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Response Spectrum Analysis for Regular Multistory Building by Using SAP 2000

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***Abstract*: Earthquake is the most disastrous and unpredictable natural phenomenon which causes huge destruction to human lives as well as infrastructure. Seismic forces generated during earthquake loads to severe damage to structural elements and sometimes structural failure. Therefore, analysis and design of the building considering the effect of lateral forces is very important aspect. In the present study, a G+15 storied building was analyzed through the response spectrum analysis using SAP 2000 software. Response spectrum analysis (RSA) is a linear dynamic analysis method which measures the structural response to seismic events. The variation of acceleration, velocity and displacement responses with respect to change in period of the structure was identified, model load participating percentage and model mass participating factor.**

***Keywords*: Response spectrum analysis; Sap2000; Residential building; Acceleration; velocity; displacement analysis.**

1. Introduction

A large portion of India is susceptible to damaging levels of seismic hazards. Hence, it is necessary to take in to account the seismic load for the design of structures. In buildings the lateral loads due to earthquake are a matter of concern. These lateral forces can produce critical stresses in the structure, induce undesirable stresses in the structure, induce undesirable vibrations or cause excessive lateral sway of the structure. Sway or drift is the magnitude of the lateral displacement at the top of the building relative to its base. Traditionally, seismic design approaches are stated, as the structure should be able to ensure the minor and frequent shaking intensity without sustaining any damage, thus leaving the structure serviceable after the event.

The structure should withstand moderate level of earthquake ground motion without structural damage, but possibly with some structural as well as non-structural damage. This limit state may correspond to earthquake intensity equal to the strongest either experienced or forecast at the site. In present study the results are studied for response spectrum method. The main parameters considered in this study to compare the seismic performance of different models are base shear and time period.

A. *Seismic Analysis of Structure*

In our study of the structure the analysis is being done using the response spectrum method in SAP 2000 v14 and modal mass analysis.

1) *Response Spectrum Method*

In order to perform the seismic analysis and design of a structure to be built at a particular location, the actual time history record is required. However, it is not possible to have such records at each and every location. Further, the seismic analysis of structures cannot be carried out simply based on the peak value of the ground acceleration as the response of the structure depend upon the frequency content of ground motion and its own dynamic properties. To overcome the above difficulties, earthquake response spectrum is the most popular tool in the seismic analysis of structures. There are computational advantages in using the response spectrum method of seismic analysis for prediction of displacements and member forces in structural systems. The method involves the calculation of only the maximum values of the displacements and member forces in each mode of vibration using smooth design spectra that are the average of several earthquake motions. It will deal with response spectrum method and its application to various types of the structures. The codal provisions as per IS: 1893 (Part 1)-2002 code for response spectrum analysis of multi-story building is also summarized.

2) *Modal Analysis Method*

Modal analysis is the study of the dynamic properties of structures under vibration excitation. Modal analysis is the field of measuring and analyzing the dynamic response of structures and or fluids when excited by an input. In structural engineering, modal analysis uses the overall mass and stiffness of a structure to find the various periods at which it will naturally resonate. These periods of vibration are very important to note in earthquake engineering, as it is imperative that a building's natural frequency does not match the frequency of expected earthquakes in the region in which the building is to be constructed. If a structure's natural frequency matches an earthquake's frequency, the structure may continue to resonate and experience structural damage. Although modal analysis is usually carried out by computers, it is possible to hand-calculate the period of vibration of any high-rise building through idealization as a fixed-ended cantilever with lumped masses.

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B. *Objectives*

- Modeling – The modeling of Residential building located in seismic zone III will be done using SAP 2000.
- To find out the Peak response (deformation, velocity, acceleration) of the structure involving response spectral curve.
- To review the response of the structure how it may behave during earthquake before constructing it.

2. Literature Review

Varalakshmi et al., Investigated the design & analysis of multi-storey G+4 building at Kukatpally, Hyderabad, India. The study includes design & analysis of columns, beams, footings & slabs by using well known civil engineering software named as SAP2000. Test on safe bearing capacity of soil was obtained. L. G. Kalukar et al., in the design & analysis of multi-storeyed G+4 building using composite structure at earthquake zone 3. A 3D modelling & analysis of the structure are carried out with the help of SAP 2000 software. Equivalent static method of analysis & response spectrum analysis method are used for analysis of both composite & RCC structures. P. Jayachandran et al., Investigated in The design & analysis of multistoried G+4 building at Salem, Tamilnadu, India. The study includes design & analysis of footings, columns, beams, and slabs by using two software's named as SAP2000 & AUTOCAD.

