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EFFECT OF VARIATION OF FOCAL DEPTH OVER PEAK GROUND ACCELERATION USING DETERMINISTIC APPROACH

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Abstract—
The present paper revels a deterministic seismic hazard analysis for the central headquarters of Chhattisgarh. Central part of Chhattisgarh comes under Peninsular India which is tectonically identified as an intraplate region of Indian plate. Due to the convergent movement of Indian plate with Eurasian plate, movements are occurring along major intraplate faults resulting the seismic activity of the region and so its hazard assessment is very important. For deterministic hazard analysis, – linear seismic sources within a radius of 300 km were considered and the peak ground acceleration (PGA) at rock level was evaluated for the district headquarters Bilaspur, Janjgir, Raigarh and Korba of Chhattisgarh . The attenuation relations proposed by Iyengar and Raghukanth (2004), was used in the analysis. The effects of variation of focal depth over maximum PGA (g) values at rock level were reported for central district headquarters Bilaspur, Janjgir, Raigarh and Korba.

Keywords— Earthquake, Focal depth, Attenuation Relationship, DSHA, PGA.

I. INTRODUCTION

Earthquakes can occur at any place between the Earth's exterior face and about 700 km below the surface. For scientific principles, this earthquake depth range of 0 - 700 km is divided into three zones: shallow, intermediate, and deep. Shallow earthquakes are between 0 and 70 km subterranean; intermediate earthquakes, 70 - 300 km deep; and deep earthquakes having depth, ranging between 300 - 700 km. In general, the term "deep-focus earthquakes" is applied to earthquakes deeper than 70 km. (https://earthquake.usgs.gov/learn/topics/determining_depth.php). The earthquakes having their depth more than 70 km, are restricted within great slabs of lithosphere that are plummeting into the Earth's mantle. The existence of bottomless-focus earthquakes was confirmed in 1931, from the studies of the seismograms of numerous earthquakes, which in turn led to the construction of travel-time curves, for intermediate and bottomless earthquakes. Occasional shallow earthquakes—those that originate within 60 km (40 miles) of the Earth's superficial surface are seen to affect most of the parts of the world. In fact, the large majority of earthquake foci are known to be shallow. It should be noted however that, the geographic division of smaller earthquakes is fewer completely determined than more severe earthquakes, partly because the accessibility of relevant data is reliant on the distribution of observatories. As observed from the past frequently occurring earthquakes, it is becoming obvious that, due to rapid urbanization, many big cities are becoming prone to earthquake hazard. As in Chhattisgarh state (a newly developed state) also, lot of construction activity is being carried out without giving much thought to the earthquake resistant design, due to which there is a continuous risk to the life and property of the population. The present study is focus on the effect of variation of focal depth over maximum peak ground acceleration at bed rock level by using deterministic approach.

II. METHODOLOGY

In the deterministic approach, main focus is on the largest possible earthquake event, including all earthquake sources capable of producing damaging ground motions at a site. Faults may perhaps be those earthquake sources, which are typically planar surfaces, being identified through various means such as observations of past earthquake locations and geological evidences. A theoretical framework is shown in Figure 1 which clearly reflects the steps involved in DSHA. In the present study, the DSHA was applied over district headquarters Bilaspur, Janjgir, Raigarh and Korba of Chhattisgarh. The literature review reveals the information regarding different parameters, for assessment of seismic hazard. 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. In the Deterministic approach of hazard estimation, the minimum source to site distance is taken as the distance parameter in the attenuation equation. A set of possible values of PGA at the site due to the various sources is computed with the help of the attenuation equation given by Iyengar and Raghukanth (2004). The maximum of this set of values is chosen as the quantified hazard and estimates the effect when the focal depth is increasing. The known seismic sources those which are adequately near the site, along with available historical seismic and geological data are used to generate discrete, single-valued events or models of ground motion at the site, in the DSHA approach. Theoretical frame-work for deterministic seismic hazard analysis is as shown in Fig. 1.

