Seismic Ground Response Analysis of Site using Various Input Motions

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ABSTRACT

When the seismic waves travel through the bedrock to the surface of the ground they are reflected, deflected and refracted at the interface between the soil layers causing the waves to get amplified in motion as they reach the surface. The level of amplification in ground motion varies at different locations based on the characteristics of the overburden soil. Hence, the ground response analysis is performed to determine the influence of local soils on seismic waves to estimate the ground response spectra for design. In this study, 1D Equivalent Linear Analysis is performed using Midas GTS NX, for the realistic soil profiles of Panaji city of Goa, subjected to six different input motions. The output parameters such as surface ground acceleration and the response spectrum are plotted. Most of the input accelerations are found to be amplified at the surface which can get transferred to the structure causing more damage to the structure during earthquake.

Keyword: ***- 1D Equivalent linear analysis, Ground response analysis, Midas GTS NX, Response spectrum, Surface ground acceleration***

1. INTRODUCTION

Earthquakes are the natural calamities. The damage caused during earthquakes is dependent on the characteristics of the soil as well as the characteristics of the strong ground motion. When the seismic waves travel through the bedrock to the surface of the ground they are reflected, deflected and refracted at the interface between the soil layers causing the waves to get amplified in motion as they reach the surface. The level of amplification in ground motion varies at different locations based on the characteristics of the overburden soil. Hence, the ground response analysis is performed to determine the influence of local soils on seismic waves to estimate the ground response spectra for design.

Many methods have been developed for predicting the influence of local soil conditions on the strong ground motions, 1 dimensional ground response analysis being one of them. The basic assumption of this method is that shear waves propagate in upward direction through the underlying bedrock. In this study ground response analysis is carried out for a soil profile located at Panaji Goa, subjected to six different input bedrock motions. The effect of soil profile is studied in amplifying and de-amplifying these bedrock motions. The inbuilt shear modulus and damping ratio curves are used for the analysis in Midas GTS NX.

2. LITERATURE REVIEW

A study carried out by Naik and Choudhury [1] for the variability in seismic ground response for typical soil profile from Goa, for various input parameters and using various softwares shows that the soil model with more number of layers gives better estimate of ground response. The mean spectral values yielded by equivalent linear analysis are higher than that of the nonlinear analysis. Effect of depth of half-space for site response analysis is studied by Shivprakash and Dinesh [2] by carrying out 1D nonlinear analysis. As the peak spectral acceleration and peak ground acceleration are found to be constant when depth is increased beyond 300m, the depth of input for 1 dimensional ground response analysis shall be equal to or more than 300 m for deepsoil deposits. Kumar et al. [3] observed that site response is influenced by local site geology as well as the strong motion characteristics and response obtained from equivalent linear and nonlinear analysis will be nearly same when the soils are stiff. Study by Bhingarde and Naik [4] for Mormugao port, Goa concludes that amplification is more for time histories with higher duration as compared to time histories with lower duration. The type of soil and vertical extent of each type of the soil strata is found to be significantly influenced by the ground analysis carried out by Naik and Choudhury [5]. The codal spectrum defined by IS 1893:2002(Part I) for Zone III is found to be unconservative for the Panaji site. Evaluation of surface response by altering shear modulus and damping curves is done by Anbazhagan and Parihar [6]. For sand Seed and Idriss upper limit curves and for clay Vucetic and Dobry curve with PI=10 is found to produce spectrum comparable with the recorded data.

3. SOIL PROFILE

The soil profile is obtained from a reputed company for the site located at Panaji Goa as shown in Fig 1 [1]. Panaji is the capital city of Goa, located in Tiswadi taluka. Soils in this area are of amplifying in nature and the response is site specific [5]. The details of the bore-hole is as shown in the figure below. The soil overburden is 27.5 m thick above the hard bedrock. The water table is found at a depth of 1.65m below the ground level. The soil profile consists of 7 different types of soils with varying density and the standard penetration test SPT (N) values. The dynamic properties of the soil are unavailable. Naik [7] proposed correlations between the shear wave velocity and SPT(N) values for the various talukas of Goa. Relation for Tiswadi taluka as given by equation (1) is used to find the shear wave velocity for this study:

$$Vs=76.635(N_1)_{60}^{0.3796} \quad (1)$$

Where Vs= Shear wave Velocity in (m/s)
(N1)60= Corrected SPT (N) value [7]

