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Comparative Study of Seismic Response for Seismic Coefficient and Response Spectrum Methods

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ABSTRACT
Right from the evolution of the earth, Earthquakes have been cause great disasters in the form of destruction of property, injury and loss of life to the population. The effective design and construction of earthquake resistant structures has much greater importance in this country due to rapid industrial development and concentration of population in cities. In this thesis, the earthquake response of symmetric multi-storied building by two methods are studied. The methods include seismic coefficient method as recommended by IS Code 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 idealizing the building as shear building. The responses obtained by above methods in two extreme zones as mentioned in IS code i.e. zone II and V are then compared. Test results Base Shears, Lateral Forces and Storey Moments are compared.
Keywords - Earthquake analysis, Modal analysis, Response spectrum analysis, Seismic coefficient method, SRSS.

I. INTRODUCTION

A large portion of India is susceptible to damaging levels of seismic hazards. Hence, it is necessary to take into account the seismic load for the design of high-rise structure. In tall building 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 (2). 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 withstand moderate level of earthquake ground motion without structural damage, but possibly with some structural as well as non-structural damage (2). In present study, the earthquake analysis of 20 Storied building was done by both methods. They are Seismic Coefficient Method and Response Spectrum Method. In Response Spectrum Method, the Time Periods, Natural Frequencies and Mode Shape Coefficients are calculated by MATLAB program then remainig process was done by manually (5). The modal combination rule for Response Spectrum Analysis is SRSS. The main parameters considered in this study to compare the seismic performance of different Zones i.e. II and V are Base Shear, Storey Moment and Lateral Forces.

II. RESPONSE SPECTRUM MODAL ANALYSIS OF BUILDINGS USING IS 1893 (PART 1)-2002

As per IS 1893 (part1)-2002, Dynamic analysis shall be performed to obtain the design seismic force, and its distribution to different levels along the height of the building and to the various lateral load resisting elements, for the following buildings:

a) Regular buildings -Those greater than 40 m in height in Zones IV and V, and those greater than 90 m in height in Zones II and III.
b) Irregular buildings - All framed buildings higher than 12 m in Zones IV and V, and those greater than 40 m in height in Zones II and III.

Dynamic analysis may be performed by The Response Spectrum Method. Procedure is summarized in following steps (6).

a) Modal mass (M_k) – 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.

$$M_k = \frac{\left[\sum w_i \ \phi_{ik}\right]^2}{g \sum w_i \ \phi_{ik}^2}$$

Where
g = acceleration due to gravity
ϕ_{ik} = mode shape coefficient at floor i in mode k
W_i = Seismic weight of floor i.

b) Modal Participation factor (P_k) – 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.

$$P_k = \frac{\sum w_i \phi_{ik}}{\sum w_i \phi_{ik}^2}$$

c) Design lateral force at each floor in each mode – The peak lateral force (Q_{ik}) at floor i in Mode k is given by

$$Q_{ik} = A_{hk} \phi_{ik} P_k W_i$$

Where,
A_{hk} = Design horizontal spectrum value using natural period of vibration (T_k) of mode k.

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

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 by

$$V_{ik} = \sum_{j=i+1}^{n} Q_{ik}$$

e) Storey shear force due to all modes considered – The peak storey shear force (V_i) 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

$$\lambda = \sqrt{\lambda_1^2 + \lambda_2^2 + \lambda_3^2 + \lambda_4^2 + \ldots}$$

Dynamic analysis may be performed either by time history method or by the response spectrum method. However in either method, the design base shear V_B shall be compared with a base shear (V_B) calculated using a fundamental period T_a. When V_B is less than all the response quantities shall be multiplied by V_B/V_B.

III. SEISMICCOEFFICIENT ANALYSIS OF BUILDINGS USING IS 1893 (PART 1)-2002

As per IS 1893 (part1)-2002, Seismic Coefficient analysis Procedure is summarized in following steps (6).

a) Design Seismic Base Shear- The total design lateral force or design seismic base shear (V_b) along any principal direction of the building shall be determined by the following expression

$$V_B = A_h W$$

Where
A_h = Design horizontal seismic coefficient
W = Seismic weight of the building.

b) Seismic Weight of Building- The seismic weight of each floor is its full dead load plus appropriate amount of imposed load as specified. 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. The seismic weight of the whole building is the sum of the seismic weights of all the floors. Any weight supported in between the storey shall be distributed to the floors above and below in inverse proportion to its distance from the floors.

c) Fundamental Natural Time Period- The fundamental natural time period (T_a) calculates from the expression

$T_a = 0.075h^{0.75}$ for RC frame building
$T_a = 0.085h^{0.75}$ for steel frame building

If there is brick filling, then the fundamental natural period of vibration, may be taken as

$$T_a = \frac{0.09\ h}{\sqrt{d}}$$

d) Distribution of Design Force- The design base shear, V_B computed above shall be distributed along the height of the building as per the following expression

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2}$$

IV. METHODOLOGY

The 20 storied building is shown in Fig 1. The seismic analysis of building is done by Seismic Coefficient and response spectrum methods with given above procedures for Zone II and V. The obtained results of both methods are compared with each other.

