Spectral Amplification Factors of Indian Earthquake Ground Motion

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Abstract— The spatial verification of ground motion in Kolkata which is as metropolitan district (KMD) has been estimated by generating synthetic ground motion considering the point source model coupled with site response analysis. The most important source was picked out from regional seismotectonic map which covers the area around 350km radius all over the Kolkata. When the soil investigation of 121 boreholes the report of soil data bank project were collected. As maximum amplification in some areas of KMD was found to around 3.0 times as compare to rock level. Damages of buildings are the effects of earthquake in which the motion of surface ground motion at the site. Presently work highlights are the importance of bedrock motion upon the response of a soil column. When a typical borehole was analyzed for a wide range was up to 30m depth and was recorded bedrock motion in the absence of region ground motion records. Answer it has been recorded that the bedrock motion with low amplitude produces high amplification factor while high amplitude produces low amplification factor. In seismic microzonation practices of urban centers, the amplitude of bedrock motion and the amplification factor are considered independently for assigning rank and hazard index. A combine approach is required while assigning the rank in estimating the hazard index value .such outcome will affect the current seismic microzonation practices as well.

Key words: Site Response Analysis, Bedrock Motion, Amplification Factors, Hazard Index, Seismic Microzonation, Response Spectra, Synthetic Ground Motion, Time History

I. INTRODUCTION

Earthquake which can also be known as EQ is generated from ground motion and are altered at a site due to the presence of the local soil which is available under the ground. So as a result, a complete change in ground motion characteristics between the bedrock and the surface is clearly observed. Thus by this a changed ground motion in building response as well as induced effect are controlled. Effects of local soil in controlling the Earthquake damage were evidenced during 1918 Srimangal EQ in Assam,1985 Michoacan EQ in Mexico ,1989 Loma Peieta EQ in San Francisco,1999 Chamoli EQ in Delhi, 2001 Bhuj EQ in Ahemdabad in India,2005 Kashmir EQ in India,2011 Sendai EQ in Japan, 2015 Nepal and many more. A very detailed discussion of this suggests a failure of geotechnical structures during the year 2001 in BhujEQ. Due to this event ground shaking was also felt upto many locations which is Nepal in the east, Pune in the south-west, Himachal Pradesh and Haryana which is in the north and Uttar Pradesh and Bihar which is in the east.

There are many examples of local site effects which is in the year 2011 Sydney EQ which is located about 130km off from the Eastern coast of Sydney in the Pacific Ocean. Ground shaking developed during this event triggered liquefaction and differential settlement in the area of Maihama. Induced ground motion were assigned intensity of VIIin thepicentral region and the intensity which was felt in the south east of the epicentre was 170km.The shaking of the ground was so intense that it was felt in Delhi which is located 850km from the epicentre. The severe intensity which was felt was of IV. These were some examples of induced ground shaking which has not only caused damage to concentrated area which is near the epicentral area but also the larger area distance which is covered by the presence of the local soil.

The correct estimation of the induced effect will also help in the correct estimation and the accuracy of the site responsive analysis. Much emphasis is given while the determination of the properties of subsoil while addressing the local site effects. The selection of input motion at bedrock is very important. However the importance is not highlighted in many of the available site response studies. Highlighting these limitations in ongoing practices, an attempt was been made to study the dependency of the bedrock PHA on site amplification factor .A soil column was analyzed for large set of the globally record input ground motion.

II. STUDY AREA:

In the presently analysis, a typical borehole from shallow deposite was selected in National capital of india “Delhi”. Delhi got its centre from 29.62*N to 77.20*E and is home to approximately 11 million people as per census 2011. Iyenger and Ghosh were the two people who discover the developed the tectonic map for delhi with getting the radial distance of 300 km around the city centre .As per the Iyenger and Ghosh in the Delhi region 13 activate source as well as in Himalayan region 7 activated source can be contribute to the hazard in Delhi region.

