RESPONSE SPECTRA ANALYSIS OF SYMMETRIC AND ASYMMETRIC BUILDINGS WITH VARIATION IN NATURAL PERIOD AND SOIL STRATA

Rajesh Kadiyala[1], Tejaswi Kota[2]

[1]P.G. Student, VR Siddhartha Engineering College, Andhra Pradesh, India.
[2]Assistant Professor, VR Siddhartha Engineering College, Andhra Pradesh, India.

Abstract

Seismic analysis and design of any structure requires time history data. Unavailability of records at all the locations makes response spectra as a powerful analysis tool. As a scope of this paper, a set of 10 buildings with their period varying from 0.1 to 1.18 sec were considered and response spectra analysis was carried out for the soil site conditions as per IS code. The variation of acceleration, velocity and displacement responses with respect to change in period of the structure and the soil type were compared. This study is extended to buildings with asymmetry as well. Another set of asymmetric buildings whose time periods were varied from 0.1 to 1.19 sec are also analyzed for the same above mentioned soil conditions. It was observed that all buildings with fundamental mode period between 0.1 to 0.4 sec in the chosen direction have same response irrespective of the soil type. The maximum variations in the responses for building resting on stiff medium and soft strata are presented for both the buildings with symmetry and asymmetry. The results obtained shows need to carefully study responses of buildings with smaller frequencies and that resting on less stiffer soils.

Keywords: *Response Spectra, Soil Amplification.*

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INTRODUCTION

Response-spectrum analysis (RSA) is a linear-dynamic statistical analysis method which measures the contribution from each natural mode of vibration to indicate the likely maximum seismic response of an essentially elastic structure. Response-spectrum analysis provides insight into building behavior by measuring pseudo-spectral acceleration, velocity, or displacement as a function of structural period for a given time history and level of damping. It is practical to envelope response spectra such that a smooth curve represents the peak response for each realization of structural period. Response-spectrum analysis is useful for design decision-making because it relates structural type-selection to dynamic performance. A numerical method for computing response spectra from strong-motion earthquake records was developed using Range Kutta method (C. Nigam 1969). For the design of buildings with longer period velocity and acceleration are the more important design parameters required as they are dominant in such buildings (Rafael 1994). The thickness and the site conditions impact the response and there are many investigations going on in these aspects (Kyriazis PITILAKIS2004). Soil soils are to be checked for liquefaction analysis as well (T. Leslie Youd). In this paper a study of responses of structures with varying period and soil type are compared.

BUILDINGS CONSIDERED

Set of symmetric buildings (B-1) given by its plan geometry spanning 9, 9 m along X and Y directions respectively (*Figure 1*) are considered. The building is varied in height which in turn changes the natural time period of the structure. The heights of buildings chosen for analysis range from 3m to 30m with an increment of 3m, resulted in a natural time period range of 0.1 sec to 1.18 sec. The buildings considered are modeled, analyzed and designed as per the IS codal provisions using SAP 2000 (*SAP 2000*). The time period of the fundamental mode in the required analysis direction is considered for the comparison purpose. The details of the range of time period and the fundamental mode time period in X and Y directions are given in *Table 1*.

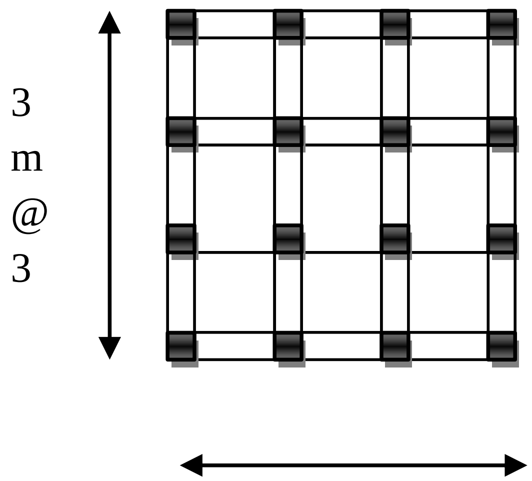


Figure 1. Plan of Symmetric Building

Table 1: Time period of B-1 (symmetric)

No of Floors	Time Period	Time Period_Fundamental Mode_X-Direction	Time Period_Fundamental Mode _Y-Direction
1	0.1366	0.099153	0.099153
2	0.242967	0.184896	0.184896
3	0.354969	0.276553	0.276553
4	0.469136	0.370746	0.370746
5	0.585024	0.46694	0.46694
6	0.702678	0.565195	0.565195
7	0.822268	0.665728	0.665728
8	0.944001	0.768798	0.768798
9	1.068099	0.874671	0.874671
10	1.194784	0.983615	0.983615

Another set of buildings asymmetric with respect to geometry are considered. The plan of this is given in Figure 2 and the height is varied from 3m to 30m with 3m increment. The time periods for this building set are as follows (*Table 2*).

