Analysis Of A Multistory Building By Response Spectrum Method And Seismic Coefficient Method

Sonali G. Yeole[1], Prof. M. R. Wagh[2]
[1, 2] Department of Civil Engineering
[1, 2] Yeshwantrao Chavan College of Engineering, Nagpur

Abstract- *In this project, the earthquake response of symmetric multi-storied building by two methods will be studied. The methods include seismic coefficient method and response spectrum method as recommended by IS Code 1893-2002 part I, where natural frequencies, period, base shear, lateral forces are calculated by STAAD-PRO software as well as manually by seismic coefficient method. The methods include seismic coefficient method (by empirical formula) and modal analysis using response spectrum method of IS Code in which the stiffness matrix of the building corresponding to the dynamic degrees of freedom is generated by considering the building as shear building. The responses obtained by above methods in zones III, IV and V as mentioned in IS code will be studied. Test results on Base Shears, Lateral Forces and Storey Moments will be compared.*

Keywords- Earthquake analysis, Modal analysis, Response spectrum analysis, Seismic coefficient method, SRSS (Square Root Sum of Squares).

I. INTRODUCTION

Each tall building represents a significant investment and as much tall building analysis is generally performed using more sophisticated techniques and methodologies. Structural engineer's role becomes especially challenging when the building facility is located in a seismic zone. So it is important to estimate and stipulate these lateral forces on the structure in order to design the structure to resist an earthquake. 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 structures withstand moderate level of earthquake ground motion without structural damage, but possibly with some structural as well as non-structural damage. In present study, the earthquake analysis of (G+10) storied building will be done by both methods i.e. Seismic Coefficient Method and Response Spectrum Method. In Response Spectrum Method, the Time Periods, Natural Frequencies and Mode Shape Coefficients are calculated by STAAD-Pro program then remaining process will be done by manually. The modal combination rule for Response Spectrum Analysis is SRSS (Square Root Sum of Squares). The main parameters considered in this study to compare the seismic performance of the zone III, zone IV, zone V and having medium soil and hard soil are Base Shear, Story Moment and Lateral Forces.

II. STUDY OF RELEVANT IS CODE

1. RESPONSE SPECTRUM METHOD

As per IS 1893 (part1)-2002, Response Spectrum Method is summarized in following steps:-

7.8.4.5 Buildings with regular, or nominally irregular plan configurations may be modeled as a systems of masses lumped at the floor levels with each mass having one degree of freedom, that of lateral displacement in the direction under consideration. In such a case; the following expressions shall hold in the computation of the various quantities:

a) Modal mass (Mk)–

Modal mass of the structure subjected to horizontal or vertical as the case may be, ground motion is a part of the total seismic mass of the Structure that is effective in mode k of vibration. The modal mass for a given mode has a unique value, irrespective of scaling of the mode shape.

$$Mk = \frac{\left[\sum_{i=1}^{n} Wi\ \emptyset ik\right]^2}{g\sum_{i=1}^{n} Wi\ (\emptyset ik)^2}$$

Where,

g = Acceleration due to gravity,

Øik = Mode shape coefficient at floor i in mode k,

Wi = Seismic weight of floor i

b) Modal Participation factor (Pk)–

Modal participation factor of mode k of vibration is the amount by which mode k contributes to the overall vibration of the structure under horizontal or vertical earthquake ground motions. Since the amplitudes of 95 percent mode shape can be scaled arbitrarily, the value of this factor depends on the scaling used for the mode shape.

$$Pk = \frac{\sum_{i-1}^{n} Wi\ \emptyset ik}{g\sum_{i=1}^{m} Wi\ (\emptyset ik)^{2}}$$

c) Design lateral force at each floor in each mode–

The peak lateral force (Qik) at floor i in Mode k is given by:-

$$Q = Ak\ \phi ik\ Pk\ Wi$$

Where, Ah = Design horizontal spectrum value using natural period of vibration (Tk) of mode k.

$$Ah = \frac{Z}{2}\frac{I}{R}\frac{Sa}{G}$$

Where,

Z = zone factor for the maximum considered earthquake,

I = Importance factor depending upon the functional use of the structures,

R = Response Reduction factor

Sa/g=Average response acceleration coefficient for rock or soil sites as given by response spectra and based on appropriate natural periods and damping of the structure.