V. RESULTS AND GRAPHS

The Natural Time periods, Frequencies and Mode Shape Coefficients are given in Table 1. The comparative results of both methods for Zone II and V is given in Table 2 and Table 3 respectively.

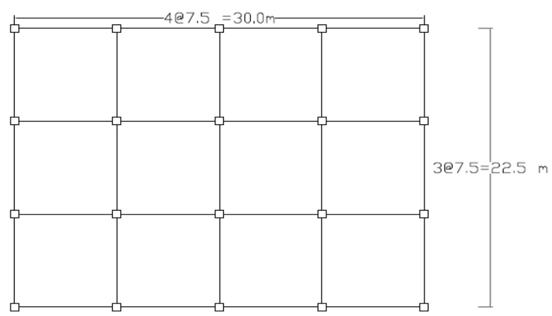

Fig 1. Plan for the 20 storied building

MODE	1	2	3
Time period(Sec)	1.339	0.449	0.271
Natural frequency (rad/sec)	4.692	13.993	23.185
Mode Shape Coefficients at Various Floor Levels			
20	12.826	-4.3275	2.632
19	12.777	-4.1547	2.3338
18	12.6502	-3.7576	1.6894
17	12.4464	-3.1579	0.7944
16	12.1669	-2.3877	-0.2184
15	11.8133	-1.4887	-1.1988
14	11.3877	-0.5093	-2.0014
13	10.8929	0.4975	-2.5071
12	10.3317	1.4774	-2.6411
11	9.7077	2.3777	-2.3833
10	9.0245	3.1496	-1.772
9	8.2864	3.7517	-0.898
8	7.4979	4.1512	0.1093
7	6.6637	4.3268	1.1003
6	5.789	4.269	1.9282
5	4.879	3.9807	2.47
4	3.9393	3.4777	2.6456
3	2.9757	2.7871	2.4287
2	1.9939	1.946	1.8517
1	1.00	1.00	1.00