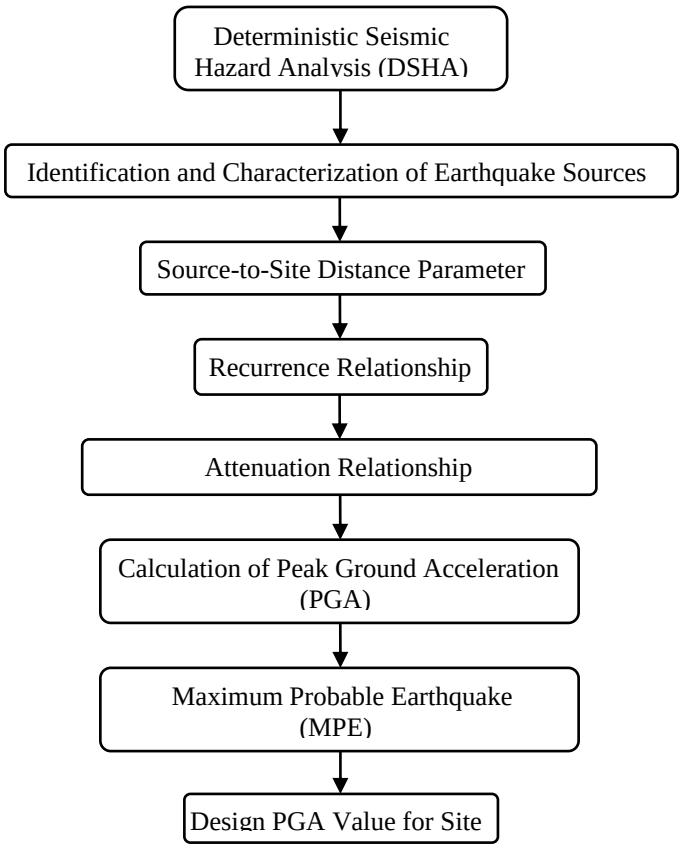


Fig. 1 Theoretical Frame-work for Deterministic Seismic Hazard Analysis

III. COMPUTATION OF SEISMIC HAZARD PARAMETERS

In the context to estimate the peak ground acceleration for district headquarters of Bilaspur, Janjgir, Raigarh and Korba of Chhattisgarh, it is essential to estimate seismic hazard parameters (a & b value) for particular site. The "b" Value is the measure of the frequency of the occurrence of earthquakes of different sizes. There are two techniques, currently utilized for determination of seismic hazard parameters (a & b-value)

A. Estimation of "b" value

Two approaches have been included to estimate the "b" value for district headquarters Bilaspur, Janjgir, Raigarh and Korba of Chhattisgarh.

- Linear Least-Squares Fit [Stepp, 1972)]
- Maximum-Likelihood Estimation (Utsu, 1965)

In Linear Least-Squares Fit the earthquake data analysis is to investigate the available data set, to assess its nature and degree of completeness. The incompleteness of available earthquake data, make it difficult to obtain fits of Gutenberg-Richter recurrence law that is believed to represent true long term recurrence rate. There are many recurrence laws that help to describe the uncertainty in size of earthquakes produced by each source zone. To account for minimum and maximum magnitudes, Gutenberg-Richter recurrence law assumes an exponential distribution of magnitude, which is used with modification and is given by:

$$\text{Log } N = a - b*M \text{ ------ (1)}$$

As recommended by Stepp (1972), the problem data incompleteness can be overcome by a method of analysis, which involves the grouping of earthquake data into several magnitude classes. By taking the help of the property of statistical estimation that, variance of the estimate of a sample mean is inversely proportional to the number of observations in the sample (Stepp, 1972). The b value obtained from Linear Least-Square Fit for district headquarters Bilaspur, Janjgir, Raigarh and Korba of Chhattisgarh was reported as tabulated in TABLE I .

Another method is Maximum-Likelihood Estimation, was applied over district headquarters Bilaspur, Janjgir, Raigarh and Korba as:

$$b = \log 10e/(Mav - Mmin) = 0.43/(Mav - Mmin) \text{----------(2)}$$

where M_{av} is the mean of the observed magnitudes and M_{min} is the minimum or threshold magnitude, for present study the value is taken as 3.0.