d) Storey shear forces in each mode– The peak shear force (Vik) acting in storey i in mode k is given

$$Vik = \sum_{j=i+1}^{n} Qik$$

e) Storey shear force due to all modes considered- The peak storey shear force (Vi) in storey i due to all modes considered is obtained by combining those due to each mode as per SRSS. If the building does not have closely spaced modes, than the peak response quantity due to all modes considered shall be obtained as per Square Root of Sum of Square method Dynamic analysis may be performed either by time history method or by the response spectrum method. However in either method, the design base shear VB shall be compared with a base shear (Vb) calculated using a fundamental period Ta. When VB is less than all the response quantities shall be multiplied by Vb/VB.

7.8.4.4 Modal combination

a) Square Root of Sum of Squares (SRSS) Method-

If the building does not have closely-spaced modes, then the peak response quantity (λ) due to all modes considered shall be obtained as-

$$\lambda = \sqrt{\sum_{k=1}^{r}(\lambda k)^{2}}$$

Where

λk = Absolute value of quantity in mode k, and

r = Number of modes being considered

f) Lateral Forces at Each Storey Due to All Modes Considered- The design lateral forces. Froof and Fi , at roof and at floor i,

Froof = Vroof , and

Fi = Vi – Vi+1

2. SEISMIC COEFFICIENT METHOD

As per IS 1893 (part1)-2002, Seismic Coefficient Analysis Procedure is summarized in following steps: -

6.4 Design Spectrum

6.4.2 The design horizontal seismic coefficient Ah for a structure shall be determined by the following expression:

$$Ah = \frac{Z}{2}\frac{I}{R}\frac{Sa}{g}$$

Provided that for any structure with T <0.1 s, the value of Ah will not be taken less than Z/2 whatever be the value of I/R

Where

Z = Zone factor

I = Importance factor

R = Response reduction factor

Sa/g = average acceleration coefficient

7.4 Seismic Weight

7.4.1 Seismic Weight of Floors

The seismic weight of each floor is its full dead load plus appropriate amount of imposed load, as specified in 7.3.1 and 7.3.2. While computing the seismic weight of each floor, the weight of columns and walls in any storey shall be equally distributed to the floors above and below the storey.

7.4.2 Seismic Weight of Building

The seismic weight of the whole building is the sum of the seismic weights of all the floors.

7.4.3 Any weight supported in between storeys shall be distributed to the floors above and below in inverse proportion to its distance from the floors.

7.5 Design Lateral Force

7.5.1 Buildings and portions there of shall be designed and constructed to resist the effects of design lateral force specified in 7.5.3 as a minimum.

7.5.2 The design lateral force shall first be computed for the building as a whole. This design lateral force shall then be distributed to the various floor levels. The overall design seismic force thus obtained at each floor level, shall then be distributed to individual lateral load resisting elements depending on the floor diaphragm action.

7.5.3 Design Seismic Base Shear

The total design lateral force or design seismic base shear (Vb) along any principal direction of the building shall be determined by the following expression: -

$VB = Ah \times W$

Where,

Ah = Design horizontal acceleration spectrum value as per 6.4.2, using the fundamental natural period T as per 7.6 in the considered direction of vibration, and

W = Seismic weight of the whole building. 7.4.2

7.6 Fundamental Natural Period

7.6.1 The approximate fundamental natural period of vibration (Ta), in seconds, of a moment-resisting frame building without brick infill panels may be estimated by the empirical expression:

Ta = 0.075 h0.75 for RC frame building

= 0.085 h0.75 for steel frame building

Where,

h = Height of building, in m. This excludes the basement storeys, where basement walls are connected with the ground floor deck or fitted between the building columns. But it includes the basement storeys, when they are not so connected.

