EARTHQUAKE LOADS ON MULTISTOREY BUILDINGS AS PER IS: 1893-1984 AND IS: 1893-2002: A COMPARATIVE STUDY

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ABSTRACT :

Considerable improvement in earthquake resistant design has been observed in recent past. As a result Indian seismic code IS: 1893 has also been revised in year 2002, after a gap of 18 years. This paper presents the seismic load estimation for multistorey buildings as per IS: 1893-1984 and IS: 1893-2002 recommendations. Four multistorey RC framed buildings ranging from three storeyed to nine storeyed are considered and analyzed. The process gives a set of five individual analysis sequences for each building and the results are used to compare the seismic response viz. storey shear and base shear computed as per the two versions of seismic code. The seismic forces, computed by IS: 1893-2002 are found to be significantly higher, the difference varies with structure properties. It is concluded that such study needs to be carried out for individual structure to predict seismic vulnerability of RC framed buildings that were designed using earlier code and due to revisions in the codal provisions may have rendered unsafe.

KEYWORDS: Earthquake loads, IS: 1893, RC buildings, strengthening, codal recommendations.

1. INTRODUCTION

Recommendations provided by seismic codes help the designer to improve the behaviour of structures so that they may withstand the earthquake effects without significant loss. Seismic codes are unique to a particular region or country. They take into account the local seismology, accepted level of seismic risk, properties of available materials, methods used in construction and building typologies. Further, they are indicative of the level of progress a country has made in the field of earthquake engineering and property. Most of the recommendations of IS codes are based on observation during past earthquakes as well as experimental and analytical studies made by scientists, engineers and seismologists. In India, the first seismic code namely IS: 1893 (Criteria for earthquake resistant design of structures) was published in 1962. Thanks to (i) analysis of performance of structures during past seismic events and (ii) efforts put by researchers, considerable advancement have been made over the years in earthquake resistant design of structures, and seismic design requirements in building codes have steadily improved. Therefore, the seismic code needs revision from time to time. IS: 1893-2002 has been revised in year 2002 after the gap of 18 years (IS:1893-1984). The building designed as per the earlier version of the code may be checked for recommendations made by the revised code. Such comparison is to be carried out to establish whether existing buildings designed by earlier version are safe for revised recommendations also (Gupta et al., 2003). Buildings known to possess structural deficiency should be retrofitted to withstand expected design earthquake vibrations (Thakkar and Agarwal, 2004). This paper aims to determine and compare the seismic forces on buildings computed as per the last two version of IS: 1893. Four multistorey buildings, three to nine storey heights, are considered. Seismic Coefficient, Response Spectrum and Modal Analysis Methods are used to compute the seismic forces on these buildings.

2. CHANGES MADE IN IS: 1893-1984

Fifth revision of IS: 1893 was published in year 2002.The previous version of code was published in 1984. Following are the major modifications made in the fifth revision of IS: 1893 (Jain, 2003).

(i) The seismic zone map is revised with only four zones, instead of five. Zone-I has been merged in zone-II.
(ii) The values of seismic zone factors have been changed. These now reflect more realistic values of effective peak ground acceleration.
(iii) Response spectra are now specified separately for three types of founding strata namely rock and hard soil, medium soil and soft soil. Therefore, the soil foundation system factor is dropped.
(iv) Empirical expression for estimating the fundamental time period T_a of regular moment resisting framed buildings has been revised. Empirical estimate of the fundamental natural period T_a are considered to be more realistic. The code now requires that there be a minimum design force based on empirical estimate of fundamental period of the building even if the dynamic analysis gives low seismic force.
(v) The new version recommends to first determining the actual force that may be experienced by the structure during the probable maximum earthquake, if it were to remain elastic. The design force is then reduced for inelastic deformations through response reduction factor (R). Inclusion of **R** makes it clear that design seismic force is much lower than what can be expected during strong shaking.
(vi) Torsional eccentricity values have been revised upwards.

3. DETAILS OF BUILDINGS

Four multistory RC buildings are considered for the study. The structures are treated as a discrete system having lumped masses at each floor level. The loads considered on each floor, are (i) the permanent loads consisting of all the dead loads on each floor, (ii) weight of one-half of the columns and walls above and below the floor, and (iii) an appropriate portion of the live load that always act on the structure. Geometrical details of the four buildings are as follows. Fundamental time periods of the buildings are estimated by using empirical relations given in the two versions of IS code. Holzer's method is used for dynamic characteristics i.e period and mode shapes for first three modes of the buildings.

