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Seismic Analysis of on the Ground, Partial and Fully Underground Building using Response Spectrum and Time History Analysis

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ABSTRACT

This paper presents study on seismic analysis of G+7 building using STAAD PRO V8i software. Building is analysed for three different positions i.e. on the ground, partially and fully underground building. Seismic analysis is done using two methods- Response spectrum and Time history methods. To check accuracy of results and actual behavior of building, results of both the methods are compared. Parameters which are taken into consideration are node displacement, beam end forces, modes shapes and graphs on time vs acceleration , velocity and displacement plotted. After obtaining results, it is found that results obtained from both the methods is not varied much and therefore analysis done by both the methods are accurate. Node displacement for both methods found to be decrease as building moved on the ground towards underground. it means impact of earthquake reduces for fully underground building. While, results obtained in beam end forces refers that building considers strong column and weak beam concept. Mode shapes obtained from both methods concludes that fully underground building deformation is regular and uniform in nature. While, graphs obtained from time history method for acceleration, velocity and displacement shows fully underground building has less variations than other. In this way, it can be summarizes that fully underground building are less prone to earthquake. Hence, in highly earthquake prone areas fully underground building should be preferred for security against earthquake and also for sustainable development.

Keywords: structure, underground, mode shape, sustainable development, seismic, time history.

1. INTRODUCTION

In present time, seismic analysis of the building mainly performed by dynamic method which includes response spectrum method and time history method. Response spectrum method is generally based on complete quadratic combination (CQC) method and it is mentioned in IS 1893-2002 (Part 1). This method presents two critical parameter that helps in analysis are base shear and mode shapes. While, time history method is also mentioned in IS 1893-2002 (part 1). This method uses ground motion data of previous earthquake obtained from accelerometer. this method not only provides mode shapes but also provide time history graphs- time vs acceleration, time vs velocity and time vs displacement.

Therefore, This paper presents the study based on these two methods for the analysis of building positioned at three different place- on the ground, partially and fully underground. it aims to find out which building performs better in earthquake. Therefore, for accuracy, parameters obtained in both the method is compared. Though various studies has been carried out in this area, some of them are as follows.

2. LITERATURE REVIEW

Madane J.J. et al. (2014): It highlights various studies conducted on RCC building, built underground, having shear wall. And study proposes seismic behavior of underground parking with ideal location of shear wall. It concludes that building with shear wall deflects less as compared to without wall[18].

Brito A. et al. (2015): This paper discusses about design of seismic underground building (4 -storey). Study shows comparison between eurocode EC (part-1)-2004 and methodology proposed by author. Paper discusses capacity based method for design purpose. Hence, it is concluded that proposed methodology is applicable in increasing lateral deformation capacity of structure. The structure´s deformation capacity is evaluated by means of static monotonic nonlinear analysis[3].

Genidi Magdy. M. M. et al. (2017): Study conducted to determine the seismic effect on underground floors using ANSYS and CivilFEM. It is found that the story shear of building structure may be significantly underestimated if the underground floor(s) of the building is ignored in the analysis. The lateral displacements of building structure may be significantly underestimated if the underground floor(s) of the building is ignored in the analysis [13].

Nimade A. et al. (2018): Underground water tank was analysed using FEM. Under FEM, STAAD pro software was used. It aims to study behavior of underground water tank for varied L/B ratio. Node displacement and stress pattern was also taken into consideration. Empty and full condition of tank was considered [20].

Zheng G. et al. (2020)**:** This study introduces correlation effects of underground subway, soil and nearby existing structure during earthquake. Simulation was done on ANSYS [14].

Dubey R. et al. (2021)**:** Seismic analysis of underground water tank was conducted based on soil structure interaction using ETABS 17 software. It is found that shear force influence the thickness of wall. While soil structure interaction taken into account , design forces increases in comparison to seismic design of tank with rigid base[8].

Dhanawade S. V. et al. (2021): Study conducted using STAAD Pro to analyse underground and elevated reservoir. It is found that lateral displacement in tank due to wind is critical. Base shear in empty condition is more than full condition. Natural frequency decreases with increase in water storage[9] .

Wagh K. K. et al. (2021**):** Underground water tank was analysed using STAAD Pro software. IS 456-2000 and SP-16 was used for reference. Limit state design method was used for design purpose. It is found that there was total 15-20% saving in steel [33].

Sun-Yong K. et al. (2021): This research describes dynamic numerical analysis for deep underground structures. In this paper, PLAXIS 2D software is used. Also, dynamic behavior of underground building structure was evaluated. In conclusion, results was compared with centrifuge test data for verification. While centrifuge test conducted in dry dense sand condition [17].

Gupta D. et al. (2022): Response spectrum method was used to conduct seismic analysis of multistory building for different zones. Later, these building analysis was compared using STAAD Pro. Various parameters such as base shear, storey drift and storey displacement was also evaluated [11].

Borkar Y. et al. (2022): ETABS 18 software was used to seismic analyse the underground, above the ground and elevated water tank on different soil condition. Total 9 cases was analysed using response spectrum method. Base shear, base moment and storey drift was also obtained. It is found that Drift is decreases with increases in stiffness of soil for all water tanks [4].

Soumya A. et al. (2022**):** Seismic analysis of G+12 RCC building was conducted using ETABS software.comparision is made on static and dynamic method of analysis.it is found that storey drift is slightly higher in Y direction than in X direction [28].

Gadekar D. et al. (2022**):** STAAD pro software was used to analyse the underground water tank for different fill condition. It is concluded that shear force rise by 8% in fill condition. In empty condition axial force value declined by 14%. There was 11% variation in full condition for support condition in compare with empty condition [12].

Upadhyay A. et al. (2023): STAAD Pro software was used to analyse underground circular and rectangular water tank. It is found that more shear force obtained in rectangular water tank than in circular water tank. Greater moment in circular tank than in rectangular tank. Axial force found to be same in rectangular tank for empty and full condition while same in circular tank in full condition [32].

3. METHODOLOGY

G+7 building is analysed seismically for three different condition- on the ground, partially underground and fully underground. Software used for analysis is STAAD PRO V8i.

Initially modeling is done using structure wizard in software and symmetrical structure is formed have four bays each side, as shown in figure 1. Support is applied which is fixed in nature. Loads applied that include self weight, wall load- 12.42 KN/ m (outer wall) and 5.94 KN/ m (Inner wall), Parapet load 4.14 KN/m , Dead Floor load 3KN/sq.m, Floor Finish load 1KN/sq.m and Floor Live load 2KN/sq.m are considered. IS 1893- 2002 (Part 1) table 8 refers to consider 25% of live load for seismic analysis, which is taken into account. Load combinations is applied as per IS 1893-2002 (Part 1). In case of partially and fully underground building, shear wall is designed of 150 mm on which 29.9 KN/sq. m and 118.8 KN/ sq.m respectively soil pressure is applied as shown in figure.4. For dynamic (Response spectrum method) analysis, Dynamic loads need to generate and on which response spectra is applied using CQC (complete quadratic combination method) (IS 1893-2002 part 1). For study, earthquake Zone V (Chamoli district- uttarakhand) and Medium soil is considered and ground motion data is also obtained for same place from PESMOS (Indian institute of technology- roorkee).

3.1 RESPONSE SPECTRUM METHOD

After load definition in load case details, Seismic definition is described as shown in figure 2. It includes Zone, importance factor, Response reduction factor, Damping, Natural time period.

These parameters are defined in IS 1893 (Part 1) 2002 such as Importance factor is taken as 1.o for all other building category (refer table 6 IS 1893-2002). Similarly, 5% damping is considered and response reduction factor is taken as 5 for special RC moment resisting frame (Table 7 IS 1893-2002). Natural time period for frame with brick infill panels is defined in clause 7.6.2 IS 1893 is evaluated as 0.54 second in both X and Z direction.