As Sharma and Wason perform the seismic hazard analysis of delhi as Iyenger and Ghosh has done for analysis of Delhi considering the 6 regional source from around the Delhi region. These were the moderate level of ground motion reported in terms of felt intensity during 1825EQ and 1831 EQ, with epicenter near Delhi. Later during the 1956 Khurja EQ in Delhi the injuries and damages were reported. For the present work, a typical borehole for the River Yamuna was selected and located to the north-eastern part of Delhi. As the boreholes were drilled for a clients based project but not under any research work, the extract location for the site has not been disclosed here.

III. IN-SITU SUBSOIL PROPERTIES:

Information which was on subsoil lithology at the site was obtained on the base of 41 boreholes of 30 m carring depth each .As we keep in mind the paper length,considering the result only of one boreholes are discussed here. The classification of the soil In the work was been taken directly from the borelog. As in fig 1 the typical borelog of the study area has been given. As the increase in the depth alternate the bed of silty sand (SM) and medium to low compressibility index of the in-situ soil (CL) varies between 10% to 24%.

Over all the observation by combining all the boreholes suggests the presence of silty sand at most of the location at various depth follows by layer of medium to low compressibility clay. As per MoES suggested borelog report in alternate layers of sand and clay upto the depth of 30m and the measured was varying upto 83 as per MoES is consistent with the boreholes properties presently in fig 1,in the menuscripts.

IV. LOCAL SITE EFFECTS

Effects such as amplified ground motion, liquefaction and landslides are the results of modified ground motion from the surface of the bedrock. During the effect of local soil were evidenced in 1989 Loma Prieta EQ when 2 to 4 range of amplification factor was observed in San Francisco-Oakland region which was located about 120km away from the epicenter. The biggest EQ was observed and recorded in Japan with large amount of liquefaction and uneven settlement in Maihami and Tokai Mura region located about 150km away from the epicenter.

In the city Sikkim EQ (Mw=6.8) caused several buildings to collapse in Mangam, Jorethang located to the epicenter about 150km away. As in Sikkim 2011 EQ the ground motion were felt in many places in West Bengal and Bihar as well. Recently in 2015 EQ in Nepal (Mw-7.8) was recorded about 80km in Kathmandu northwest. The ground shaking due to this event was felt in distant places. The upper qaries clearly shows that depending upon the subsoil properties ,that EQ induces the vibration of the earth can cause the large damage in the large area of the specified area with a large distance away from the epicenter. The input bedrock motion based on equivalent linear site response approach using SHAKE2000.

V. SELECTION OF INPUT MOTION:

As the subsoil data of the similar site of interest, the input motion is also a pre-requisite for site response analysis. As the EQ induced damages as well documents prehistoric EQ but the motion of the ground was recorded as very limited. At the absence of ground motion was recorded selects the ground motion from the EQ such as 1940 EI-Centro, 1995 Mexico and hyogoken-nandu and 1999 chi-chi etc. The generation of synthetic ground motion compatible with uniform hazard spectra and hazard was also followed worldwide for the studies site.

Ground motion characteristic which control the response of the soil include the frequency content, duration and EQ ground motion amplitude . In the absence of the regional ground motion reccord ground motion characteristics for the future EQ at the site of interest can not be approximately by selecting single ground motion from another region. A large set of bedrock motion should be considered. These selected ground motion should cover a wider range of frequency content, amplitude and duration.

As the table 1 presents the ground motion characteristics of all the 30 selected ground motion. As it can be seen from the table 1 that the frequency content for the motion of the ground which varies from the lowest value of 1.2Hz tp the highest value of 50Hz. As the selected ground motion duration varying from as low as 6.8s to high as 140s as shown in table 1. All the selected ground motion are applied at the base of the soil and the response in terms of the amplification factors is assessed for each selected ground motion.

VI. ANALYSIS AND RESULTS

As to perform the equivalent linear analysis using the SHAKE2000, the generated soil column is generated sub-soil considering properties of the selected boreholes as given above. As in In-situ the thicknesses and the density of the various layers are modelled. The thickness of the layer is >3m are subdivided into 3m thickness sublayer. For the estimation of the shear modulus built correction between Gmax are used in present analysis N-SPT is available for Delhi. This is the region the built empirical correlation in SHAKE2000, originally proposed by seed is adopted.