Layer no.	Depth	Profile	Thk (m)	Layer	SPT (N)
1	1.65	1	1.65	Fill-stiff lateritic clayey silt	50
2	2.50		0.85		19
3	3.50	2	1.00	Alluvial deposits-Loose fine sand with silt	5
4	4.50	3	1.00	Chicol-soft marine Clayey Silt	19
5	5.00		0.50		23
6	6.50	4	1.50	Medium dense medium to fine quartzitic sand with marine silts	16
7	8.00		1.50		14
8	9.50		1.50		21
9	11.00		1.50		17
10	13.50		2.50		18
11	15.00	5	1.50	Insitu strata-very stiff lateritic clayey silt with gravels	22
12	16.50		1.50		23
13	18.00		1.50		21
14	19.50		1.50		49
15	21.00		1.50		
16	27.50	6	6.50	Very stiff clayey silt	50
17		7		Hard Rock	>50

Fig -1: Soil profile of site at Panaji Goa. [1]

4. METHOD OF ANALYSIS

The 1D linear equivalent analysis is carried out using geotechnical finite element software Midas GTS NX, which provides unique feature for free field analysis. Vucetic and Dobry curves for modelling of sands and silts and Rock curve for the modelling of the bedrock, are used out of the set of the various shear modulus reduction and damping ratio curves available in-built in GTS NX. 5% damping is used and the effective strain coefficient is set to be 65% for maximum of 8 iterations. Six different input motions of varying characteristics are applied to the soil profile as within motion. Table-1 shows the peak horizontal acceleration (PHA) and bracketed duration of the input motions. The bracketed duration of the input bedrock motions is found out using *SeismoSignal* [8] software.

Table -1: Characteristics of Input Motion

Earthquake	Magnitude	PHA (g)	Bracketed Duration (sec)
1940 El Centro	6.9	0.357	29.36
1952 Kern County	7.5	0.156	19.6
1971 San Fernando	6.5	0.315	14.92
1966 Parkfield	6.1	0.237	7.86
1989 Loma Prieta	6.9	0.276	9.94
1995 Hyogoken	6.9	0.828	24.47

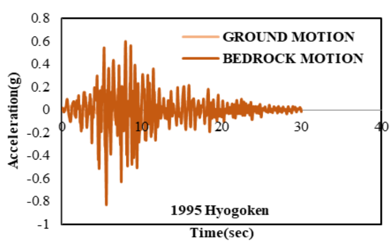
4. RESULTS AND DISCUSSION

4.1 Surface Acceleration Time History

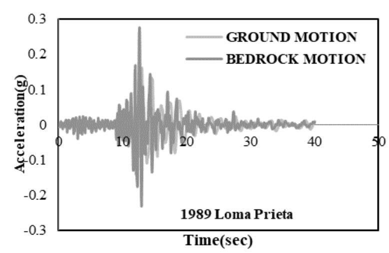
Table-2 shows the characteristics of input motion recorded at ground level. The peak ground acceleration (PGA) of some of these input motions are found to be amplified at the ground level. Amplification of the earthquake is defined as the ratio of the peak ground acceleration to that of the peak horizontal acceleration. 1952 Kern County earthquake shows maximum amplification ratio of 1.78. While 1940 El Centro, 1971 San Fernando, 1952 Kern County, 1966 Parkfield earthquakes are amplified, 1989 Loma Prieta and 1995 Hyogoken earthquakes are found to be having amplification ratio less than 1 for site under consideration. The bracketed duration of the amplified accelerations is found to be increased when the waves reach the ground surface. When the de-amplification happens, the bracketed duration is reduced at the ground surface as compared to that of the input ground motion. Fig 2 (a) to (f) shows the variation in acceleration vs time history for the input motions at the bedrock and ground surface level.