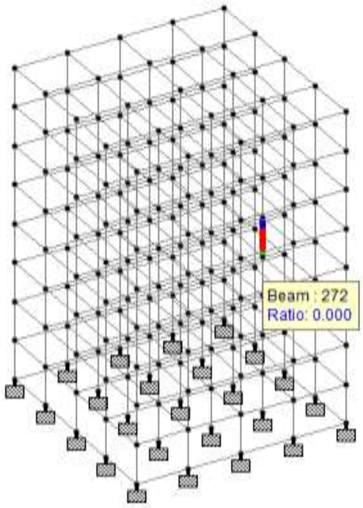


Figure 1. Modelling and assigning of support

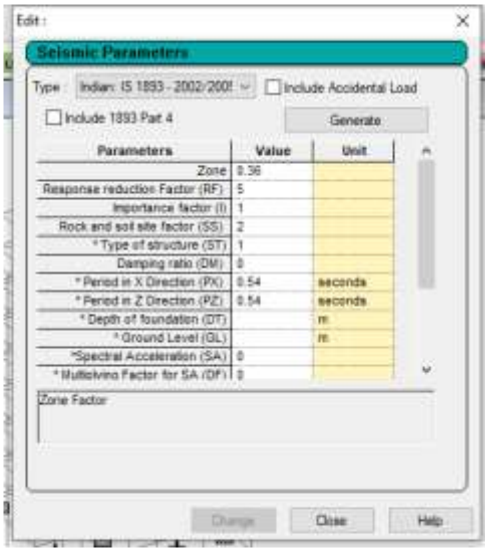


Figure 2. Seismic Definition

Similarly, for dynamic analysis using response spectrum method,

As per IS 1893 cl. 6.4.2, horizontal acceleration spectrum is (figure 3)-

$$A_h = \frac{Z I S_a}{2 R g}$$

Where,

Z = 0.36 (zone factor table 2 IS 1893)

I = Importance factor =1 (table 6 IS1893)

R= Response reduction factor (table 7 iS 1893)= 5

g = Average response acceleration coefficient (IS 1875 cl. 6.4.5)

In our case, for medium soil

For medium soil sites

$$\frac{S_a}{g} = \begin{cases} 1 + 15\,T; & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.55 \\ 1.36/T & 0.55 \le T \le 4.00 \end{cases}$$

For natural time period T= 0.54 (refer section 3.1.1)

Average response acceleration coefficient = 2.5 (in X and Z direction).

Horizontal acceleration spectrum = 0.09

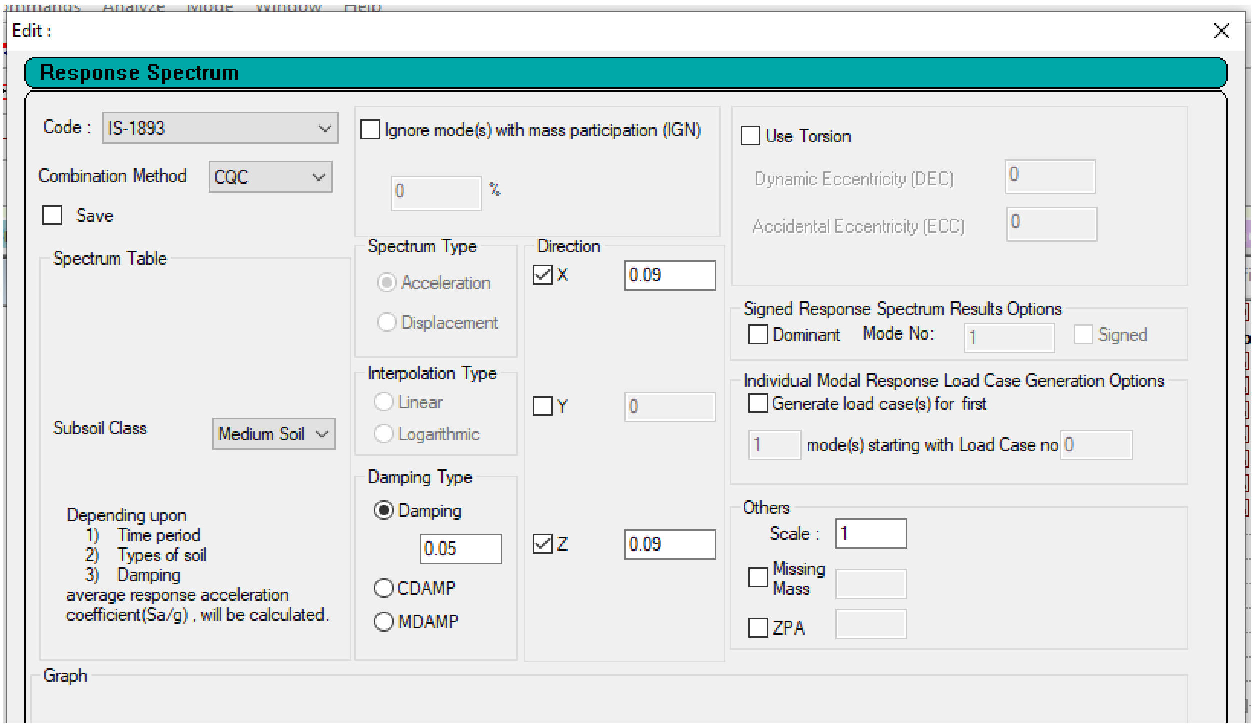


Figure 3. Response Spectra

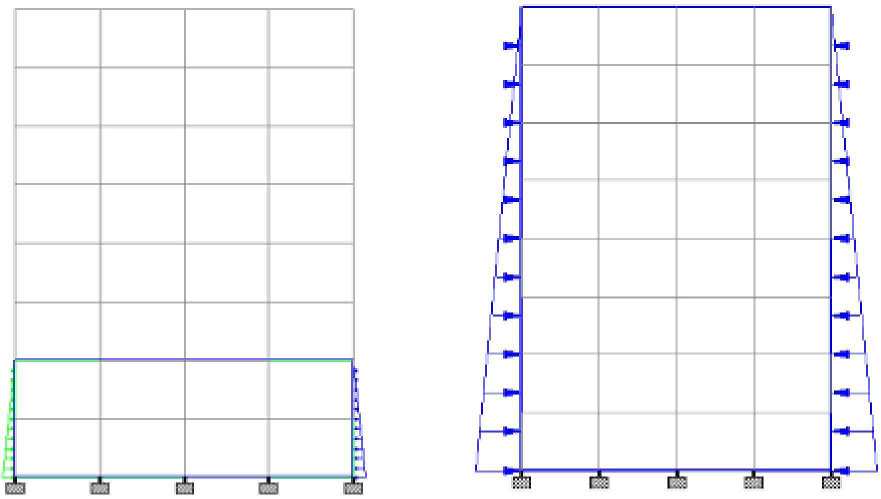


Figure 4. Soil pressure on partially and fully underground building

3.2 TIME HISTORY ANALYSIS

This method is introduced using time history definition parameter as shown in figure 5. From figure 5, integration time step is defined at 0.002 second and ground motion data is introduced for chamoli district includes time and acceleration. Damping is taken as 5%.