3.1 Three Storey Building

The building is a framed RC moment resisting framed building with 4x3 bay configuration. Each bay is of size 5m. The single line plan and elevation of the building are shown in Fig.1. The building is located in seismic zone V and is detailed as per seismic detailing code (IS: 13920-1993). Fundamental time period for the building computed by empirical expressions given in IS:1893:1984 and IS:1893:2002 is same as 0.213 second.

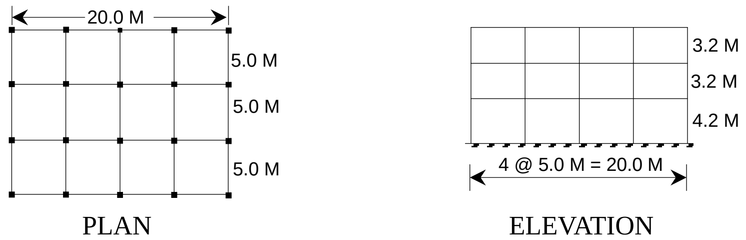


Fig. 1: Details of 3 storey building

3.2 Five Storey Building

The building is a framed RC building with 3 X 3 bay configuration. Each bay is of size 7.5m. The building is commercial complex and is located in seismic zone III. It does not have ductile detailing. The single line plan and elevation of the building are shown in Fig. 2. Fundamental time period for the building computed by empirical expression is found to be 0.50 second (1984 version) and 0.851 second (2002 version).

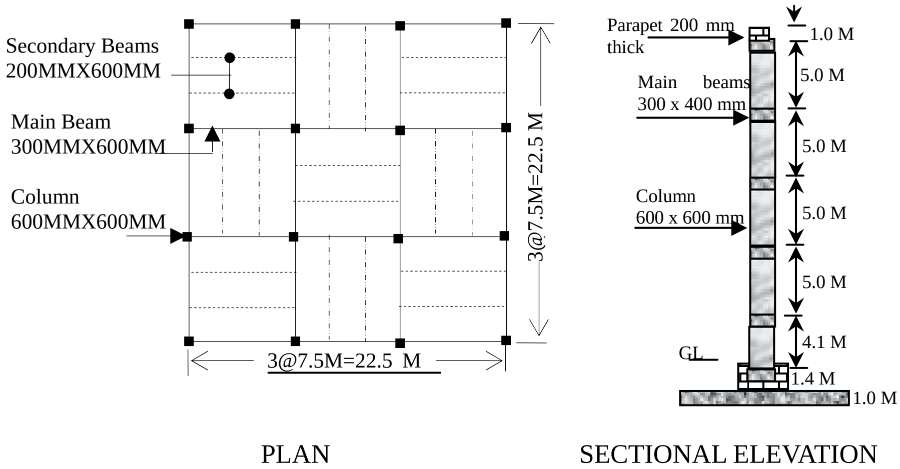
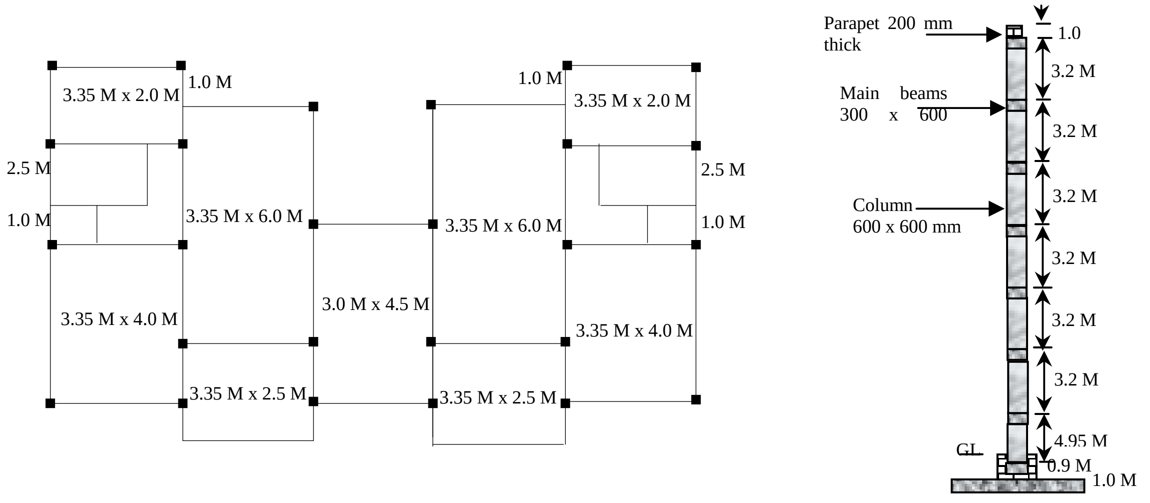