Table -2: Characteristics of the Ground Motion obtained for the Applied Input Motions

Earthquake	PGA (g)	Bracketed Duration (sec)	Amplification ratio
1940 El Centro	0.473	36.06	1.33
1952 Kern County	0.277	31.12	1.78
1971 San Fernando	0.466	19.32	1.48
1966 Parkfield	0.299	19.28	1.27
1989 Loma Prieta	0.162	7.82	0.58
1995 Hyogoken	0.197	13.53	0.24



(a)



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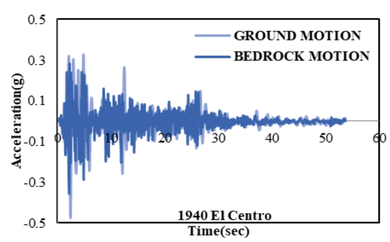

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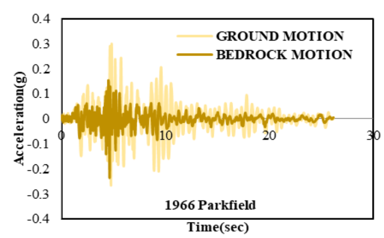

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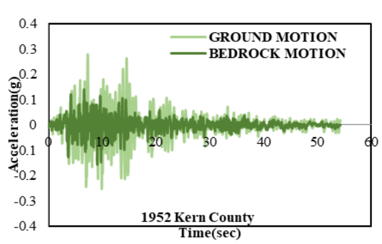
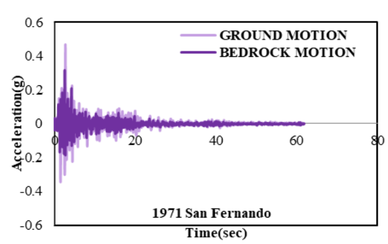


(e)



(f)

Fig -2: Acceleration vs time history graphs showing variation in bedrock and ground level acceleration for various input motions (a) 1995 Hyogoken (b) 1989 Loma Prieta (c) 1940 El Centro (d) 1966 Parkfield (e) 1952 Kern County (f) 1971 San Fernando

4.2 Response Spectrum

Response Spectra obtained for the ground and bedrock level for the input motions are plotted as shown in Fig. 3 (a) to (f). Fig 4 compares the responses recorded at the ground level for the various input motion corresponding to 5% damping. The maximum acceleration is observed for the 1940 El Centro earthquake while the 1995 Hyogoken earthquake exhibits the least acceleration. The peak spectral acceleration at the ground surface level is recorded in the time period range of 0.15 sec to 1.45 sec for the applied motions.