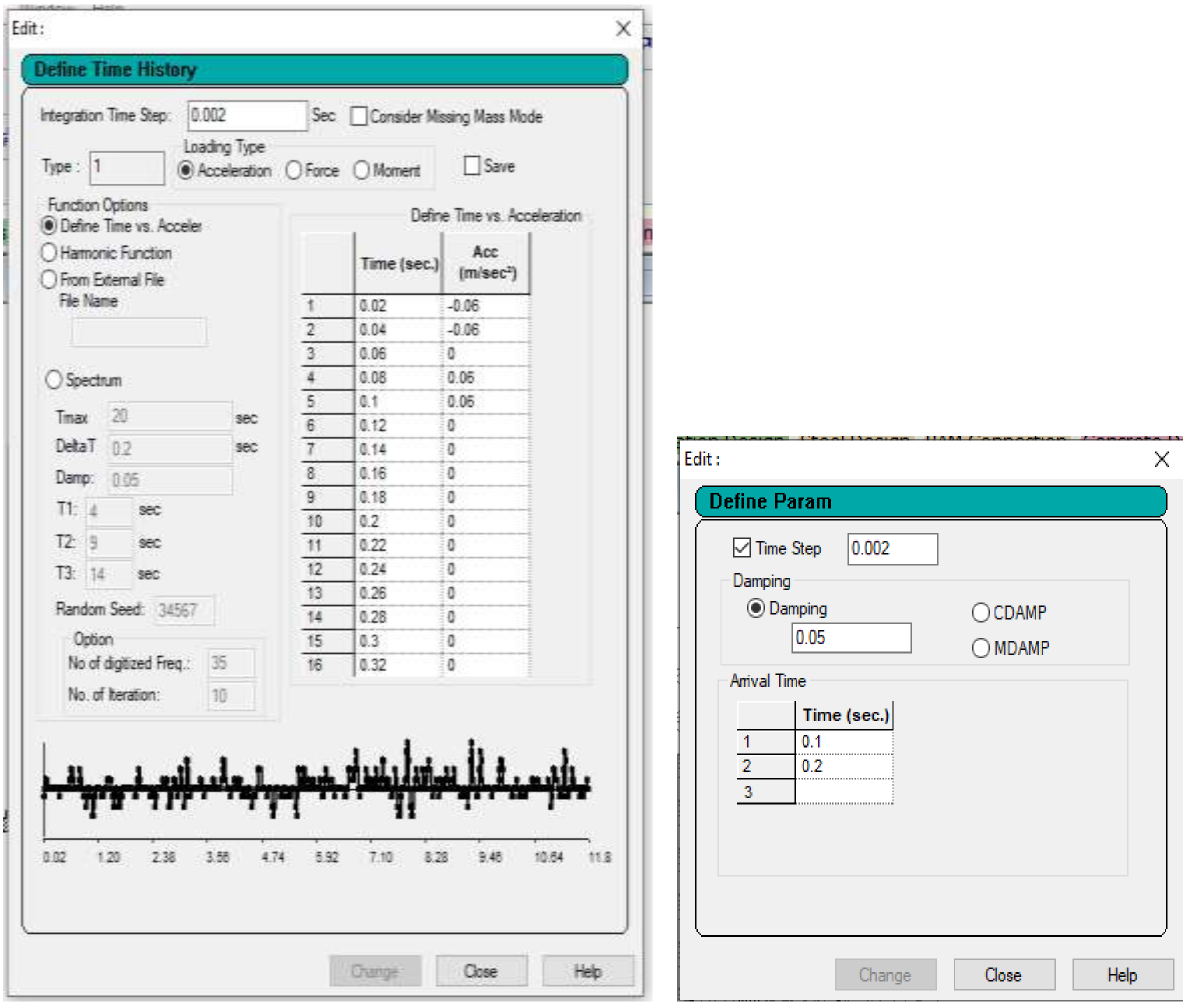


Figure 5. Time history definition

Now, after this, load case details are defined as in response spectrum method. Difference here is that after defining dead load and live load, single dynamic load also defined and for which time history load is defined as shown in figure 6.

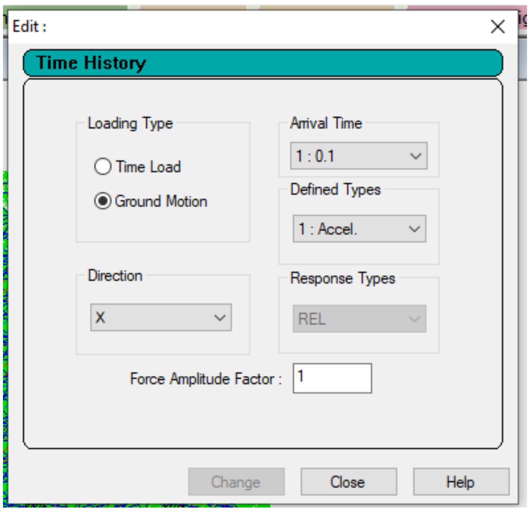


Figure 6. Time history load case

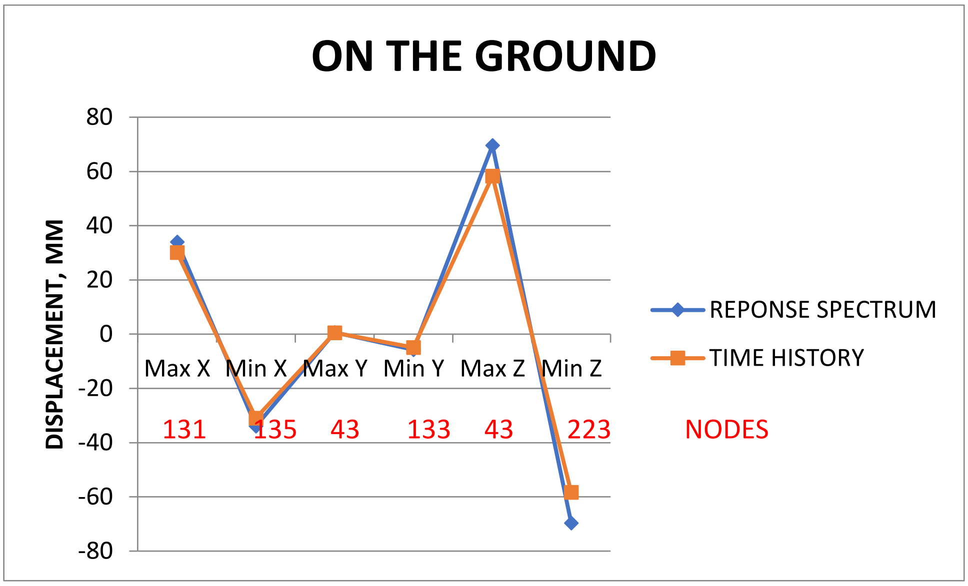
After this step, load combination is applied from load case details as per IS 1893-2002 (Part 1).

Later, analysis is done. And necessary parameters are noted down.

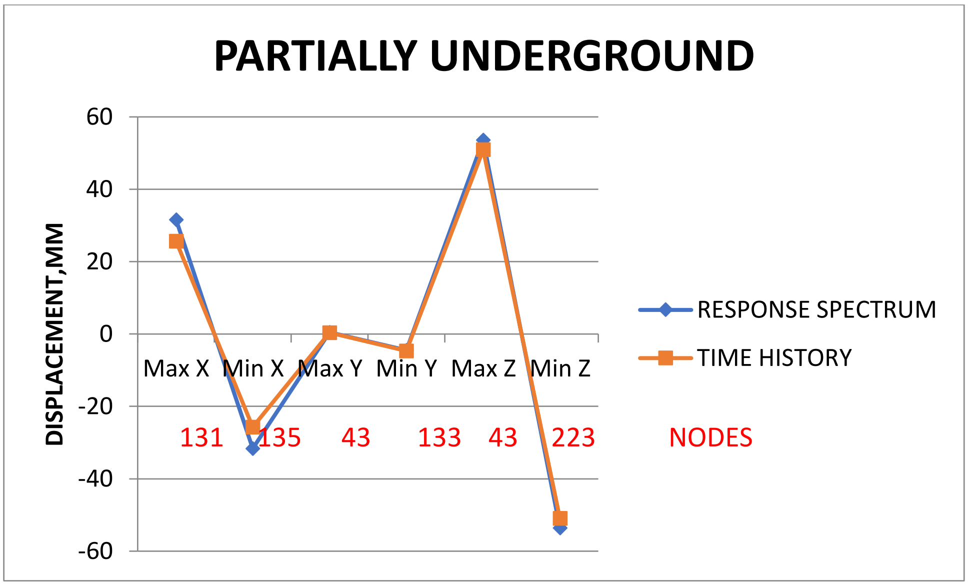
4. RESULTS AND DISCUSSION

Comparison is carried out between response spectrum and time history analysis for node displacement, mode shapes and beam end forces. While the results obtained from time history method- time vs acceleration, time vs displacement are also discussed.

