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Floor Response Spectra Generation for Seismic Design of Buildings

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ABSTRACT:

Response spectrum method and Time history analysis are widely used in the seismic design of buildings. In the case of large multistoried buildings the response at different levels vary due to different factors in dynamic load and lateral load, therefore it is necessary to determine the response at different floors for efficient design. In this paper a fifteen storied commercial building is subjected to an earthquake load histogram as in the case of Bhuj earthquake in Gujarat. The response spectrum is determined with SAP 2000 software and designed in accordance with IS 1893: 2002 (Part 1).

Keywords*:* - Response Spectrum, Seismic design, Bhuj earthquake.

I. INTRODUCTION

Response spectrum is the curve showing the maximum response versus the structural frequency relationship. Seismic design by this method generally is based on dynamic analysis of building. If you consider the multistoried buildings in the present generation the number of stories are much greater and to design the structure considering as a whole is quite uneconomical. Usually the buildings which have more than 10 stories, the column sections size are reduced as we go to from lower to top floors. The main advantage of generating the response spectrum is that a greater view of the response of each floors are obtained thereby we can design it accordingly. For this a specific building had to modelled with 15 stories and for the seismic anaylsis zone III was preferred, because Chennai being categorized under zone III. As far as the software is concerned SAP 2000 v15 is used for the spectral design and analysis as it is considered as one of the high end software available for structural design.

II. LITERATURE REVIEW

Saatcioglu and Naumoski[3] developed the design response spectra for six functional buildings (5 , 10 and 15 storeyed) and each building was moment resisting frame buildings considered in vancouver and ottawa and a total of the fifteen accelerograms were used for the seismic analysis. A computer software called the DRAIN-2DX was used for the analysis. These graphs give the peak value of the load. The result they obtained was that the higher floors showed higher amplification due the earthquake load and the difference in spectra are more profound for the low rise building. The response amplification relative to the ground excitations varied from floor to floor. The amplification was of the highest at the roof level and the amplification factor for roof is approximately 4.0 for 5 – storeyed buildings and, 3.0 for 10 storeyed buildings and 2.0 for 15-storeyed buildings. It decreases gradually going from roof level to the first storey level. Equations were developed in the project and they can also be used to generate floor design spectra from the UHS specified for a given location.

Antonov and Apostolov[2] studied the impact of a large aircraft on an NPP buildings. Different scenarios were considered and the impact was simulated at different levels of the building. Factors influencing the floor response spectra, as the non linearities of the impact area,load time function shape and impact velocity are pointed out and corresponding conclusions were arrived. For the damage assessment potential alternative motion parameters were used and a procedure for indirect assessment of the equipment capacity is also discussed. They used ANSYS software for detailed modeling of these buildings and the result obtained was that the highest intensity of the response obtained does not necessarily give conservative results for the locations having lower response.

Jiang and Gao[4] developed a new method for using the cosine transform to calculate the response spectrum from the strong motion earthquake. This proposed method has higher accuracy in displacement and velocity response spectra under the damping ratios of higher value. But in case of the acceleration response spectra the accuracy is comparatively lesser. The values of EI centro response spectra which is considered as a classical seismic record is calculated by the cosine transform are actually consistent with the exact method under damping ratios of different values. The only problem of this proposesd method is the accuracy of the acceleration spectrum at short periods. But this method is cost effective in terms of the computational load and it can implemented easily on a computer.

III. GEOMETRY AND MATERIAL PROPERTY

A fifteen storied reinforced concrete building was considered for the spectral analysis of the building. The geometry of the building is shown in figure 1. The structure comprises of fifteen floors with 4 bays in th X- direction and 3 bays in the Z – direction. The width of the bays are 3m and this is an open frame model.

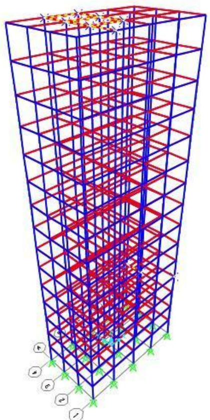

Fig 1: Fifteen storied 4 X 3 bay model.

Table 1 comprises of the details of the structure in a condensed form.