Table 1
Building Specifications

Component	Value
Structure	SMRF
Number of stories	16
Each Storey height	3.5 M
Type of building	Residential
Seismic Zone	III

Table 2
Material Properties

Component	Value
Grade of concrete	M25 & M30
Grade of steel	Fe 500
Density of reinforcement concrete	25 kN/m^2
Density of steel	78.5 kN/m^2

Table 3
Member Properties

Component	Value
Beam grade	M25
Beam size (All storey's)	0.23m x 0.45m
Column grade	M30
Column sizes	0.23m x 0.65m
Slab grade	M25
Slab thickness	150mm

Table 4
Seismic Properties

Component	Value
Live Load	3.0 kN/m^2
Zone factor(Z)	0.16
Importance factor(I)	1
Response reduction factor	5
Soil type	II
Damping factor	0.05

3. Modelling Using SAP 2000

1) *Building Specifications*

The building is 16 storey's SMRF framed with live load of 3 kN/m^2 are to be analyzed in seismic zone III. The properties of the considered building configurations in the present study are summarized below:

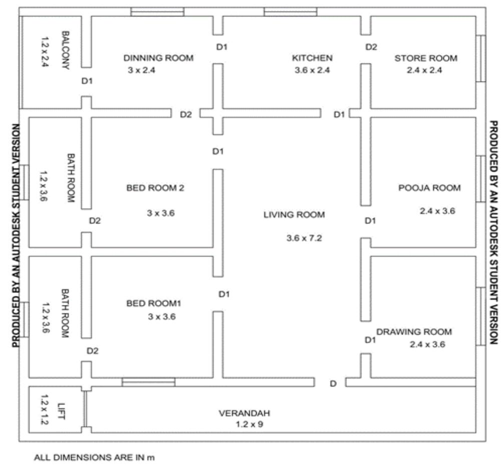

Fig. 1. Ground Floor Plan

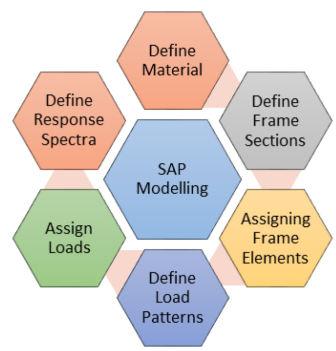

Fig. 2. SAP Modelling

2) *Modelling Procedure Using SAP 2000*

Step by step procedure to draw modeling in sap2000:

1. Open the SAP-2000 SAP program
2. Check the units of the model in the drop-down box in lower right-hand side corner of the SAP-2000 window, click the drop-down box to set units to kN-m
3. Click the File menu > New model command.
4. The next form of Grid System and Story Data Definition will be displayed after you select NO button set the grid line and spacing between two grid lines. Set the story height data using Edit Story Data command.
5. Click on grid only. A new window of SAP2000 will be displayed.
6. Edit grid data and storey data as per the structural framing plan.
7. Click the Define menu > Material Properties.
8. SAP2000 Define section columns and beams using Define > Frame section properties.
9. Define wall/slab/deck To define a slab as membrane element and one way slab define using special one way load distribution.

10. Generate the model Draw beam using Create Line Command and draw column using Create Column command Above creating option used to generate the model as shown in below figure.
11. Assign support condition drop-down box in the lower right-hand corner of the SAP2000 window, Select only bottom single storey level to assign fixed support using assign > Joint/Point>Restrain (Support).

3) Analyze the Model

a) Click on Analyze > Run analysis in order to run the analysis. Dialog box will display.
b) Click on Run now to run analysis.