7.6.2 The approximate fundamental natural period of vibration (Ta), in seconds, of all other buildings, including moment-resisting frame buildings with brick infill panels, may be estimated by the empirical expression:

$$Ta = \frac{0.009\,h}{\sqrt{d}}$$

Where,

h = Height of building, in was defined in7.6.1; and

III. METHODOLOGY

1. ANALYSIS OF (G+10) BUILDING USING STAAD. Pro

Step-1: Creation of nodal points. Based on the column positioning of plan we entered the node points into the STAAD file.

Step-2: Representation of beams and columns. By using add beam command we had drawn the beams and columns between the corresponding node points.

Step-3: 3D view of structure. Here we have used the Transitional repeat command in Y direction to get the 3D view of structure.

Step-4: Supports and property assigning. After the creation of structure the supports at the base of structure are specified as fixed. Also the materials were specified and cross section of beams and columns members was assigned.

Step-5: 3D rendering view. After assigning the property the 3d rendering view of the structure can be shown.

Step-6: Assigning of seismic loads. In order to assign Seismic loads firstly we have defined the seismic loads according to the code IS 1893:2002 with proper floor weights. Loads are added in load case details in +X,-X, +Z,-Z directions with specified seismic factor.

Step-7: Assigning of dead loads, live load. Dead loads are calculated as per IS 875 PART 1 Step - 8: Adding of load combinations. After assigning all the loads, the load combinations are given with suitable factor of safety as per IS 875 PART 5.

Step-8: Assigning RESPONSE SPECTRUM FACTOR as per IS 1893:2002 PART 1.

Step-9: Analysis. After the completion of all the above steps we have performed the analysis and checked for errors.

Step-10: Design of Beam, Column and check for reinforcement details.

2. SEISMIC COEFFICIENT METHOD

Step - 1: Calculation of Dead load, Live load and Floor finish of the structure.

Step - 2: Calculation of seismic weight on each floors and then total seismic weight.

Step - 3: Calculation of Fundamental time period.

- In X direction
- In Y direction

Step - 4: Calculation of horizontal seismic coefficient. (Ah)
- In zone III, IV and V
- In medium soil and hard soil

Step - 5: Calculation of Design Seismic Base Shear.
Step - 6: Calculation of Design lateral force at each floor.
Step – 7: Calculation of Storey moment at each floors.

IV. MODELLING

A (G+10) RCC multi-story structure is considered for the study. Modeling and analysis of the structure is done on STAAD Pro software.

Length in X-direction = 16 m
Length in Z direction = 16 m
Beam Size = 400 mm × 450 mm
Column Size = 500 mm × 550 mm
Support Condition = Fixed
Grade of Steel and Concrete = M20 and Fe415
Seismic Zone = III, IV and V
Floor Height = 3.2 m
Depth of foundation = 3 m
Thickness of Slab = 0.15 m

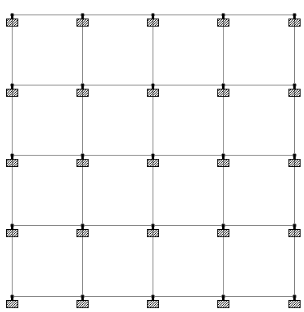

Figure 1. Plan of Structure

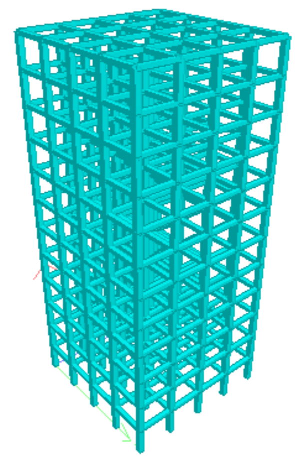

Figure 2. Modeling of Structure

V. RESULTS

The structure is analyzed by the STAAD Pro. Software using RESPONSE SPECTRUM METHOD, The results are as follows-Headings, or heads, are organizational devices that guide the reader through your paper. There are two types: component heads and text heads.