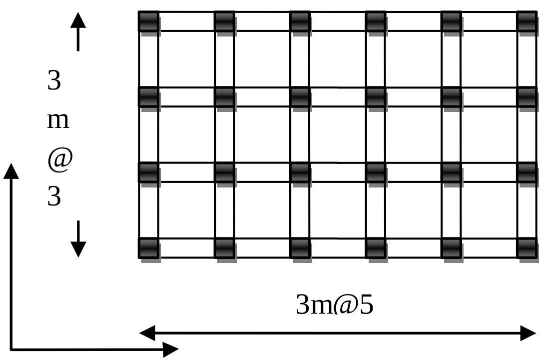


Figure 2: Plan of Asymmetric Building.

Table 2: Time Periods of Asymmetric Building .

No of Floors	Time Period	Time Period_Fundamental Mode_X-Direction	Time Period_Fundamental Mode_Y-Direction
1	0.140947	0.102325	0.140947
2	0.248605	0.189516	0.248605
3	0.361321	0.282475	0.361321
4	0.475717	0.377967	0.475717
5	0.591278	0.475529	0.591278
6	0.707945	0.575258	0.707945
7	0.825757	0.677396	0.825757
8	0.944784	0.78222	0.944784
9	1.065105	0.890016	1.065105
10	1.186804	1.001065	1.186804

METHODOLOGY

The building sets chosen are analyzed for response spectra with a P.G.A level of 0.16g. Response spectra as per IS code is considered for the analysis purpose. Time period of the buildings fundamental mode along the required direction is estimated. Responses of the above described buildings assumed to be resting on soil strata ranging from stiff to soft soils are determined. With reduction in stiffness of the soil, there occurs amplification and leading to scaled up responses when compared with stiff soils. This is repeated for the buildings with asymmetry as well.

RESULTS AND DISCUSSIONS

The buildings with fundamental time period between 0.1 to 0.4 s respond similarly for all soil strata. This can be observed from the Figure 3.

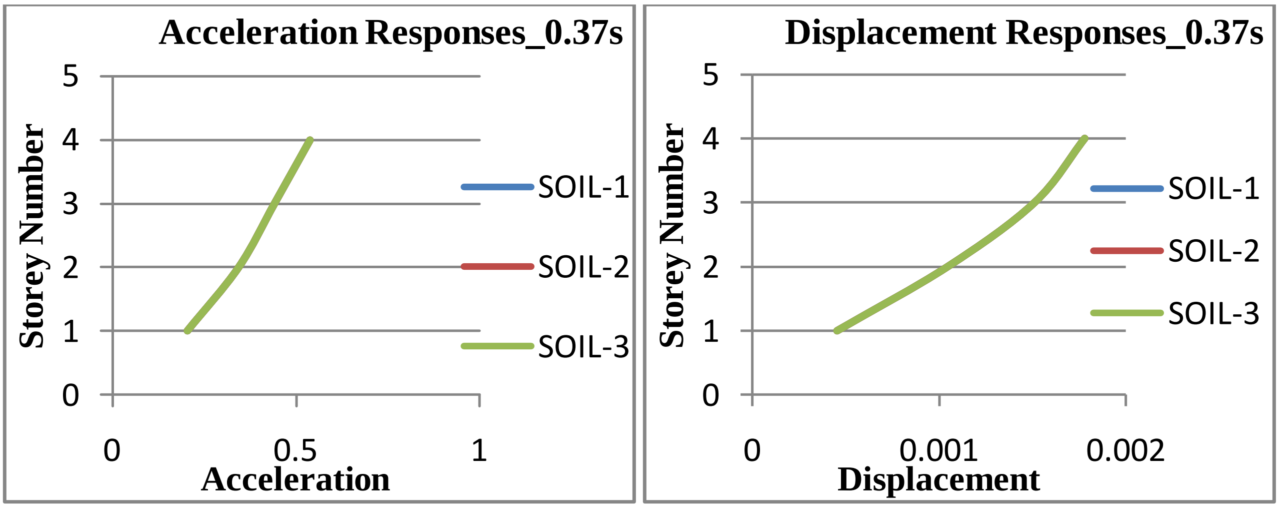


Figure 3: Acceleration and Displacement Response similar for all soil types.

Buildings with higher time period (i.e., lower frequencies) have peak response amplified when resting on soft soil strata. The amplification of response with decrease in stiffness of soil can be observed from the response plots (Figure 4). The range of amplification in response for symmetric buildings of time period ranging from 0.1 to 1.16 s resting on soft, medium soils are compared with respect to those resting on stiff soil. The variation in response obtained in the X and Y directions are given in Table 3. This is extended for buildings with asymmetry as well and their responses are presented in Figure 5.