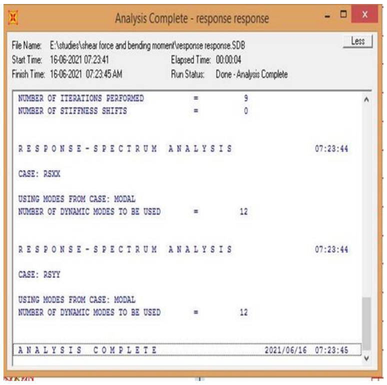

Fig. 3. Model Analysis

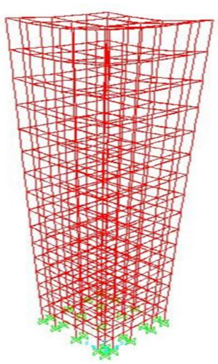

Fig. 4. Deformed Shape of Building

4) Base shear

Table 5
Base Shear Calculations

FLOOR	W_i	h_i	Whi	$Whi^2/\Sigma wihi^2$	ai	Vi
16	1671.26	56	5241071.36	0.124	101.828	101.828
15	2363.26	52.5	6513735.375	0.158	126.684	228.512
14	2363.26	49	5674187.26	0.138	110.648	339.16
13	2363.26	45.5	4892539.015	0.119	95.414	434.574
12	2363.26	42	4168790.64	0.101	80.981	515.555
11	2363.26	38.5	3502942.135	0.085	68.153	583.708
10	2363.26	35	2894993.5	0.07	56.126	639.834
9	2363.26	31.5	2344944.735	0.057	45.702	685.536
8	2363.26	28	1852795.84	0.045	36.081	721.617
7	2363.26	24.5	1418546.815	0.034	27.261	748.878
6	2363.26	21	1042197.66	0.025	20.045	768.923
5	2363.26	17.5	723748.375	0.018	14.432	783.355
4	2363.26	14	463198.96	0.011	8.82	792.175
3	2363.26	10.5	260549.415	0.006	4.811	796.986
2	2363.26	7	115799.74	0.003	2.405	799.391
1	2363.26	3.5	28949.935	0.001	0.802	800.193
			41138990.76			

4. Results

1) Model Period and Frequencies

Table 6
Model Period Frequencies

TABLE: Modal Periods And Frequencies				
Output Case	Step Type	Sternum	Period	Frequency
Text	Text	Unit less	Sec	Cyc/sec
MODAL	Mode	1	1.506433	0.66382
MODAL	Mode	2	0.917358	1.0901
MODAL	Mode	3	0.898051	1.1135
MODAL	Mode	4	0.493159	2.0277
MODAL	Mode	5	0.297052	3.3664
MODAL	Mode	6	0.282311	3.5422
MODAL	Mode	7	0.274056	3.6489
MODAL	Mode	8	0.199714	5.0072
MODAL	Mode	9	0.168519	5.9341
MODAL	Mode	10	0.154813	6.4594
MODAL	Mode	11	0.14442	6.9243
MODAL	Mode	12	0.127289	7.8562

2) Model Load Participation Ratios

Table 7
Model Load Participation Ratios

TABLE: Modal Load Participation Ratios			
Output Case	Item	Static	Dynamic
Text	Text	Percent	Percent
MODAL	UX	93.9461	99.8842
MODAL	UY	98.994	99.7152
MODAL	UZ	0.004	0.1061

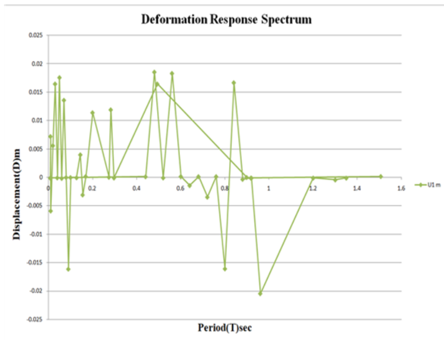

Fig. 5. Deformation of Response Spectrum

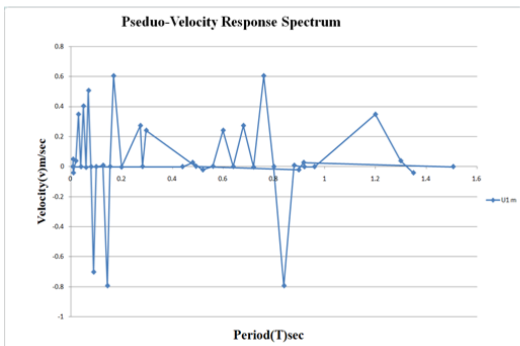

Fig. 6. Pseudo Velocity Response Spectrum

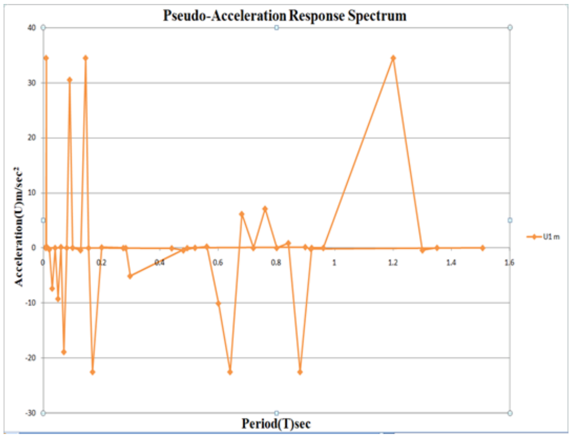

Fig. 7. Pseudo Acceleration Response Spectrum

5. Conclusion

1. The response in any direction is dependent on the period of the fundamental mode in the chosen direction.
2. As the modal mass participating factor is more than 75% in the higher mode, the considered structure is stiff for earthquake excitation.
3. The joint displacement in X- direction is found more as compared to Y and Z directions due to the fact that the earthquake motion was applied in X-direction. This shows the uplift in Y- direction and displacement in Z-direction.
4. The frequency in first mode of vibration is found between 0.66 cyc/sec, from first mode to higher mode frequency is increases whereas time period is reduced.
5. Dynamic load having the higher model load participation percentage.

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