Table 1. Time Period, Natural Frequency and Mode shapes

Mode	Frequency	Time Period (sec)
1	0.433	2.308
2	0.433	2.255
3	0.504	1.984
4	1.332	0.751
5	1.368	0.731
6	1.541	0.649
7	2.335	0.428
8	2.338	0.428
9	2.414	0.414
10	2.661	0.376
11	2.694	0.371
12	3.405	0.294

For Seismic zone III, IV & V, Medium soil condition

Table 2. Lateral Force

STOREY	SCM	RSM	SCM	RSM	SCM	RSM
	III, MS	III MS	IV, MS	IV, MS	V, MS	V, MS
11	317.79	324.60	476.48	486.87	714.82	730.93
10	305.86	268.22	458.58	411.62	678.98	617.97

9	247.67	187.41	371.34	286.90	557.09	430.73
8	195.45	138.92	293.04	192.93	439.63	289.64
7	149.20	112.20	223.70	157.19	335.60	236.00
6	110.40	92.54	165.53	151.75	248.34	227.82
5	74.60	86.88	111.85	138.70	167.80	208.23
4	49.23	89.61	73.82	123.08	110.74	184.78
3	26.85	90.45	40.26	129.02	60.40	193.70
2	11.93	91.63	17.89	143.54	26.84	215.50
1	2.98	79.39	4.47	121.36	6.71	182.20
0	0.00	35.10	0.00	50.73	0.00	76.15

For Seismic zone III, IV & V, Hard Soil Condition

Table 3. Lateral Force

STOREY	SCM	RSM	SCM	RSM	SCM	RSM
	III, MS	III MS	IV, MS	IV, MS	V, MS	V, MS
11	220.66	254.48	331.00	381.98	496.29	573.21
10	212.38	205.90	318.57	309.04	477.65	463.78
9	171.97	131.00	257.96	196.64	386.78	295.08
8	135.71	81.04	203.57	121.63	305.23	182.53
7	103.60	73.59	155.40	110.46	233.00	165.76
6	76.66	81.44	114.99	122.25	172.42	183.45
5	51.80	72.56	77.70	108.90	116.50	163.60
4	34.18	55.00	51.28	82.56	76.89	123.72
3	18.64	54.97	27.97	82.50	41.94	123.81
2	8.288	69.570	12.432	104.43	18.64	156.71
1	2.072	65.260	0.108	97.95	4.66	146.99
0	0.000	28.570	0.000	42.89	0.00	64.36

For Seismic Zone III, IV & V, Medium Soil Condition

Table 5. Story Shear

STOREY	SCM	RSM	SCM	RSM	SCM	RSM
	III, MS	III MS	IV, MS	IV, MS	V, MS	V, MS
11	317.796	324.600	476.481	486.87	714.828	730.93
10	623.656	592.820	935.066	898.49	1402.808	1348.90
9	871.328	780.230	1306.408	1185.39	1959.904	1779.63
8	1066.780	919.150	1599.455	1378.32	2399.540	2069.27
7	1215.980	1031.350	1823.155	1535.51	2735.140	2305.27
6	1326.388	1123.890	1988.693	1687.26	2983.483	2533.09
5	1400.988	1210.770	2100.543	1825.96	3151.284	2741.32
4	1450.224	1300.380	2174.364	1949.04	3262.032	2926.10
3	1477.080	1390.830	2214.630	2078.06	3322.440	3119.80
2	1489.016	1482.460	2232.526	2221.60	3349.288	3335.30
1	1492.000	1561.850	2237.000	2342.96	3356.000	3517.50
0	1492.000	1596.950	2237.000	2393.69	3356.000	3593.65

For Seismic Zone III, IV & V, Hard Soil Condition

Table4. Story Shear

STOREY	SCM	RSM	SCM	RSM	SCM	RSM
	III, MS	III MS	IV, MS	IV, MS	V, MS	V, MS
11	220.668	254.480	331.002	381.980	496.290	573.21
10	433.048	460.380	649.572	691.020	973.940	1036.99
9	605.024	591.380	907.536	887.660	1360.720	1332.07
8	740.740	672.420	1111.110	1009.290	1665.950	1514.60
7	844.340	746.010	1266.510	1119.750	1898.950	1680.36
6	921.004	827.450	1381.506	1242.000	2071.370	1863.81
5	972.804	900.010	1459.206	1350.900	2187.870	2027.41
4	1006.992	955.010	1510.488	1433.460	2264.760	2151.13
3	1025.640	1009.980	1538.460	1515.960	2306.700	2274.94
2	1033.928	1079.550	1550.892	1620.390	2325.340	2431.65
1	1036.000	1144.810	1554.000	1718.340	2330.000	2578.64
0	1036.000	1173.380	1554.000	1761.230	2330.000	2643.00