Table 3: Table showing comparison of variation in responses of Stiff, medium and soft soil in X and Y directions for symmetric building.

(a)

No of Floors	Time Period_ Y-Direction	Time Period_ X-Direction	Percentage Variation_of_Acc_1_ X-Direction	Percentage Variation_of_Ac c _2_X-Direction	Percentage Variation_of_Ac c _2_Y-Direction	Percentage Variation_of_Ac c _2_Y-Direction
1	0.1366	0.099153	0	0	0	0
2	0.242967	0.184896	0	0	0	0
3	0.354969	0.276553	0	0	0	0
4	0.469136	0.370746	0	0	12.53698131	12.53698131
5	0.585024	0.46694	12.21625785	12.21625785	35.89735849	42.04981132
6	0.702678	0.565195	33.65281615	36.22371314	34.44843232	58.61041511
7	0.822268	0.665728	35.76093536	58.17005958	30.01266357	56.63993246
8	0.944001	0.768798	33.56427713	60.75290348	29.17773098	55.18725391
9	1.068099	0.874671	32.60840737	61.16783804	27.51237199	52.25635749
10	1.194784	0.983615	28.9483344	54.78113242	26.81039543	51.02193287

(b)

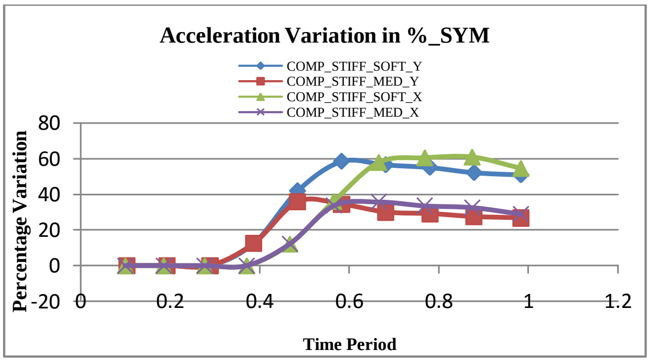
No of Floors	Time Period_ Y-Direction	Time Period_ X-Direction	Percentage Variation_of_Dis_1_ X-Direction	Percentage Variation_of_Dis _2_X-Direction	Percentage Variation_of_Dis _2_Y-Direction	Percentage Variation_of_Dis _2_Y-Direction
1	0.1366	0.099153	0	0	0	0
2	0.242967	0.184896	0	0	0	0
3	0.354969	0.276553	0	0	0	0
4	0.469136	0.370746	0	0	13.00323924	13.00323924
5	0.585024	0.46694	12.55526083	12.55526083	38.07636888	44.56051873
6	0.702678	0.565195	35.3113247	37.98579189	38.44380403	64.92795389
7	0.822268	0.665728	39.2400807	63.44989913	36.00328048	67.00382723
8	0.944001	0.768798	36.8510158	66.25282167	36.00639708	66.98652045
9	1.068099	0.874671	36.01061264	67.00434153	35.96370093	66.9560071
10	1.194784	0.983615	35.97390494	66.96178938	35.99010843	66.97736352

(c)

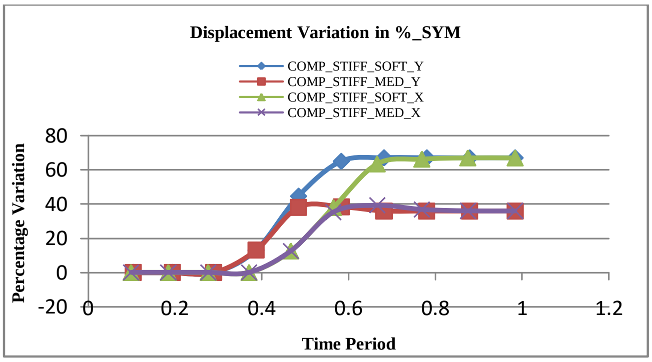
No of Floors	Time Period_ Y-Direction	Time Period_ X-Direction	Percentage Variation_of_Vel_1_ X-Direction	Percentage Variation_of_Ve l _2_X-Direction	Percentage Variation_of_Ve l _2_Y-Direction	Percentage Variation_of_Ve l _2_Y-Direction
1	0.1366	0.099153	0	0	0	0
2	0.242967	0.184896	0	0	0	0
3	0.354969	0.276553	0	0	0	0
4	0.469136	0.370746	0	0	12.75964392	12.75964392
5	0.585024	0.46694	12.45901639	12.45901639	37.79264214	44.14715719
6	0.702678	0.565195	35.36977492	37.94212219	38.14814815	64.44444444
7	0.822268	0.665728	39.14590747	63.34519573	35.66878981	66.24203822
8	0.944001	0.768798	36.89655172	66.20689655	35.49488055	66.2116041
9	1.068099	0.874671	35.78595318	66.55518395	35.66666667	66.33333333
10	1.194784	0.983615	35.52631579	66.30434783	35.48387097	65.94982079

Percentage variation 1- Stiff and medium
Percentage Variation 2- Stiff and soft.