TABLE II
SEISMIC PARAMETER DISTRICT HEAD QUARTERS OF CHHATTISGARH

S.No.	Name of District Head Quarters	b Value From Steep (1972)	b Value From Maximum Likelihood Estimation, Utsu. (1965)	b Value Considered for the Present Study
1	Bilaspur	0.5681	0.2389	0.5681
2	Janjgir	0.5087	0.2481	0.5087
3	Raigarh	0.5463	0.2552	0.5463
4	Korba	0.4899	0.2710	0.4899

B. 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 highest potential of accumulated strain energy is signified by this, which is 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 of the region. For estimation of M_{max} two methods were used as Wells and Coppersmith (1994) and Gupta (2002). Wells and Coppersmith (1994) method, has given a relation between Mw and the surface rupture length (SRL), that was developed using reliable source parameters and this is further applicable to interplate or intraplate earthquakes, shallow earthquakes, and all types of faults.

$$\text{Log (SRL)} = 0.57\text{Mw} - 2.33 \ldots\ldots\ldots\ldots (3)$$

The above equation was used to estimate M_{max}

Gupta's (2002) method was applied to estimate M_{max}.= M, by equation given as below:

$$M_{max} = M = Mobs + 0.5 \ldots\ldots\ldots\ldots (4)$$

M_{max} = M = Maximum Magnitude

M_{obs} = Observed Moment Magnitude (Mw).

IV. ATTENUATION RELATIONSHIP FOR PENINSULAR INDIA REGION

From review of literature of attenuation relationship for Peninsular India region, in the present research an attenuation relationship proposed by Iyengar and Raghukanth (2004), has been adopted. The proposed equation for peak ground acceleration (PGA), under bed rock conditions, is given as below

$$\ln Y = C1 + C2\,(M-6) + C3(M-6)2 - \ln(R) - C4(R) + \ln(\varepsilon) \ldots\ldots\ldots\ldots (5)$$

where refer to Y= PGA(g), M= Magnitude, and = Hypocentral distance

Peninsular India: C1= 1.6858; C2= 0.9241; C3= -0.0760; C4= 0.0057;

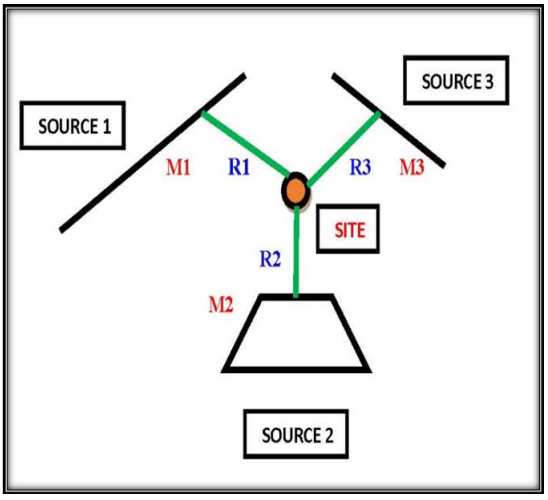


Fig.2 Source to Site Distance

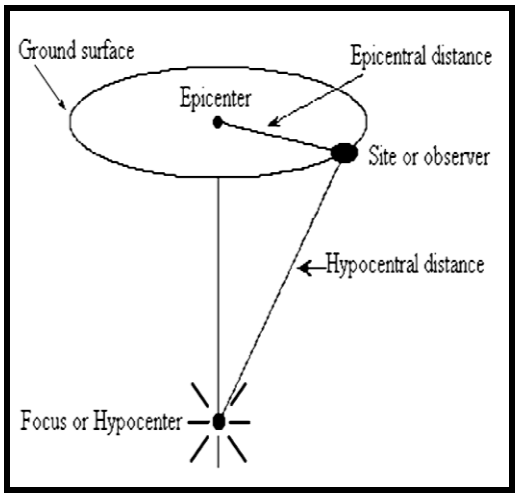


Fig.3 Hypocenter Distance

The district headquarters Bilaspur, Janjgir, Raigarh and Korba were considered for DSHA. For seismic hazard analysis the linear source as faults were consider. For DSHA of district headquarters Bilaspur, Janjgir, Raigarh and Korba the total numbers of faults 35, 38, 27 and 41 respectively were considered. The estimated PGA values are maximum for fault no. F32 for Bilaspur, F5 for Janjgir, F24 for Raigarh and F6 for Korba for focal depth assuming as 10 km.