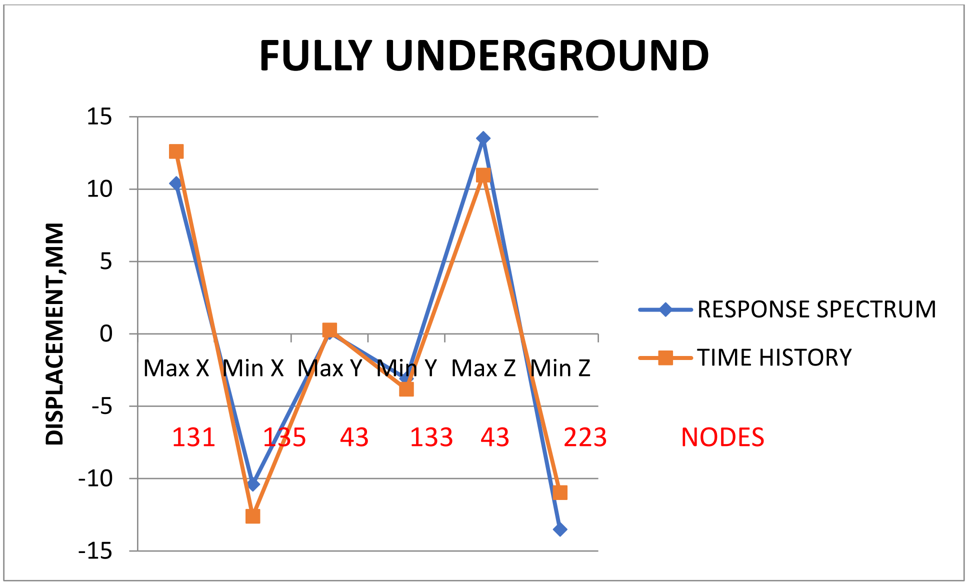
4.1 Node Displacement (Response spectrum vs Time history method)



(a)



(b)

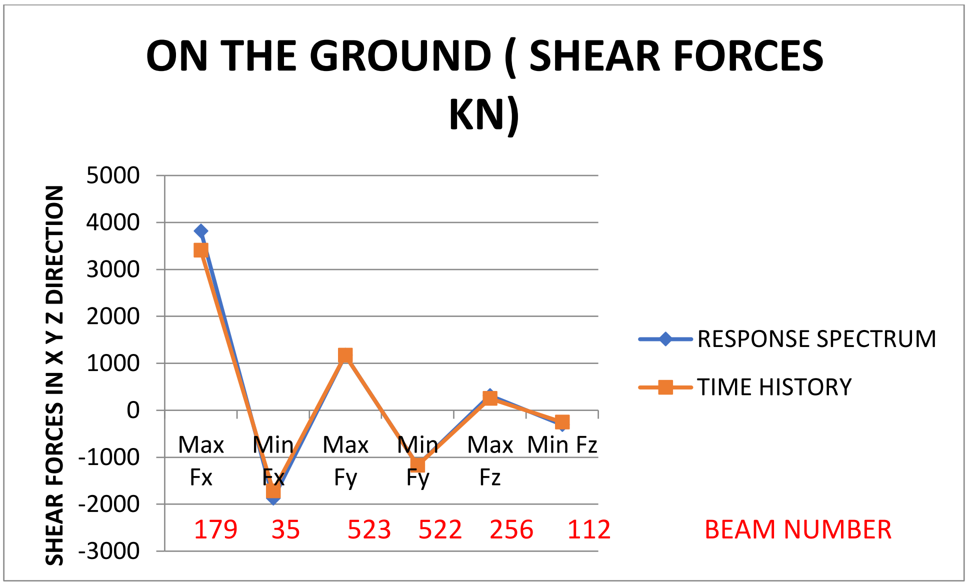


(c)

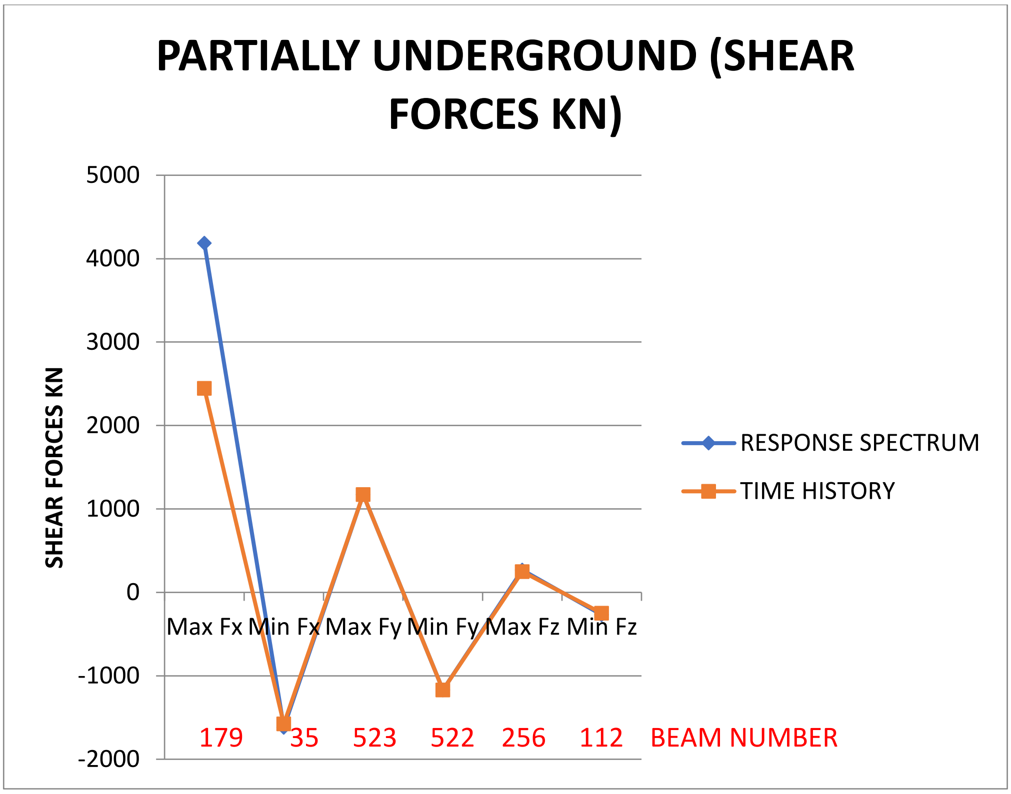
Figure 7. Node Displacement (Response spectrum vs Time history method)

Figure 7 (a), (b) and (c) shows node displacement for the on the ground, partially underground and fully underground building. It is found that results obtained from both the method shows displacement reduces as building moves towards fully underground and found to be minimum for fully underground building.

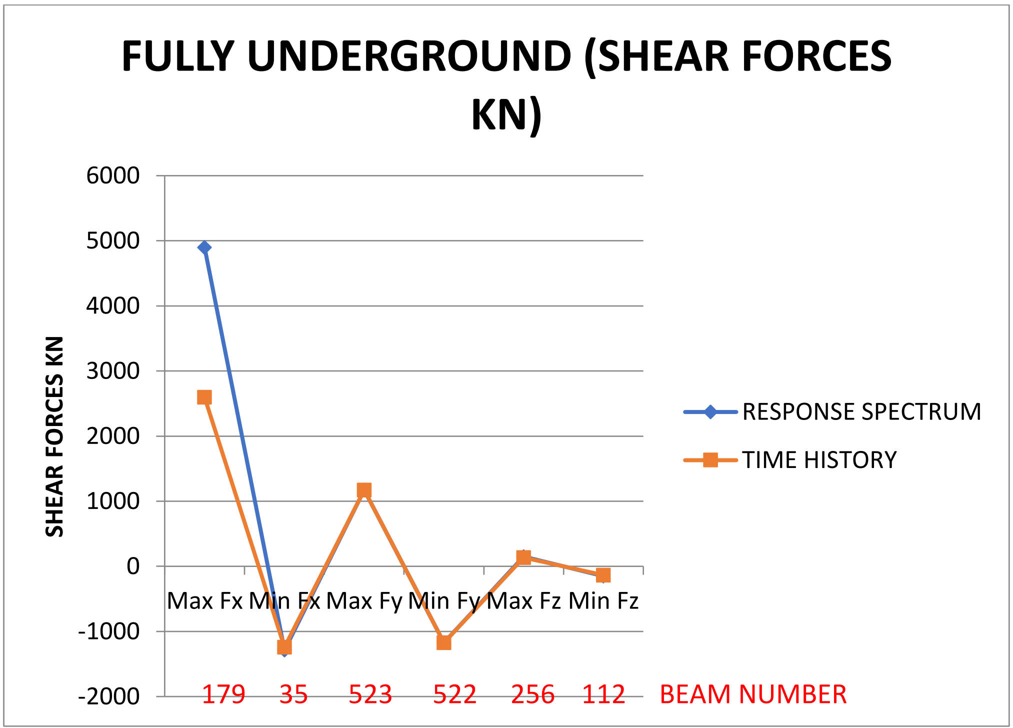
4.2 Beam End Forces (Response spectrum vs Time history method)