TABLE I GEOMETRY OF THE STRUCTURE

Description	Value
Height of the building.	45m
Width of the building	12m
Number of supports	20

The size of the beams and columns are to be determined the spectral analysis of each floors. The loads acting on each floors of the building are to be determined from the spectral graphs and each floor of the building is to be designed separately.

IV. LOADS

The load cases defined are linear static for the dead load case and both modal and response spectral load and assigned to the building. The accelerogram used were that of the ground motion data obtained from the Bhuj earthquake in 2001 with magnitude of 7.7 to simulate the response for the building under a similar scenario. This is done in addition to the static analysis. The linear time history analysis should be carried out to obtain the response spectrum curves. The acceleration time history of the earthquake is shown.

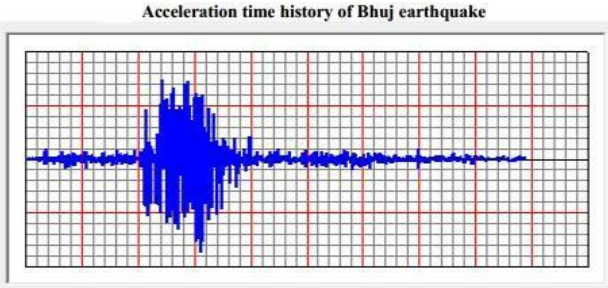

Fig 2 : Time history of Bhuj earthquake.

Details :

1. Magnitude : 7.7
2. Time period : 109.9s
3. Peak ground Accelaration : 1.0382m/s^2
4. Time taken for PGA : 46.940s
5. Time step : 0.005s

For the load pattern the Eccentricity ratio is taken as 0.05 and seismic zone is taken as Zone III therefore the zone factor is 0.3. The response reduction factor is taken as 5.

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IV. DESIGN

The grid space frame model is used for the spectral analysis. Moment resisting restraints are provided at the base of the structure

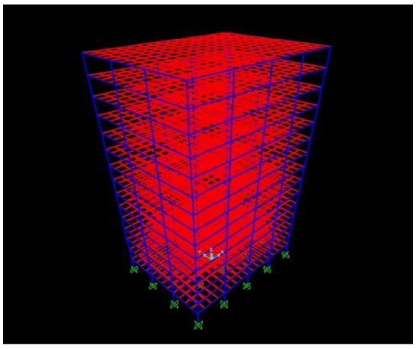

Fig 3 : Beams, Columns and mesh

Figure 3 shows the arrangement of the beams and columns which are to be designed for the optimum load cases.

V.ANALYSIS USING SAP 2000 V15

The model is analyzed using the software SAP 2000 V 15. First the building is to be modeled using the space grid pattern. The number of bays in each direction is given and the width of each bay is also specified from the software. The restraints also provided. The load patterns are specified from the define tool and the load cases and combinations are applied. The time history and the response spectrum functions are specified with the define tool. The bhuj accelerogram is added to load case with user time period option. The structure is analyzed and the results are obtained by the program.

VI .RESULTS AND DISCUSSION

The response spectrum analysis of the multistoried building is completed with the help of SAP 2000 V15 software and response spectra details are :

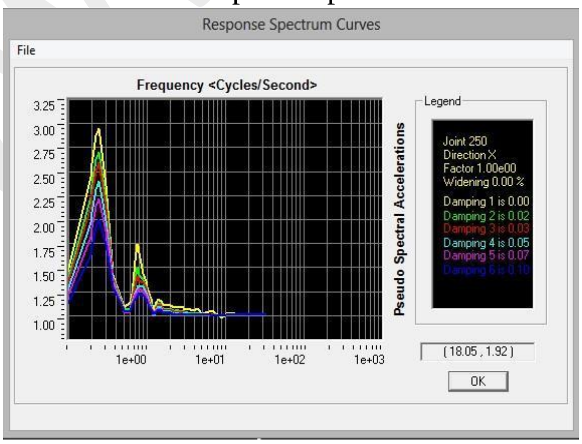

Fig 3 : Spectral Accelaration Curve

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The accelerations obtained from the spectral curves by performing the time history modal analysis in SAP has to be converted into deflections at each level of the building. These deflection are again used for determining the dimensions of the elemental structures that form the building namely, the beams and columns. The area of the reinforcement and the other basic details conforming to the Indian code can also be determined using the software or by theoretical equations that are obtained from the manual spectral analysis.