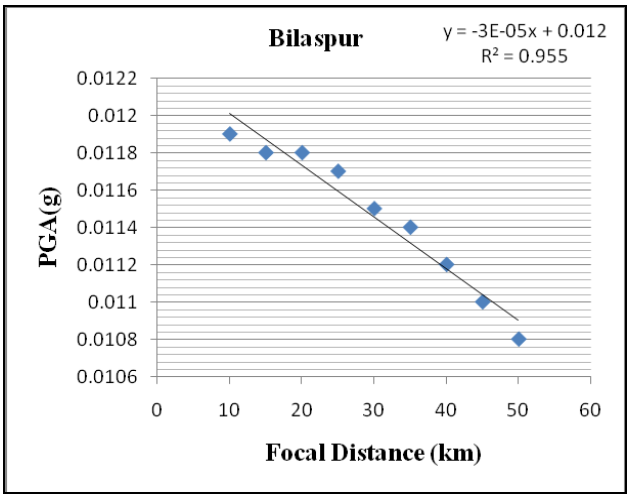
TABLE IIII
KEY FAULTS FOR DISTRICT HEADQUARTERS OF CHHATTISGARH

Name of District Headquarter	Fault Number	Fault Length (km)	Minimum Map Distance (km)	Maximum Magnitude (M)
Bilaspur	F32	58	151.652	6.3
Janjgir	F5	87	153.480	5.8
Raigarh	F24	75	70.409	5.1
Korba	F6	46	92.262	5.0

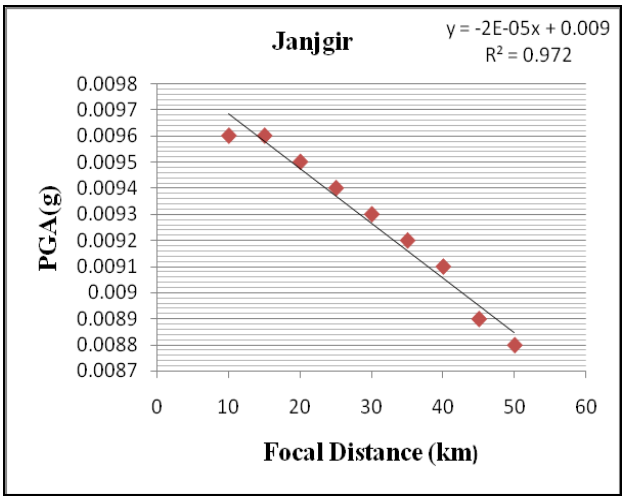
The attenuation relationship for Peninsular India region, proposed by Iyengar and Raghukanth (2004) has been adopted for estimation for Maximum PGA (g) value for 50 Percentile. The focal depth is increasing with increment of 5 km the PGA(g) values reduces as shown in Table III.