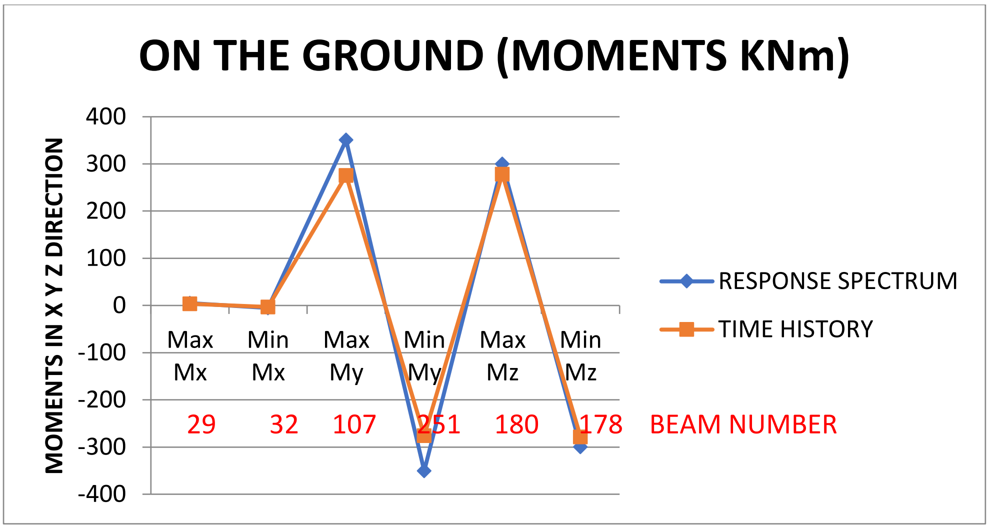
(a)


PARTIALLY UNDERGROUND (SHEAR FORCES KN)
SHEAR FORCES KN
5000
4000
3000
2000
1000
0
-1000
-2000
Max Fx Min Fx Max Fy Min Fy Max Fz Min Fz
179 35 523 522 256 112 BEAM NUMBER
RESPONSE SPECTRUM
TIME HISTORY

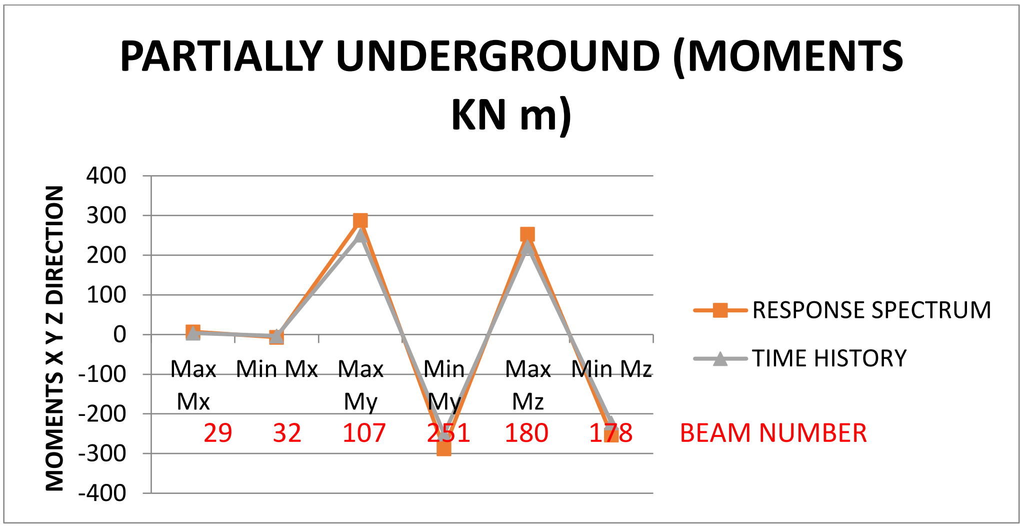
(b)


FULLY UNDERGROUND (SHEAR FORCES KN)
SHEAR FORCES KN
6000
5000
4000
3000
2000
1000
0
-1000
-2000
Max Fx Min Fx Max Fy Min Fy Max Fz Min Fz
179 35 523 522 256 112 BEAM NUMBER
RESPONSE SPECTRUM
TIME HISTORY

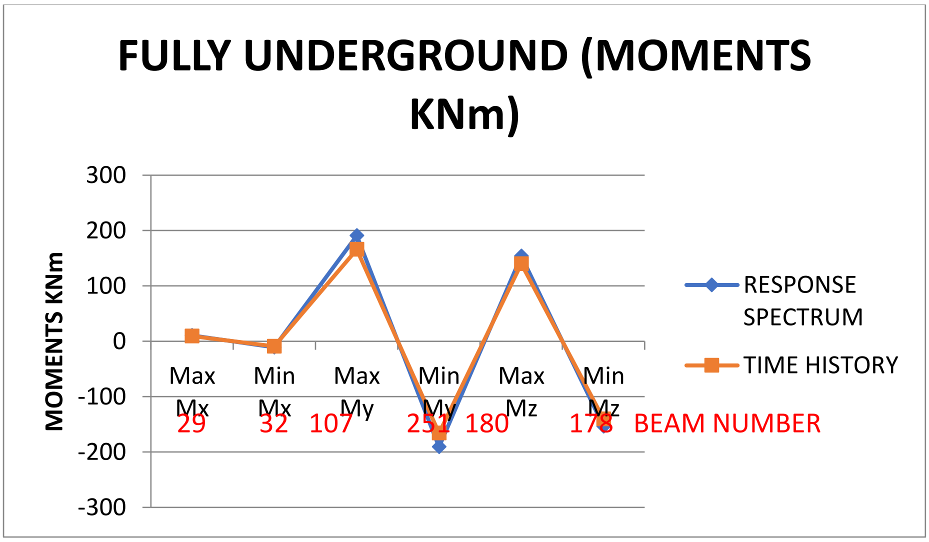
(c)



(d)



(e)

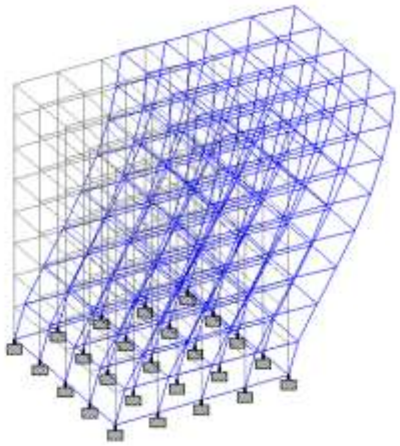
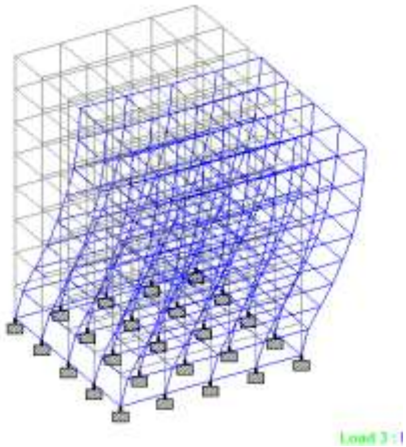
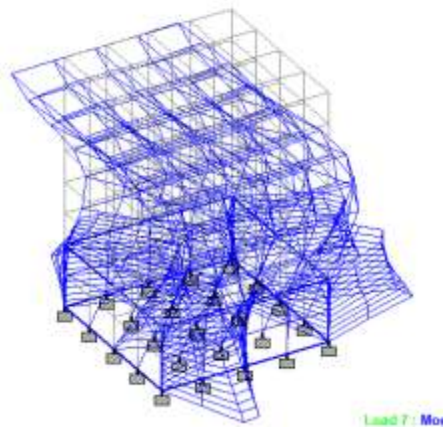
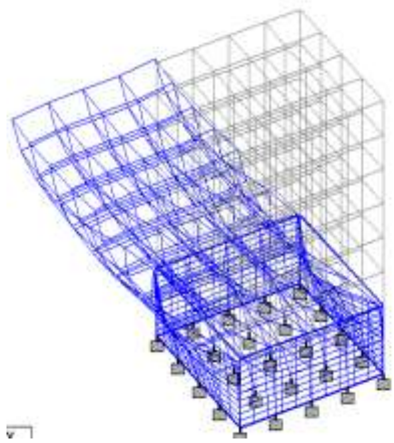