As we combine the observation in above statement indicates that the built correlation in SHAKE2000 for estimating the Gmax can be presented for studies. As for the deposit of the soil below 30m depth is modelled as elastic half space having a dynamic properties of very dense soil as given above. As the soil column is subjected to all the 30 input selected ground motion and response the observation of the term of amplification factors. Since the present work is to understand the bedrock PHA versus variation of amplification factors, the surface of each PGA for each input motion is observed from output. As boreholes is presently observed from the above analysis is given in fig 4.

In another attempt to perform the seismic microzonation of Lucknow, Abhishek1 assigned ranks to the values of PHA as well as factor of amplification independently. In the presently analysis, as shown in figure 4, the values of PHA and factors of amplification are found related to each other such that higher values of amplification factors are corresponding to low PHA values only and vice versa. The range of PHA and the corresponding range of amplification factor for above three categories are presented in table 2. In addition, the ranks to each range of PHA and the amplification factor are also given in table 2.

It can be observed from table 2 that ranks to both PHA and the amplification factor are interrelated This clearly indicates that ranks assigned to both the PHA as well as the amplification factor should be considered in a more combined manner while estimating the hazard index value. In addition, both PHA and the amplification factor cannot have a high rank simultaneously. As Seismic microzonation of urban centre utilizes various thematic layers in determining the hazard index values including the PHA and the amplification factor. In the present work the interrelation between the PHA and the amplification factor has been studied. In a similar way, the correlation between other thematic layers such as PHA, average shear wave velocity, depth to overburden etc. can be studied in future to provide a more rational approach in estimating the hazard index values.

VII. CONCLUSION

Local site effects play an important role in deciding the level of ground shaking. Present work is an attempt where the dependency of the soil response on the input motion is assessed. Large sets of globally recorded ground motions are selected covering a wide range of ground motion parameters representing both the nearby and distant sources of seismic hazard for the site under consideration. Based on the equivalent linear approach, site response analyses are performed for a typical site. From the analyses, it is found that soil columns subjected to input motions with low PHA values will have high amplification factor in comparison to the same soil column if subjected to input motion with a high PHA. These findings are in accordance with the available literature.

From the present analyses, the rate of change in amplification factor is found to be very high for PHA<0.08g, intermediate for 0.08g<PHA<0.22g and low for PHA>0.22g. In the present seismic microzonation practices, among various thematic layers, the PHA and the amplification factors are assigned ranks independently. However based on the present work, it is found that the above two parameters are strongly interrelated. In addition, high values of PHA and amplification factor are not possible simultaneously. Thus, a more combined approach while estimating the hazard index is needed. In the present work, the dependency between two thematic layers namely the PHA and the amplification factor is studied. Correlation between other thematic layers such as average shear wave velocity and depth of overburden can be studied in future.

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BH	Ground Water Table at 0.9m below Ground Level (GL)						
Depth below GL(m)	Soil Description	Thickness of Layer (m)	Legend	Soil Classification	Sample	Depth (m)	SPT-N values
1.0	Fill	1.0		-	-	1	2
2.0	Silty Sand	1.0		SM	UDS	2	4
3.0	Low Compressibility Clay	1.0		CL	SPT		
4.0					SPT	3.5	8
5.0					SPT	5	14
6.0					SPT	6.5	18
7.0					UDS		
8.0					SPT	8	22
9.0	Silty Sand	6.0		SM	UDS		
10.0					SPT	9.5	24
11.0					SPT	11	26
12.0	Medium Compressibility Clay	2.0		CI	SPT	12.5	33
13.0					UDS		
14.0					SPT	14	37
15.0					SPT	15.5	45
16.0					UDS		
17.0					SPT	17	55
18.0					SPT	18.5	62
19.0					UDS		
20.0	Silty Sand	8.0		SM	SPT	20	71
21.0					SPT	21.5	66
22.0					UDS		
23.0					SPT	23	69
24.0	Medium Compressibility Clay	4.0		CI	SPT	24.5	79
25.0					UDS		
26.0					SPT	26	84
27.0	Silty Sand	3.0		SM	SPT	27.5	95
28.0					UDS		
29.0					SPT	29	96
30.0	Medium Compressibility Clay	3.0		CI	SPT	30	101