TABLE IVII
VARIATION OF PGA VALUES DUE TO INCREASE IN FOCAL DEPTH FOR DISTRICT HEAD QUARTERS OF CHHATTISGARH

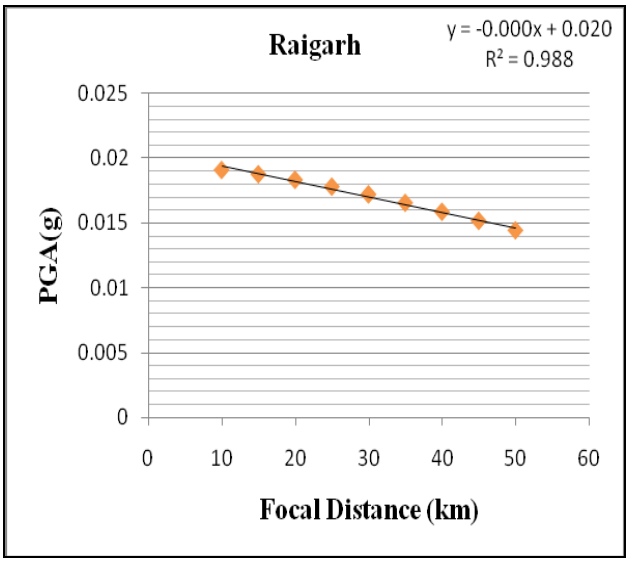
Name of District Headquarter	Fault No.	Fault Length	Minimum Map Distance to the site in km	Focal Depth F in km	Hypocentral Distance in km	100 years Reccurance M100	Peninsular India Site PGA 50 Percentile
Bilaspur	F32	58	151.652	10	151.982	5.755	0.0119
				15	152.393		0.0118
				20	152.966		0.0118
				25	153.699		0.0117
				30	154.591		0.0115
				35	155.639		0.0114
				40	156.839		0.0112
				45	158.188		0.0110
				50	159.682		0.0108
Janjgir	F5	87	153.480	10	153.806	5.559	0.0096
				15	154.212		0.0096
				20	154.778		0.0095
				25	155.503		0.0094
				30	156.385		0.0093
				35	157.421		0.0092
				40	158.607		0.0091
				45	159.941		0.0089
				50	161.420		0.0088
Raigarh	F24	75	70.409	10	71.116	5.024	0.0191
				15	71.990		0.01878
				20	73.195		0.01834
				25	74.716		0.01781
				30	76.534		0.01721
				35	78.629		0.01655
				40	80.978		0.01586
				45	83.561		0.01515
				50	86.357		0.01442
Korba	F6	46	92.262	10	92.803	4.91	0.011433
				15	93.474		0.011308
				20	94.405		0.011137
				25	95.590		0.010925
				30	97.017		0.010677
				35	98.678		0.010399
				40	100.560		0.010095
				45	102.652		0.009772
				50	104.940		0.009435



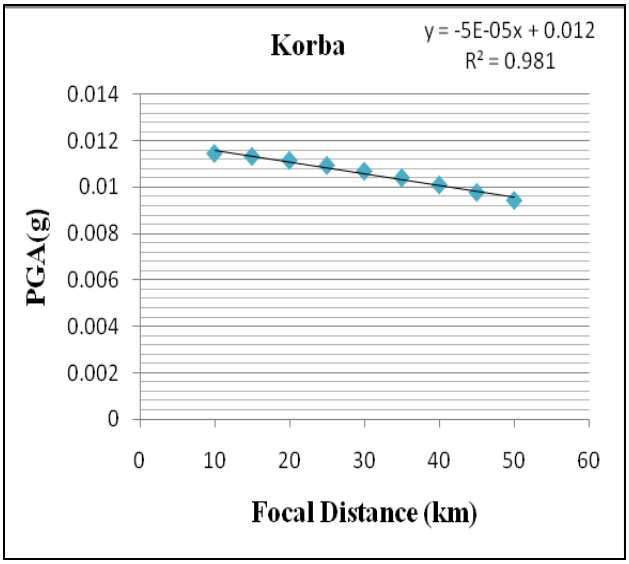
(a) Bilaspur



(b) Janjgir



(c) Raigarh



(d) Korba

Fig.4 PGA (g) variation with increasing Focal Depth for District Headquarters
(a) Bilaspur (b) Janjgir (c) Raigarh and (d) Korba

The Maximum PGA (g) value 0.0191g for 50 Percentile was reported for district headquarter Raigarh for fault F24, fault length 75 km with minimum map distance of 70.409 km. The focal depth is increasing with increment of 5 km the PGA (g) values reduces as shown in Table II. For the focal depth 50 km the PGA (g) value reduces as reported 0.01442g. On the other hand the Maximum PGA(g) value for having map distance 153.480 km for Janjgir district headquarter 0.0096g for 50 Percentile reduces and reported 0.0088g.For rest two district headquarters the PGA(g) values reported between above stated values.

V. CONCLUSIONS

An attempt has been made to estimate the variation to estimate the variation of increment in focal depth over PGA(g) values for district headquarters Bilaspur, Janjgir, Raigarh and Korba of Chhattisgarh. The DSHA is use to find out and the PGA (g) values at bed rock level for above stated district headquarters. As the focal depth increase 5 times the PGA (g) value reduces to 1.32 times for districts headquarter Raigarh having minimum map distance 70.409 km and 1.09 times for district headquarter Janjgir having minimum map distance 153.480 km.

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