The results from the asymmetric buildings depict variation in the time period of the fundamental mode in X and Y directions. This results in a lower time period along X-direction; this can be observed from the change in percentage variation between stiff and medium and stiff and soft soils for four storey building in X and Y directions.



(a)



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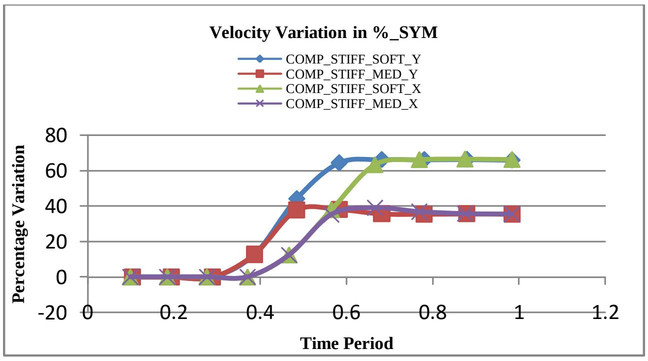
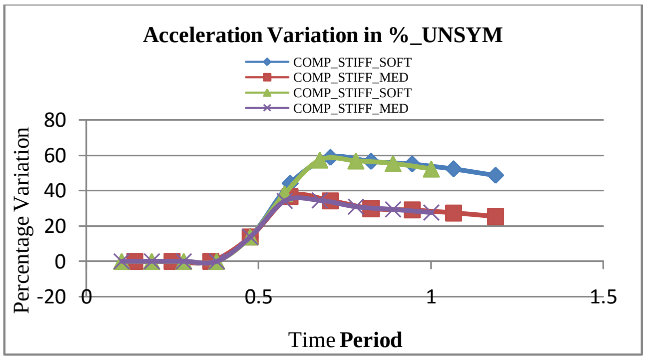


(c)

Figure 4: Plots showing comparison of variation in responses of Stiff, medium and soft soil in X and Y directions for symmetric building.



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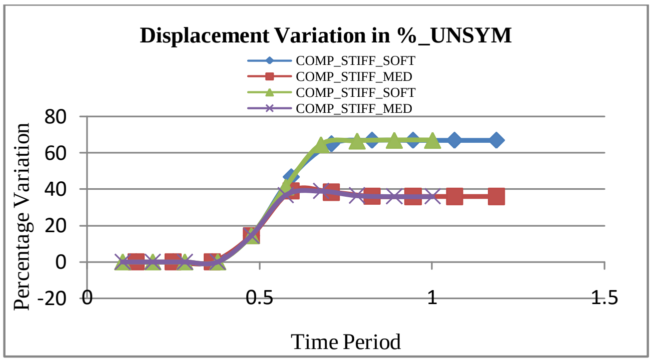

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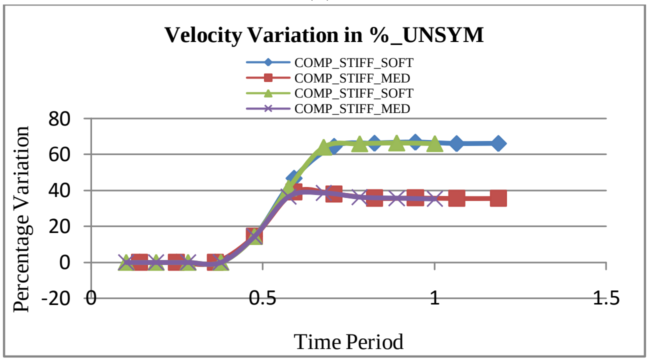

(c)

Figure 5: Plots showing comparison of variation in responses of Stiff, medium and soft soil in X and Y directions for unsymmetrical building.

CONCLUSIONS

1. It can be noted from the above responses that structural responses for buildings with shorter time period would have same response irrespective of the type of soil on which it is resting on.
2. The structures with lower frequencies should be carefully designed as the responses of the structure when rested on soft soil would have an amplified response.
3. It was observed that the acceleration, displacement, velocity responses were magnified by almost 1.35 times for medium soils and about 1.65 times for soft soils when compared to the response of that of the structures resting on stiff soils. So, careful analysis is required while considering soft and medium stiff soils.
4. The response in any direction is dependent on the period of the fundamental mode in the chosen direction.
5. The acceleration responses of buildings with lower time period have greater acceleration whereas displacement response is dominant for the buildings with higher frequency.

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