Table 1. Time Periods, Natural Frequencies and Mode Shape Coefficients

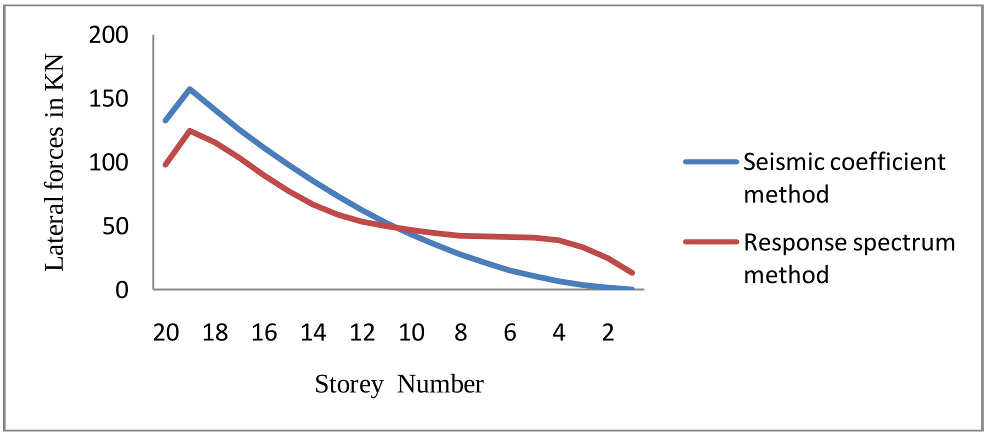

Fig 2. Lateral Forces of 20 storied building in Zone II

Storey No	Lateral Force (KN)		Storey Shear (KN)		Storey Moment (KN-M)	
	Seismic Coefficient Method	Response Spectrum Method	Seismic Coefficient Method	Response Spectrum Method	Seismic Coefficient Method	Response Spectrum Method
20	132.937	98.258	132.937	98.258	398.811	294.774
19	157.25	124.685	290.187	222.943	1269.372	963.603
18	141.162	115.77	431.349	338.713	2563.419	1979.742
17	125.921	103.6	557.27	442.313	4235.229	3306.681
16	111.526	90.176	668.796	532.489	6241.617	4904.148
15	97.979	77.467	766.775	609.956	8541.942	6734.016
14	85.399	66.914	852.174	676.87	11098.464	8764.626
13	73.544	59.095	925.718	735.965	13875.618	10972.521
12	62.658	53.706	988.376	789.671	16840.746	13341.534
11	52.739	49.948	1041.115	839.619	19964.091	15860.391
10	43.546	47.061	1084.661	886.68	23218.074	18520.431
9	35.199	44.722	1119.86	931.402	26577.654	21314.637
8	27.821	42.492	1147.681	973.894	30020.697	24236.319
7	21.289	42.091	1168.97	1015.985	33527.607	27284.274
6	15.604	41.728	1184.574	1057.713	37081.329	30457.413
5	10.886	41.053	1195.46	1098.766	40115.955	33753.711
4	6.894	38.757	1202.354	1137.523	44274.771	37166.28
3	3.87	33.615	1206.224	1171.138	47893.443	40679.694
2	1.693	25.045	1207.917	1196.183	51517.194	44268.243
1	0.362	13.421	1208.279	1209.904	55142.031	47897.055

Table 2. Comparison of Lateral Forces, Storey Shears and Storey Moments of 20 storied building for Zone II

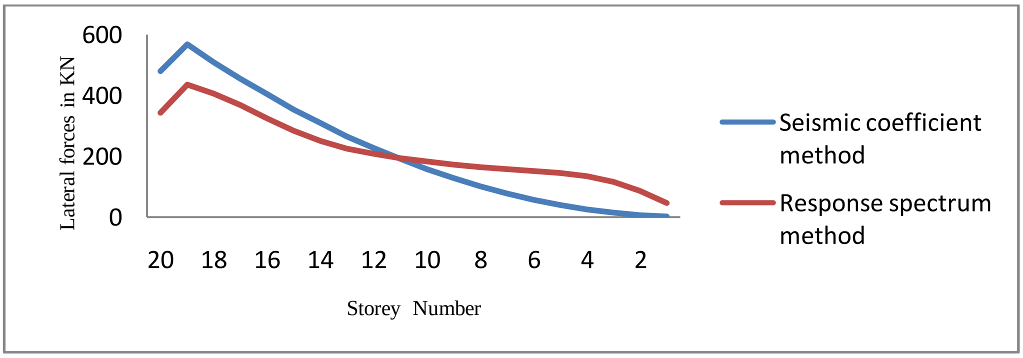

Fig 3. Lateral Forces of 20 storied building in Zone V

Storey No	Lateral Force (KN)		Storey Shear (KN)		Storey Moment (KN-M)	
	Seismic Coefficient Method	Response Spectrum Method	Seismic Coefficient Method	Response Spectrum Method	Seismic Coefficient Method	Response Spectrum Method
20	480.36	341.517	480.36	341.517	1441.08	1024.551
19	568.215	434.382	1048.575	775.899	4586.805	3352.248
18	510.082	405.648	1558.657	1181.547	9262.776	6896.889
17	455.009	366.535	2013.666	1548.082	15303.774	11541.135
16	402.995	323.556	2416.661	1871.638	22553.757	17156.049
15	354.042	283.026	2770.703	2154.664	30865.866	23620.041
14	308.584	249.394	3079.287	2404.058	40103.797	30832.215
13	265.75	224.229	3345.037	2628.287	50138.838	38717.076
12	226.412	206.296	3571.449	2834.583	60853.185	47220.825
11	190.57	192.871	3762.019	3027.454	72139.242	56303.187
10	157.352	181.509	3919.371	3208.963	83897.355	65930.076
9	127.192	170.769	4046.563	3379.732	96037.044	76069.272
8	100.53	162.401	4147.093	3542.133	108478.323	86695.671
7	76.927	155.724	4224.02	3697.857	121150.383	97789.242
6	56.384	150.65	4280.404	3848.507	133991.595	109334.763
5	39.338	144.648	4319.742	3993.155	146950.821	121314.228
4	24.914	133.82	4344.656	4126.975	159984.789	133695.153
3	13.986	114.82	4358.642	4241.337	173060.715	146419.164
2	6.119	84.395	4364.761	4325.732	186154.998	159396.36
1	1.311	44.971	4366.072	4370.703	199253.214	172508.469

