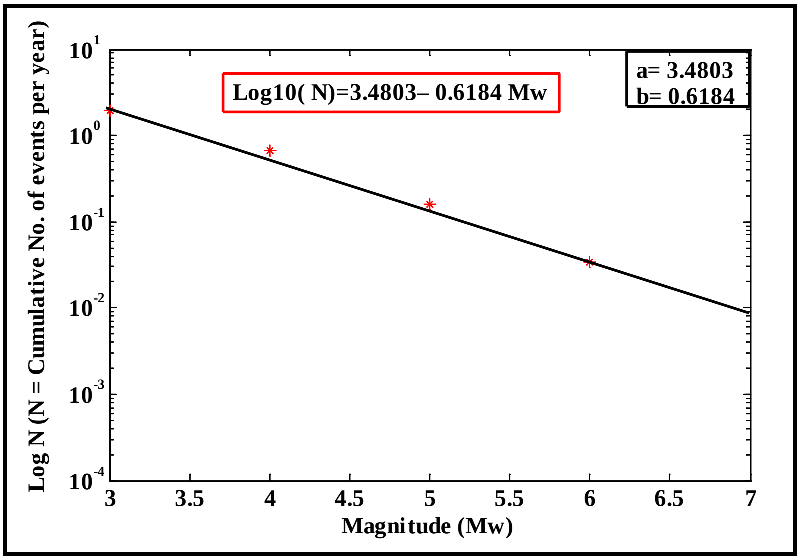

Figure 3:Frequency-Magnitude Relationship for Sondur Dam Site

Deterministic Estimation of PGA

Finally the Deterministic Seismic Hazard Analysis (DHSA) was carried out for Sondur Dam Site considering the seismic events and Seismotectonic sources from the newly developed seismotectonic model for the region, 300 km around the Sondur Dam Site. 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;

$$\lambda_m = N_i\,(m0) * \upsilon * \frac{\exp[-\beta(m-m_0)]-\exp[-\beta(m_{max}-m_0)]}{1-\exp[-\beta(m_{max}-m_0)]}$$

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

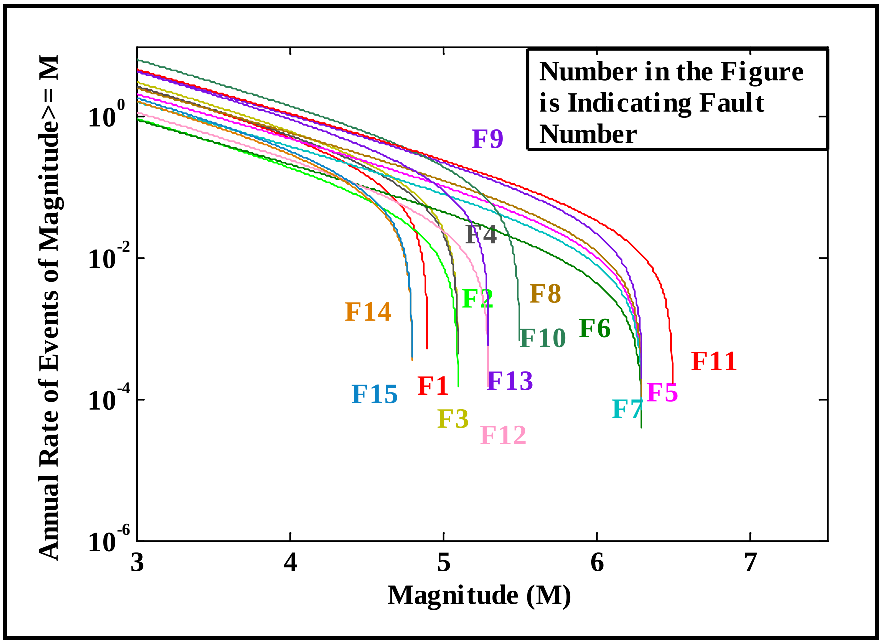

Figure 4. Deaggregation of Regional Hazards in terms of Fault Recurrence for Sondur Dam Site

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

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

R= Hypo central distance, M= Magnitude = M_{100}

ln ε = 0 (For 50 Percentile), ln ε = 0.4648 (For 84 Percentile)

Fault No.	Fault Length	Fault Name	Hypo Central Distance R in Km	MagnitudeM 100 [100 years Recurrence Period]	PGA Values (g) (100Years)	
					50 Percentile	84 Percentile
F1	75	----	279.644	4.866	0.00125	0.00199
F2	26	----	263.96	4.974	0.00163	0.00259
F3	86	-----	291.019	5.058	0.00139	0.00220
F4	75	-----	251.061	5.054	0.00201	0.00319
F5	58	-----	162.478	6.023	0.01344	0.02139
F6	25	------	202.448	5.755	0.00668	0.01063
F7	45	-----	216.737	5.944	0.00688	0.01094

F8	70	----	273.253	6.056	0.00439	0.00698
F9	125	----	257.145	6.151	0.00557	0.00886
F10	180	Godavari Valley Fault	254.487	5.463	0.00297	0.00472
F11	130	-----	253.628	6.311	0.00664	0.01056
F12	32	Kanada Fault	258.796	5.162	0.00209	0.00332
F13	121	Parvatipuram- Bobbili Fault	184.292	5.261	0.00497	0.00791
F14	46	Nagavali Fault	251.23	4.753	0.00144	0.00230
F15	51	Vamsadhara Fault	221.688	4.757	0.00194	0.00309

Table 3:Table 5.6: Deterministic PGA Values at Sondur Dam Site

Result And Discussion

The present research, the seismic hazard analysis carried out, for the establishment of PGA at substratum level for Sondur Dam Site, 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 Sondur Dam Site as depicted in Equation 1 shows, the obtained "b" value as 0.6184. The Values of P.G.A. for M100 Earthquakes have been shown in Table No.3. The Maximum value of Peak Ground Acceleration (P.G.A.) for recurrence period of 100 years for Sondur Dam Site was found to be due to the fault No. 5 (F5-Fault length 58 km, Min. Map Distance 162.478 km) which came out to be equal to 0.01344g for 50 Percentile & 0.02139g for 84 Percentile. The study results outlined in this paper can be directly be implemented for designing of earthquake-resistant structures, in and around Sondur Dam Site.

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