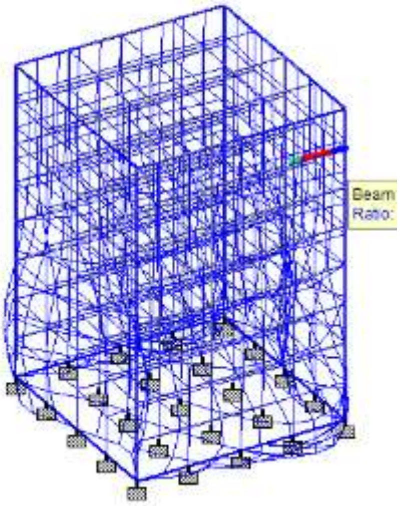
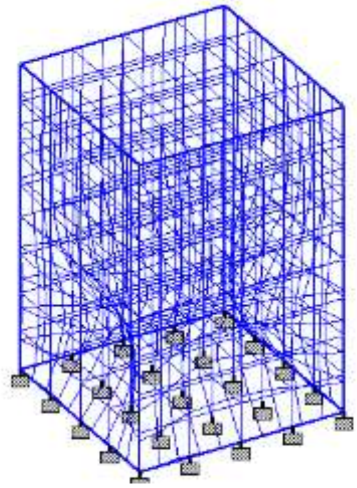
(f)

Figure 8 Beam End Forces (Response spectrum vs Time history)

Figure 8 (a) to (f) shows beam end forces for the on the ground, partially underground and fully underground building. Forces are carried out for randomly selected beams. Values of axial force, shear forces and bending moments found to be greater in response spectrum method rather than time history method. While axial force in X direction found to be increases from on the ground towards fully underground building. Shear force in Y direction found to be constant in both methods and all three buildings. Shear force in Z direction found to be dropped from on the ground towards fully underground building. Here, it is to be noted that moment in X direction found to be increased while in Y and Z direction, moment found to be dropped for respective buildings.

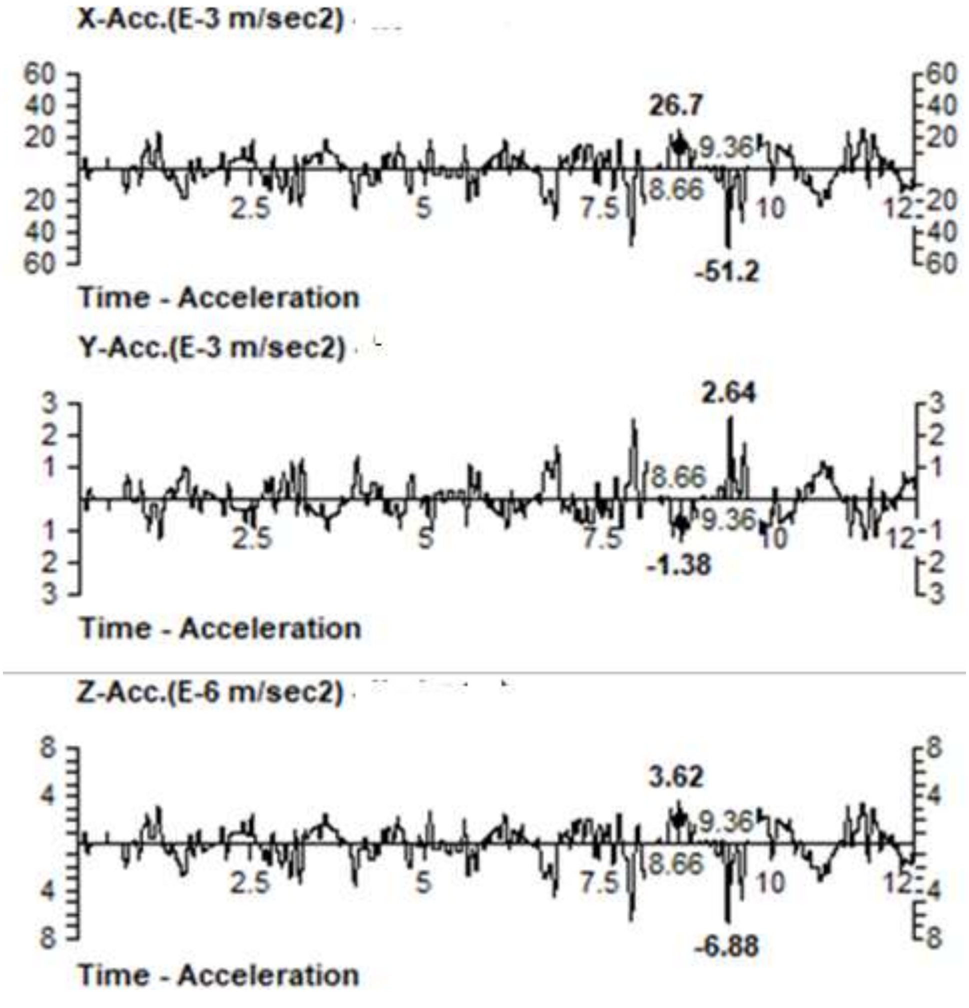
4.3 Mode Shapes (Response Spectrum Method vs Time history)

POSITION	RESPONSE SPECTRUM	TIME HISTORY
ON THE GROUND		
PARTIALLY UNDERGROUND		

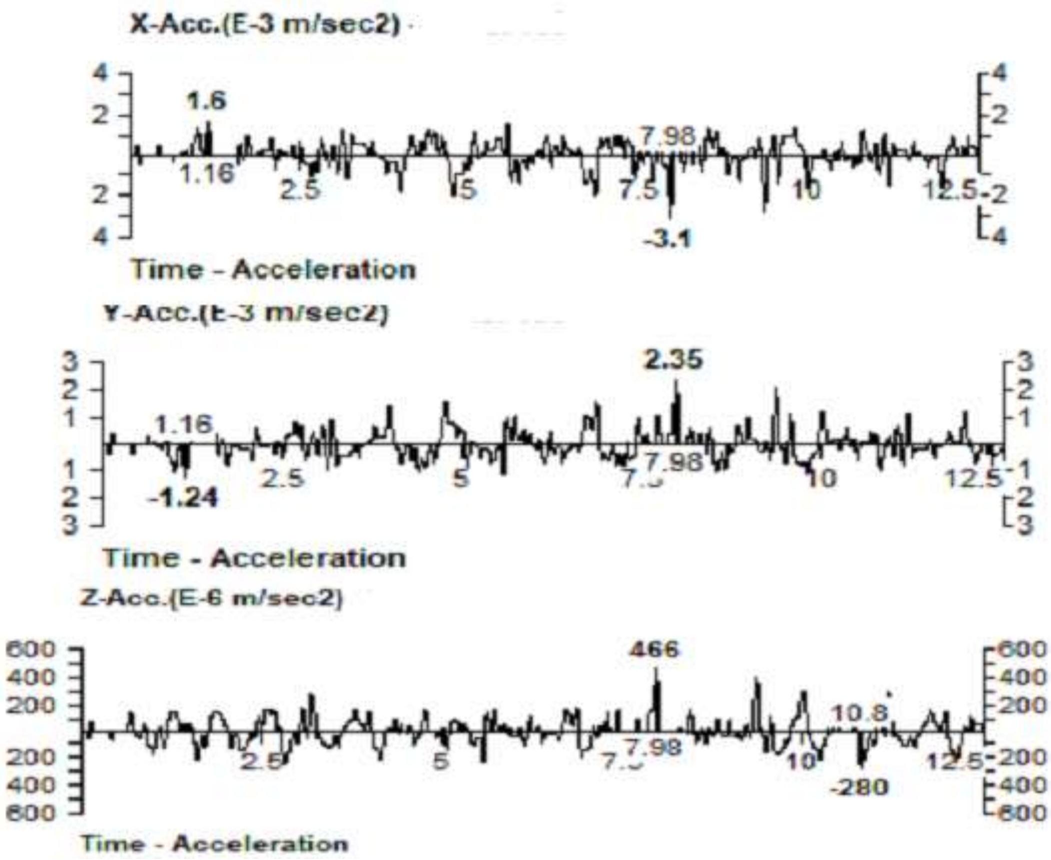
FULLY UNDERGROUND		
	Observations: it can be observed that deformation of fully underground building is regular and uniform in nature obtained from response spectrum method.	**Observations:** deformation obtained from this method gives uniform shape for fully underground building.