Table 3. Comparison of Lateral Forces, Storey Shears and Storey Moments of 20 storied building for Zone V

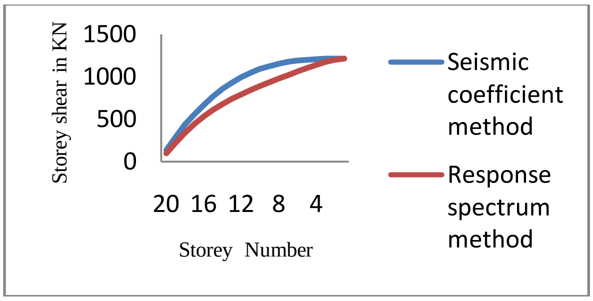

Fig 4 Storey Shears of 20 storied building in Zone II

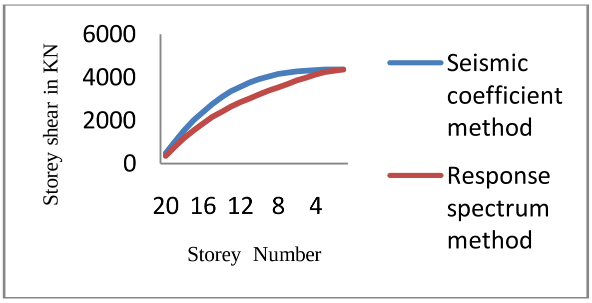

Fig 5 Storey Shears of 20 storied building in Zone V

Note: The obtained results of Table 2 and Table 3 are applied by IS 1893 (part 1): 2002 Clause 7.8.2.

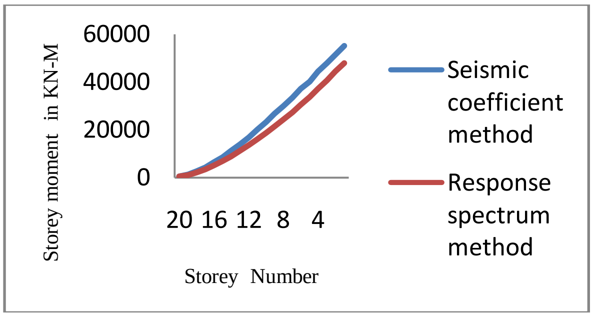

Fig 6. Storey Moments of 20 storied building in Zone II

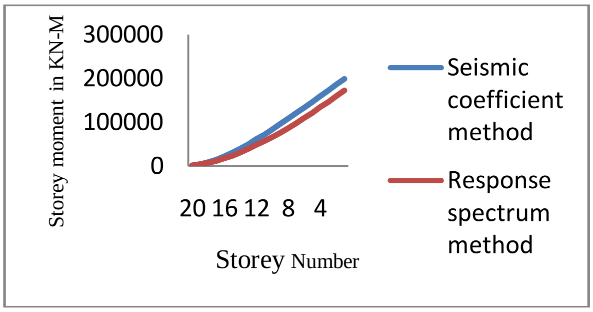

Fig 7. Storey Moments of 20 storied building in ZoneV

VI. COMPARISON OF RESULTS

- There is a gradual increase in the value of lateral forces from bottom floor to top floor in both the Seismic Coefficient Method and Response Spectrum Method in Zone II and V. The lateral forces are obtained by Seismic Coefficient Method are more for upper floors and are less for lower floors when compared to Response Spectrum Method. The variation of lateral forces is shown in Fig 2 and 3.
- The percentage of over estimation of Storey Shear in both Seismic Coefficient and Response Spectrum Methods decrease with increase in height of the building in both Zones II and V. When compared to Response Spectrum Method, the Storey Shears obtained by Seismic Coefficient Method are nearly equal for bottom floors and higher for top floors in both Zones II and V. The variation of storey shears is shown in Fig 4 and 5.
- The percentage of over estimation of Base Moment in both Seismic Coefficient and Response Spectrum Methods decrease with the increase in height of the building in both Zones II and V. When compared to Response Spectrum Method, the Storey Moments obtained by Seismic Coefficient Method are higher for all floors. The variation of storey moments is shown in Fig 6 and 7.

VII. CONCLUSIONS

- The Seismic Coefficient Method is conservative at top floors compared to response Spectrum method and vice-versa.
- According to IS 1893 (Part 1):2002, clause 7.8.2 response values have been modified and considered for comparative study.
- As storey moments are high in Seismic Coefficient Method when compared to response spectrum method, it is suggested to relay on Response Spectrum Method even in symmetric multi-storied buildings for seismic analysis and design.

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