Note Borehole terminated at 30.0 m
DS-Disturbed Sample SPT-Standard Penetration Test
UDS-Undisturbed Sample

Figure 1: Typical Borehole from the site

Table 1
Ground Motion properties of the selected input motions

S. N.	Ground Motion Details as per SHAKE 2000	Epicentral Distance (km)	Magnitude	PGA (g)	Duration (s)	Predominant Frequency (Hz)
1	ADAK, ALASKA 1971-M 6.8;R-67KM, N81E	86.77	6.8	0.098	24.58	8.33
2	ANCHORAGE, ALASKA 1875, M-6, R81-GOULE HALL STATION	81.93	6.0	0.036	18.59	10.00
3	ANCHORAGE ALASKA 1975, M 6, R 79, WESTWARD HOTEL STATION (BASEMENT)	78.37	6.0	0.049	38.96	7.14
4	ANZA 02/25/80, BORREGO AIR BRANCH 225	43.1	5.3	0.046	10.25	3.85
5	ANZA 02/25/80 1047, TERWILLIGER VALLEY 135	15.8	5.3	0.080	10.01	16.67
6	BISHOP-ROUND VALLEY 11/23/84 1914, MCGEE CREEK SURFACE 270	42.35	5.8	0.075	6.80	12.50
7	BORREGO MOUNTAIN 04/09/68 0230, EL CENTRO ARRAY 9, 270	60.0	6.4	0.056	39.95	39.95
8	BORREGO MOUNTAIN 04/09/68 0230, PASADENA-ATHENAEUM, 270	216.8	6.4	0.009	60.23	1.22
9	BORREGO MOUNTAIN 04/09/68 0230, TERMINAL ISLAND, 339	205	6.4	0.008	51.80	2.50
10	CAPE MENDOCINO EARTHQUAKE RECORD 04/25/92, MW-7.0, 90 DEG COMPONENT	10.0	7.1	1.03	59.98	50.00
11	CHALFANT 07/20/86 1429, BISHOP PARADISE LODGE,070	19.8	6.4	0.046	39.95	16.67
12	CHILE EARTHQUAKE, VALPARAISO RECORD, 3/3/85	129.2	7.8	0.120	79.39	16.67
13	COALINGA 05/02/83 2342 PARKFIELD, FAULT ZONE 6/ 090	43.9	6.5	0.055	39.95	8.33
14	COALINGA 05/09/83 PALMER AVE ANTICLINE RIDGE, 090	12.5	5.3	0.215	40.00	10.00
15	GEORGIA, USSR 06/15/91 0059, BAZ X	49.0	6.2	0.033	34.07	4.55
16	IMPERIAL VALLEY 10/15/79 2319, BONDS CORNER 230	15.9	5.0	0.100	19.885	5.56
17	KERN COUNTY 7/21/52 11:53, SANTA BARBARA COURTHOUSE 042	80.5	7.5	0.086	75.35	4.17
18	KOBE 01/16/95 2046, ABENO 000	24.9	6.9	0.22	139.98	5.00
19	KOBE 01/16/95 2046, KAKOGAWA 000	22.5	6.9	0.250	40.91	12.50
20	KOBE 01/16/95, KOBE PORT ISLAND 090	0.9	6.9	0.530	42	2.50
21	LIVERMORE 01/27/80 0233, HAYWARD CSUH STADIUM 236	33.9	5.8	0.027	15.98	3.13
22	LIVERMORE 01/27/80 0233 LIVERMORE MORGAN TERR PARK 265	20.6	5.8	0.197	24	5.56
23	LOMA PRIETA TA 10/18/89 00:05, ANDERSON DAN DOWNSTREAM 270	16.9	7.0	0.240	39.59	5.00