Therefore, it can be concluded that fully underground building is less prone to earthquake as modes shapes obtained from both the methods reflects.

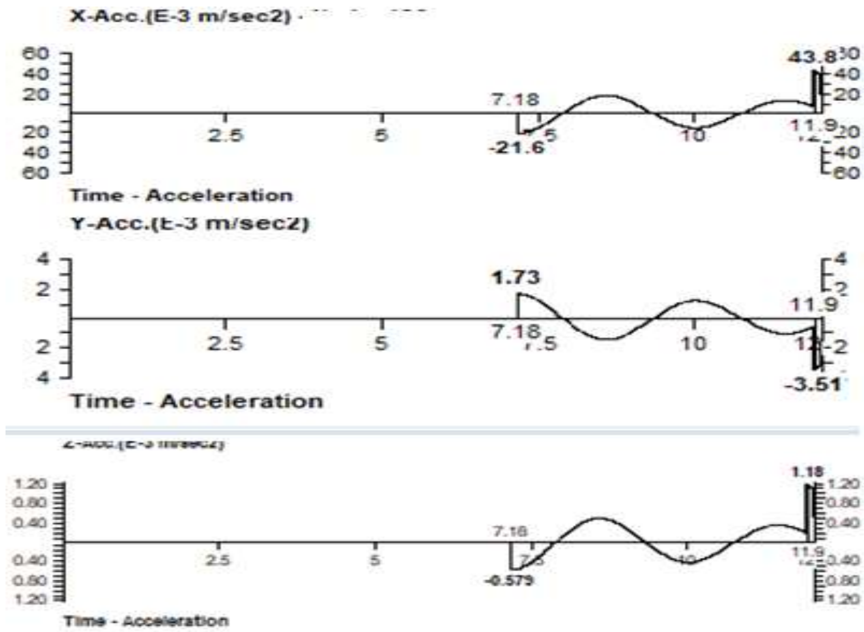
4.4 Time vs Acceleration (Time history method)



(a)



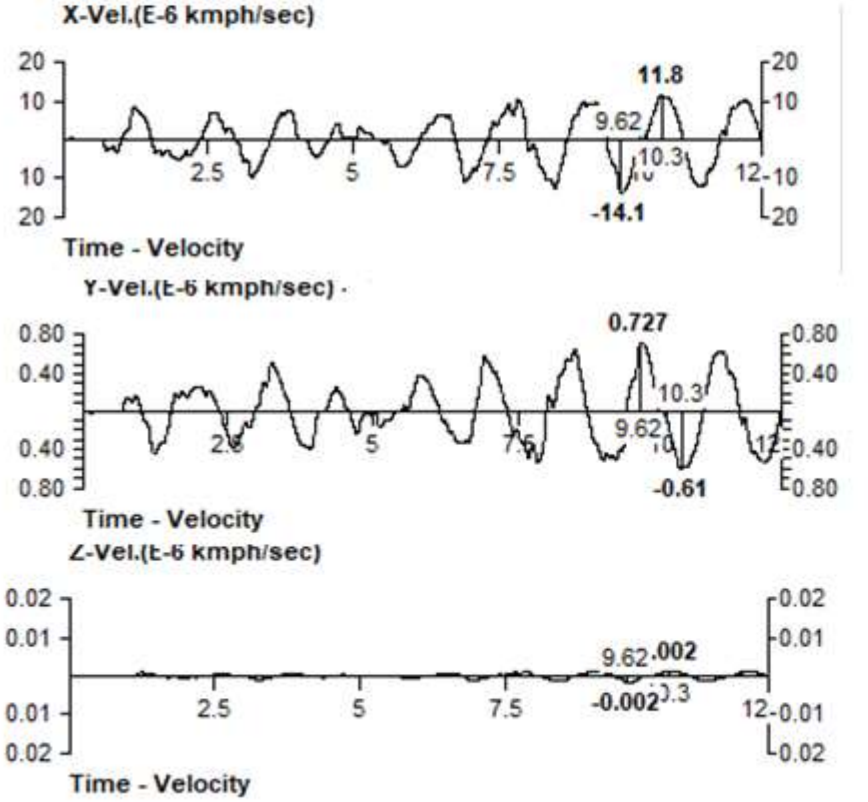
(b)



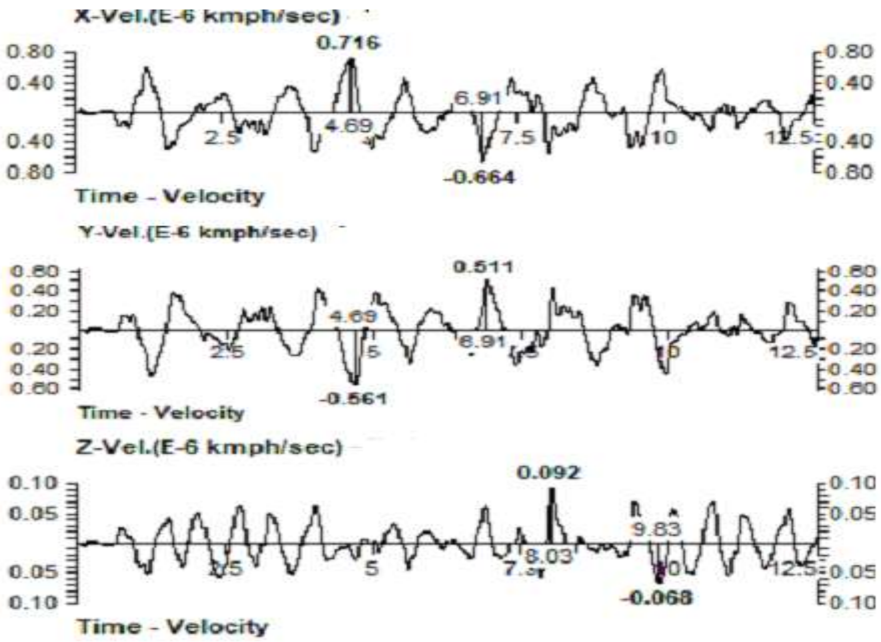
(c)

Figure 9. Time vs Acceleration graph (a) on the ground building (b) partially underground building (c) fully underground building

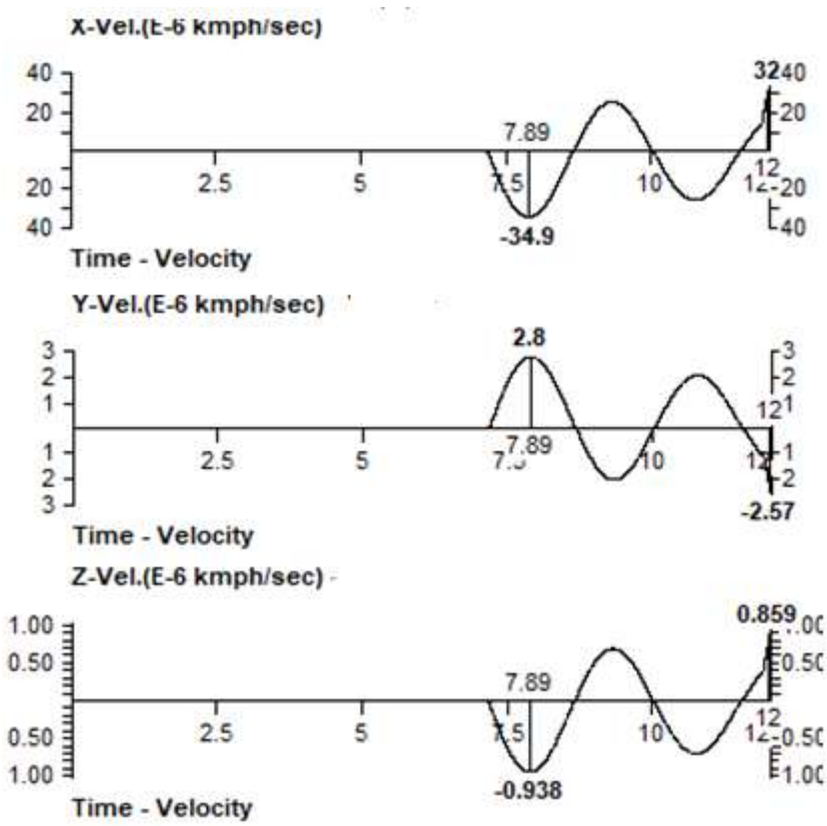
4.5 Time vs. Velocity (Time history method)