The peak response of the system is obtained at the lesser frequencies or cycles from the earthquake ground motion data. The spectral velocities are also determined from the program.

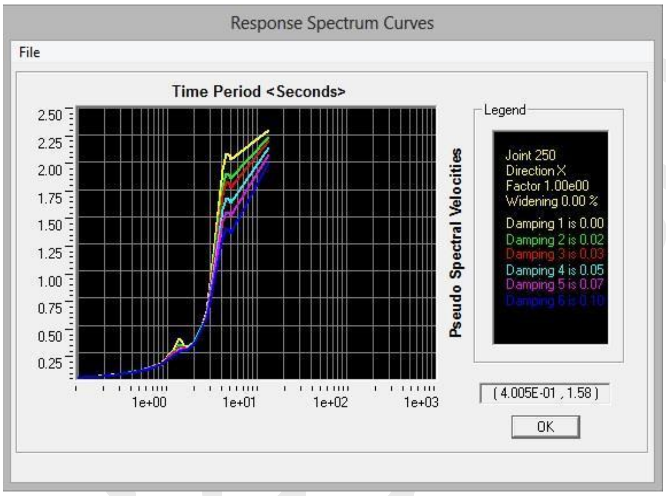

Fig 4 : Spectral Velocity curve.

The modal displacement of the buildings is also determined from the analaysis. There are 15 modes used. Fig 5 shows the mode 3 displacement of the structure.

TABLE III NODAL DISPLACEMENT

Table 3 shows the maximum nodal displacement in the building corresponding to the load cases

	Node	Horizontal X (mm)	Horizontal Y(mm)	Resultant(mm)
Max X	1172	23.24	-14.45	50.75
Max Y	663	-16.76	16.7	43.65
Max Z	1146	16.33	-33.34	61.53

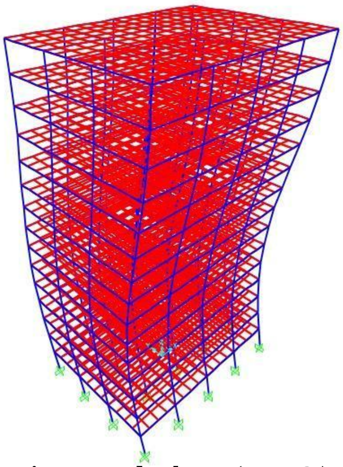

Fig 5 : Mode shape (Type 3)

TABLE III MODAL LOAD PARTICIPATION RATIOS

Table 2 compares the modal load used for the analysis and the participation of the modal load through each axis.

Axis	Static Percent	Dynamic Percent
UX	99.79	91.676
UY	99.99	99.853
UZ	3.376	4.06

VII. CONCRETE DESIGN

The usual design practice is that the columns decreases in dimension as we move towards the top floors. But in case of some buildings, pipelines and certain amenities are to be provided at any of the top floors. So spectral design helps in giving that additional safety factor while designing considering that particular floor. The optimum sections are selected based on the response from each levels of the building. The structure is divided into 3 parts of 5 floor each.

TABLE IV DIMENSIONS

Table 3 shows the different dimensions adopted for columns and beams from the spectral curves and the displacements derived.

Level	Beams(m)	Columns(m)
1-5	0.5X0.3	0.6X0.6
6-10	0.45X0.3	0.6X0.55
11-15	0.45X0.3	0.6X0.45

VIII. CONCLUSIONS

From the obtained results and data, it is preferable that the structure should be designed with the help of the response data obtained from the spectral analysis which gives scope for a more economical construction of the multistoried building. The addition of the ground motion data strengthens the design parameters to such an extent that it could withstand an earthquake upto a scale of 8. The different levels of a building had to be designed differently in accordance with optimum section with can withstand the responses at that particular level. Thus this method can be widely adopted for safe and sound construction and it also has a scope for optimization pertaining to the Indian conditions.

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