For Seismic Zone III, IV & V, Medium Soil Condition

Table 6. Story Moment

STO	SCM	RSM	SCM	RSM	SCM	RSM
	III, MS	III MS	IV, MS	IV, MS	V, MS	V, MS

RE Y						
11	1016.947	1038.720	1524.739	1557.984	2287.450	2338.976
10	3012.646	2935.744	4516.950	4433.152	6776.436	6655.456
9	5800.896	5432.480	8697.456	8226.400	13048.129	12350.272
8	9214.592	8373.760	13815.712	12637.024	20726.657	18971.936
7	13105.728	11674.080	19649.808	17550.656	29479.105	26348.800
6	17350.170	15270.528	26013.626	22949.888	39026.551	34454.688
5	21833.332	19144.992	32735.364	28792.960	49110.660	43226.912
4	26474.049	23306.208	39693.329	35029.888	59549.162	52590.432
3	31200.705	27756.864	46780.145	41679.680	70180.970	62573.792
2	35965.556	32500.736	53924.219	48788.800	80898.692	73246.752
1	40739.956	37498.656	61082.619	56286.272	91637.892	84502.752
0	40739.956	42608.896	61082.619	63946.080	91637.892	96002.432

For Seismic Zone III, IV & V, Hard Soil Condition

Table 7. Story Moment

STOREY	SCM III, MS	RSM III MS	SCM IV, MS	RSM IV, MS	SCM V, MS	RSM V, MS
11	706.138	814.336	1059.206	1222.360	1588.128	1834.272
10	2091.892	2287.552	3137.836	3433.600	4704.736	5152.640
9	4021.969	4179.968	6041.951	6274.112	9059.040	9415.264
8	6398.337	6331.712	9597.503	9503.840	14390.080	14261.984
7	9100.225	8718.944	13650.335	13087.040	16289.030	19639.136
6	12047.438	11366.784	18071.154	17061.440	22917.141	25603.328
5	15160.411	14246.816	22740.619	21384.320	29918.598	32091.040
4	18382.785	17302.848	27574.175	25971.392	37166.182	38974.656
3	21664.833	20534.784	32497.247	30822.464	44547.622	46254.464
2	24973.430	23989.344	37460.101	36007.712	51988.710	54035.744
1	28288.603	27652.736	42432.901	41506.400	59444.710	62287.392
0	28288.603	31407.552	42432.901	47142.336	59444.710	70744.992