(a)



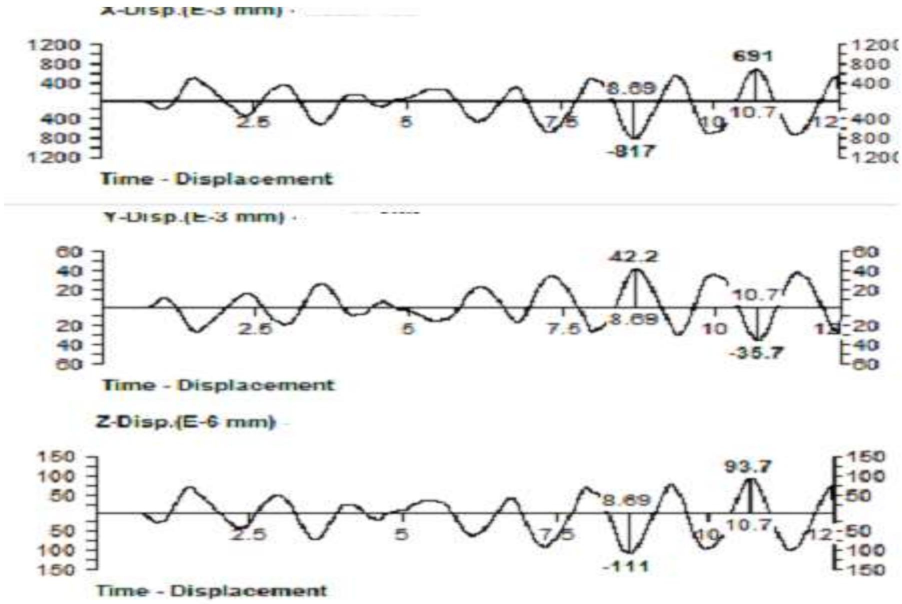
(b)



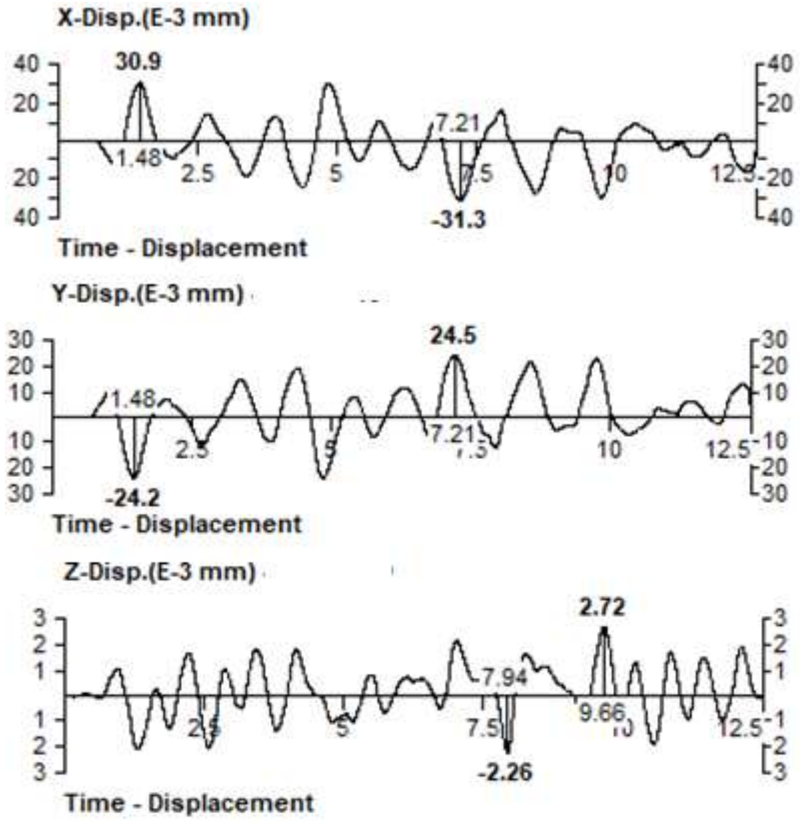
(c)

Figure 10. Time vs Velocity graph (a) on the ground (b) partially underground (c) fully underground

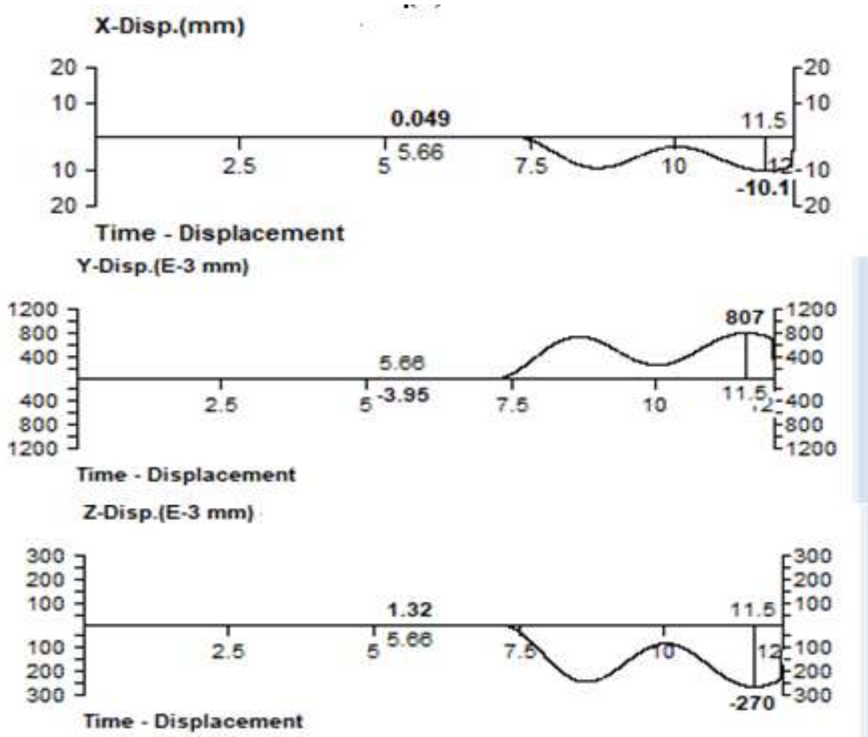
4.6 Time vs Displacement (Time history method)



(a)



(b)



(c)

Figure 11. Time vs Displacement Graph (a) on the ground building (b) partially underground (c) fully underground

Figure 9 to 11 shows graphs time vs acceleration, time vs velocity and time vs displacement. Here, It is observed that variation in on the ground and partially underground building is more in comparison to fully underground building. Such variation is reflected in all three types of graph. Therefore, fully underground building is less prone to earthquake.

This is the results obtained from research work conducted for seismic analysis of G+7 building situated at different positions using response spectrum and time history method.

5. CONCLUSION

It can be concluded that both the methods give approximately same results. Hence, analysis done is accurate. But, time history will proved to be more appropriate for analysis because structure can be analysed for each second and more important graphs can be plotted for acceleration, velocity and displacement. Also, it can be concluded that fully underground building is less prone to earthquake than other two. Because, node displacement is found to be low and mode shape is found to be regular and uniform as evaluated by both methods. Additionally, graphs obtained from time history method shows that fully underground building has low variations than other two position of building. Therefore, it is recommended that fully underground building should preferably be build in high prone areas. It will not only provide security as well as sustainable development.

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Disclosure statement

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Ethics declaration

No violation of anyone’s interest.

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