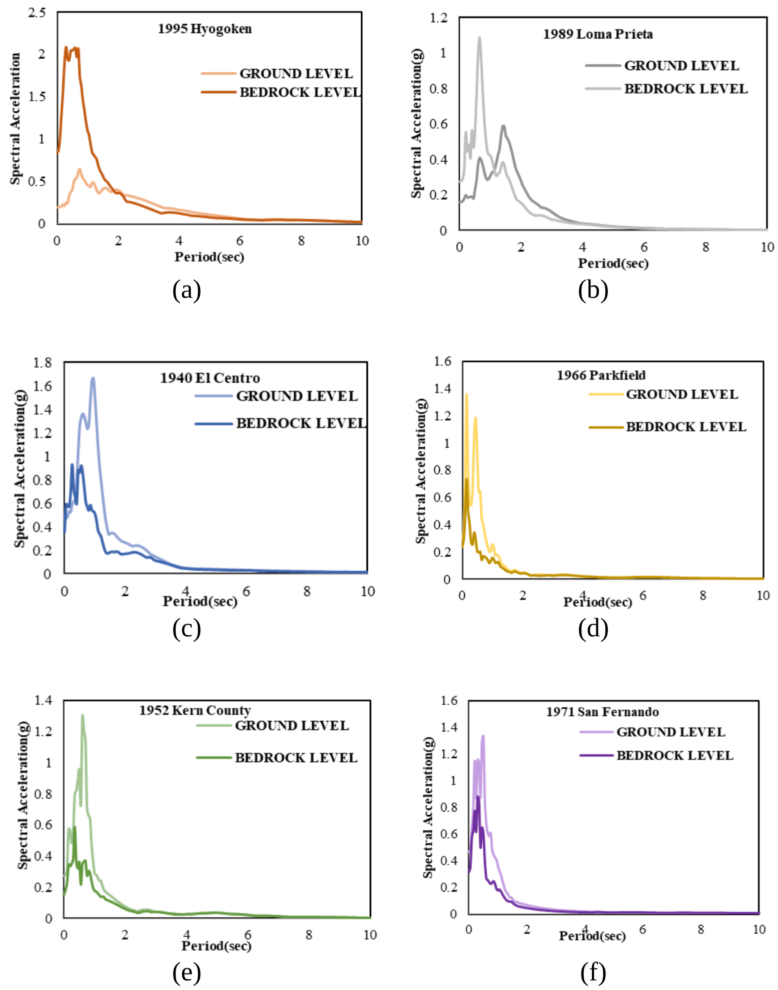


Fig -3: Comparison of variation of response spectra recorded at the ground and the bedrock level for various input motions (a)1995 Hyogoken (b)1989 Loma Prieta (c) 1940 El Centro (d) 1966 Parkfield (e) 1952 Kern County (f)1971 San Fernando

4.3 Variation of Maximum Acceleration with Depth

As can be seen in Fig. 5 the acceleration is found to be higher in soil layer consisting of the medium to fine quartzitic sand with marine clay of medium dense. This is because the average SPT (N) value is comparatively less in this layer as compared to other layers. The acceleration increases from 0.18 g to 1.11 g for the 1995 Hyogoken earthquake which is highest of all the applied input motions. The accelerations of the 1952 Kern County earthquake are found to be decreasing linearly with the increase in the depth.

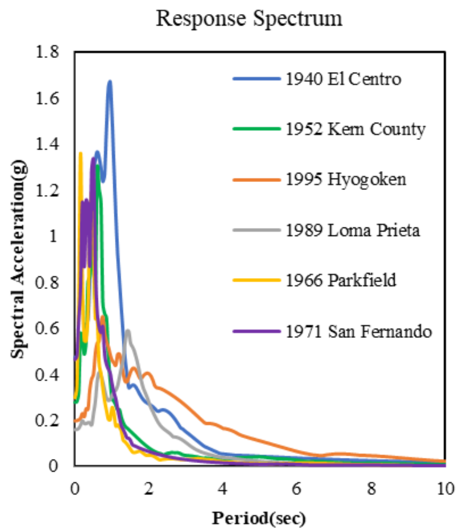


Fig -4: Response Spectra at the ground surface for all the input motions corresponding to 5% damping.

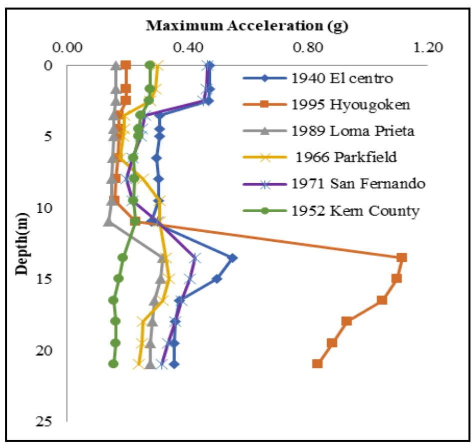


Fig -5: Variation of maximum acceleration with depth of soil column for various input motions

5. CONCLUSIONS

Influence of various input motions on the ground response of site located at Panaji Goa is studied by carrying out 1D equivalent linear analysis in Midas GTS NX. Six different input motions are applied at the bedrock. Results are obtained in terms of the surface acceleration time history, response spectrum and variation of the acceleration with the depth. Following conclusions are derived:

For the site under consideration the 1940 El Centro, 1971 San Fernando, 1952 Kern County, 1966 Parkfield earthquakes are amplified;1989 Loma Prieta and 1995 Hyogoken earthquakes are found to be having amplification ratio less than 1.

1952 Kern County earthquake is found to be amplified the most while 1995 Hyogoken earthquake gives highest de-amplification ratio.

The peak spectral acceleration corresponding to 5% damping is found to be varying in the range of time period between 0.15 sec to 1.45 sec which can be an area of concern.

The bracketed duration of the amplified motions is found to be increased at the surface level as compared to that of the recorded input motion.

Ground response varies with variation in the input motion; hence proper selection of input motion for ground response analysis plays a key role.

Ground response depends on the characteristics of the soil as well as earthquake motion.

6. REFERENCES

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