COMPARATIVE GRAPHS

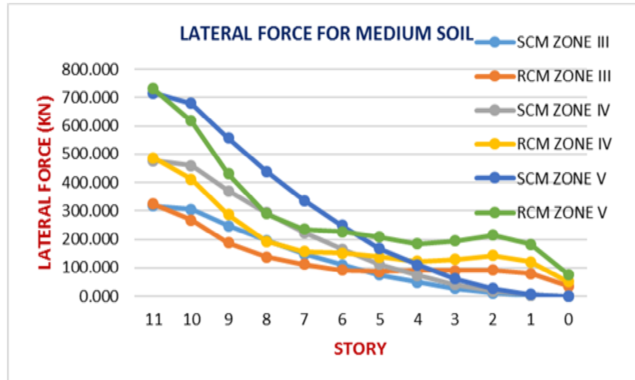

Figure 3. Lateral Force for Medium Soil

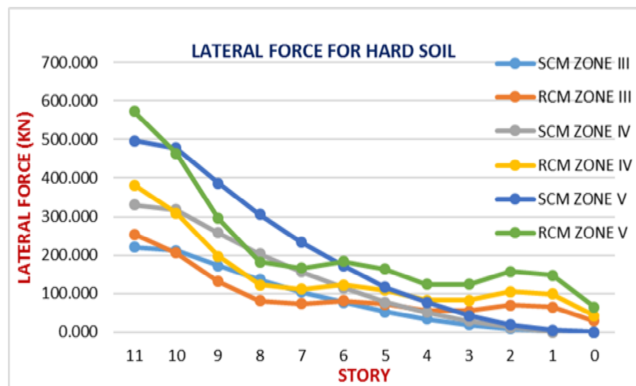

Figure 4. Lateral force for Hard Soil

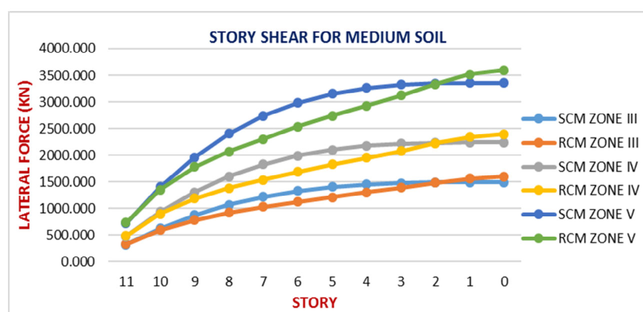

Figure 5. Story Shear for Medium Soil

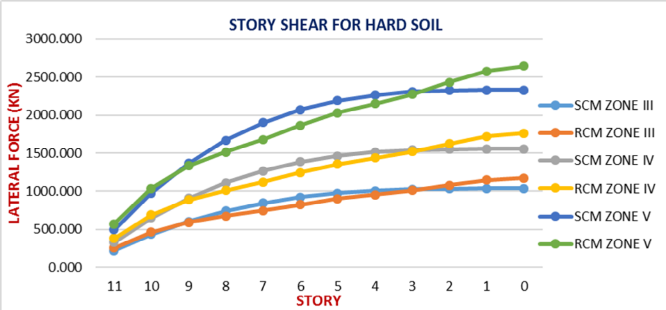

Figure 6. Story Shear for Hard Soil

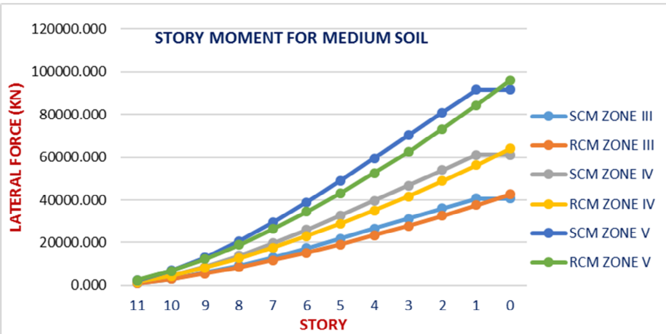

Figure 7. Story Moment for Medium Soil

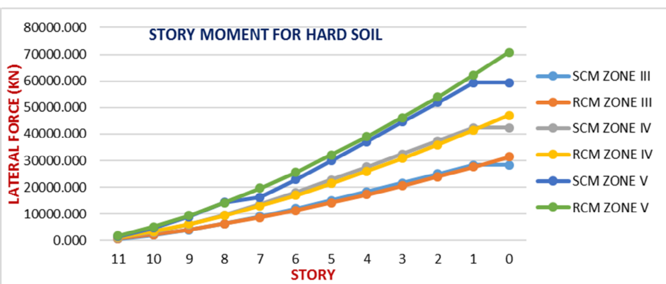

Figure 7. Story Moment for Hard Soil

VI. CONCLUSION

- The Seismic Coefficient Method is Conservative at Top floors compared to Response Spectrum Method and vice-versa, for the results of lateral forces, story shear and story moment.
- In Seismic zone V there is the higher difference in the values in high floors for lateral force, story shear and story moment
- Story moment is high in Seismic Coefficient Method when compared to Response Spectrum Method.
- There is an close comparison in the all seismic zones.
- There is a slightly difference in comparison as the soil type changes.
- As per IS 1893-2002 (Part 1) the 93% of forces are covered on 7th mode in SATAAD Pro analysis.
- Response Spectrum Method and Seismic Coefficient Method is calculate accurately as per IS 1893-2002 (Part 1).

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