Fig. 2: Details of 5 storey building

3.3 Seven Storey Building

The building is a framed RC building with symmetrical configuration. The sizes of bays are different. The single line plan and elevation of the building are shown in Fig 3. The building is RC moment resisting frame building and is located in seismic zone III. Fundamental time period, for the building computed using empirical relations of IS: 1893 is 0.70 second (1984 version) and 0.557 second (2002 version).



PLAN SECTIONAL ELEVATION

Fig. 3: Details of seven storey building

3.4 Nine Storey Building

The building is a framed RC building with unsymmetrical configuration. The building is residential and is located in seismic zone IV. The size of bays are different. The single line plan of the building is shown in Fig. 4. Storey height of ground floor is 4.05 m and 2.9 m for other storeys. Fundamental period of the building computed using IS: 1893-1984 is 0.90 second and 0.567 second when computed by IS:1893-2002 version.

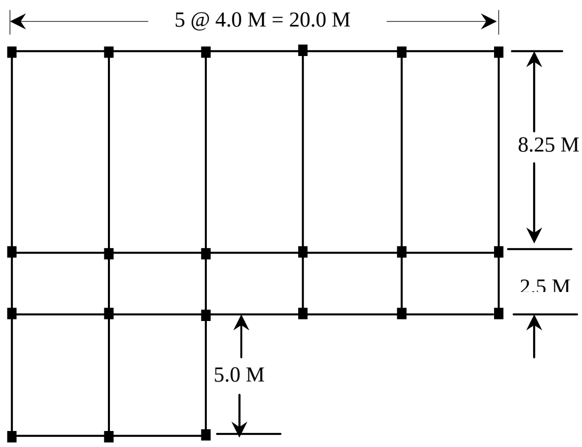


Fig. 4: Plan of nine storey building

4. LOAD CALCULATIONS AS PER IS: 1893 RECOMMENDATIONS

The objective of various recommendations of IS: 1893 is to ensure that, as far as possible, structures are able to respond earthquakes, without structural damage to shocks of moderate intensities and without total collapse to shocks of heavy intensities. General design criteria are presented in IS: 1893, which are applicable to regular structures of more or less uniform configurations. In case of common and less important structures, only elastic design may be sufficient. Three methods are recommended by IS: 1893 for calculation of seismic load on common structures namely (i) seismic coefficient method, (ii) response spectrum method, and (iii) modal analysis method. Seismic coefficient method has been removed from recent version of IS: 1893. Details of the methods are well-documented elsewhere (Jain, 2002; Chopra, 2002).

5. RESULTS AND DISCUSSION

In order to study the effect of changes made in latest revision of IS: 1893, four multistory buildings have been considered in the study. The lateral loads induced due to earthquakes are obtained using different methods recommended by IS: 1893-1984 and IS: 1893-2002 (Part -1). The buildings are located in different zones of seismicity and have different plan shapes and structural details. The value of lateral loads at different storey levels and base shear obtained by different methods of the two versions are presented and discussed in following sections.

5.1 Three Storey Building

The building is analyzed using seismic coefficient, response spectrum and modal analysis method respectively recommended by two versions of IS: 1893. Magnitudes of design lateral forces at different floor levels and base shear are shown in Table 1. It can be observed for IS: 1893-1984 that the lateral forces calculated by seismic coefficient method and response spectrum method are same. Base shear obtained by modal analysis method is least of the three. Further the lateral loads obtained by seismic coefficient method or response spectrum method are less than the lateral forces calculated by modal analysis method. Forces in lower storeys are more when computed by modal analysis method. The same trend is observed when the loads are computed as per IS: 1893-2002. However the base shear values obtained by response spectrum method and modal analysis method is found to be comparable. Table 1 also shows the comparison of values obtained as per two versions of the code. It indicates that as far as modal analysis method is concerned, , lateral force estimation (by IS: 1893-2002) is significantly higher. Estimation of base shear by 1984 version of the code is approximately 30% lower for modal analysis method. On the other hand, the values obtained by response spectrum method do not differ much.