24	LOMA PRIETA TA 10/18/89 00:05, HOLLISTER DIFF ARRAY 255	13.9	7.0	0.270	40	1.92
25	MICHIOACAN EARTHQUAKE 19/9/85, CALETA DE CAMPOS, N-COMPONENT	38.36	8.1	0.140	81.06	2.27
26	NORTHERN CALIFORNIA 09/22/52 1141, FERNDALE 134	44.3	5.2	0.070	40	5.00
27	NORTHRIDGE EQ 1/17/94 1231, ANACAPA ISLAND	71.4	6.7	0.013	40	25.00
28	NORTHRIDGE EQ 1/17/94 1231, ARLETA 360	9.5	6.7	0.310	39.94	16.67
29	PARKFIELD 06/28/66 04:26, CHROME # 8	11.2	6.1	0.116	26.09	25.00
30	TRINIDAD 11/08/08, 10:27, RIO DEL OVERPASS E	72.0	7.2	0.130	22	3.13

Table 2
Range of amplification factor corresponding to bedrock PGA

Range of bedrock PHA (g)	Ranks of bedrock PHA	Range of Amplification factor (AF)	Ranks of AF
0.03-0.08	1	7.5-2.7	3
0.08-0.22	2	2.8-2.2	2
0.22-0.53	3	2.2-1.0	1

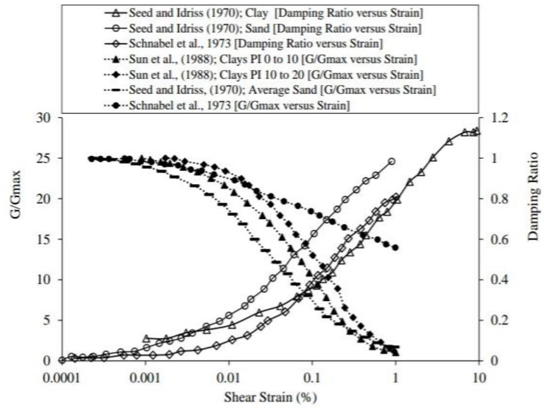

Figure 2: Dynamic properties of selected soils

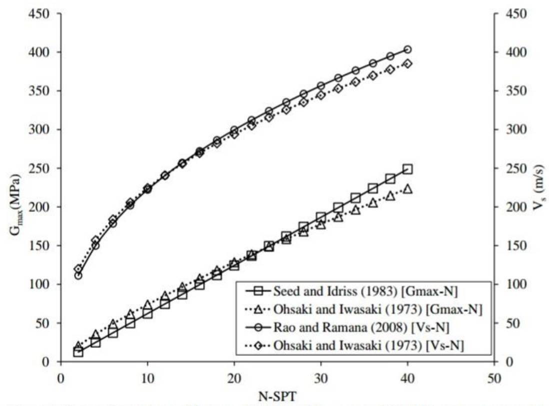

Figure 3: Comparison between Vs versus SPT-N and G_{max} versus SPT-N for the present work

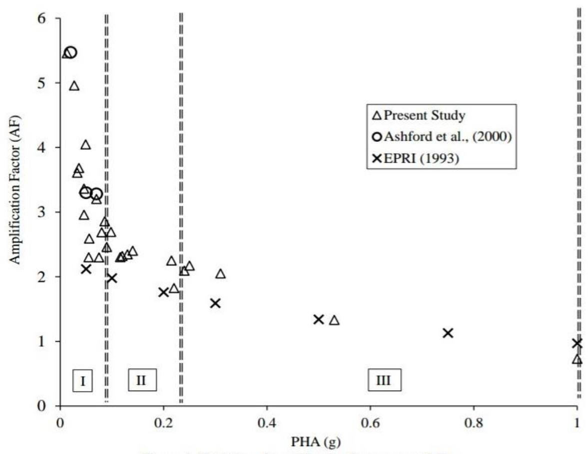

Figure 4: Variation of amplification factor versus PHA

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