Table 1 -Lateral load and base shear in three-storey building as per IS: 1893-1984 and IS: 1893 - 2002

Floor Level	Seismic Coefficient Method IS: 1893-1984	Response Spectrum Method		Modal Analysis Method	
		IS: 1893- 1984	IS: 1893 -2002	IS: 1893 - 1984	IS: 1893 - 2002
Roof	480 kN	480 kN	539 kN	201 kN	317 kN
2	327 kN	327 kN	368 kN	270 kN	402 kN
1	105 kN	105 kN	119 kN	254 kN	307 kN
Base Shear	**912 kN**	**912 kN**	**1026 kN**	**725 kN**	**1026 kN**

5.2 Five Storey Building

The building is analyzed using seismic coefficient, response spectrum and modal analysis method recommended by two versions of IS: 1893. Base shear values and distributions of lateral forces at different floor levels are tabulated in Table 2. It can be observed for IS: 1893-1984 that the lateral forces calculated by seismic coefficient method are much higher than response spectrum method. Base shear obtained by modal analysis method is least of the three. By response spectrum method, base shear is approximately 38% greater than by modal analysis method. The base shear values obtained by response spectrum method and modal analysis method is found to be similar when computed according to IS:1893-2002. Further the lateral loads on upper storeys obtained by seismic coefficient method or response spectrum method, are more than the lateral forces in upper storeys calculated by modal analysis method. Forces in lower storeys are more when computed by modal analysis method. The same trend is observed when the loads are computed as per IS: 1893-1984 and IS: 1893-2002 both.

Table 2 -Lateral load and base shear in five-storey building as per IS: 1893-1984 and IS: 1893 - 2002

Floor Level	Seismic Coefficient Method IS: 1893-1984	Response Spectrum Method		Modal Analysis Method	
		IS: 1893- 1984	IS: 1893 -2002	IS: 1893 - 1984	IS: 1893 - 2002
Roof	1013 kN	572 kN	475 kN	192 kN	381 kN
5	755 kN	426 kN	354 kN	155 kN	316 kN
4	432 kN	244 kN	202 kN	187 kN	232 kN
3	198 kN	112 kN	093 kN	255 kN	168 kN
2	052 kN	029 kN	024 kN	070 kN	052 kN
1	001 kN	001 kN	001 kN	000	000
Base Shear	**2451 kN**	**1383 kN**	**1149 kN**	**859 kN**	**1149 kN**

5.3 Seven Storey Building

The building is analyzed using seismic coefficient, response spectrum and modal analysis method recommended by the two versions of IS: 1893. Distributions of lateral forces at different floor levels are reproduced in Table 3. It can be observed for IS: 1893-1984 that again the lateral forces calculated by seismic coefficient method are much higher than the forces obtained using response spectrum method. Base shear obtained by modal analysis method is largest of the three. The base shear obtained by modal analysis method and response spectrum method recommended by 2002 versions of IS: 1893 are equal. Forces in lower storeys are more when computed by modal analysis method. Table 3 also shows the comparison of values obtained as per two versions of the code. The difference in base shears values obtained by the two versions is found to be large.

Table 3 -Lateral load and base shear in seven-storey building as per IS: 1893-1984 and IS: 1893 - 2002

Floor Level	Seismic Coefficient Method IS: 1893-1984	Response Spectrum Method		Modal Analysis Method	
		IS: 1893- 1984	IS: 1893 -2002	IS: 1893 - 1984	IS: 1893 - 2002
Roof	421 kN	280 kN	645 kN	369 kN	321 kN
7	419 kN	278 kN	642 kN	472 kN	411 kN
6	305 kN	203 kN	467 kN	454 kN	393 kN
5	209 kN	139 kN	321 kN	439 kN	365 kN
4	132 kN	087 kN	202 kN	429 kN	327 kN
3	072 kN	048 kN	110 kN	412 kN	282 kN
2	047 kN	031 kN	073 kN	585 kN	360 kN
1	000	000	000	001 kN	001 kN
Base Shear	**1605 kN**	**1066 kN**	**2460 kN**	**3161 kN**	**2460 kN**

5.4 Nine Storey Building

The building is analyzed using seismic coefficient, response spectrum and modal analysis method recommended by two versions of IS: 1893. Base shear values and distributions of lateral forces at different floor levels are shown in Table 4. It can be observed for IS: 1893-1984 that the lateral forces calculated by seismic coefficient method are more than what obtained using response spectrum method or modal analysis method. If one follows recommendations of IS:1893-1984, base shear obtained by response spectrum method is the least of the three. Further the lateral loads on upper storeys obtained by seismic coefficient method are more than the lateral forces in upper storeys calculated by modal analysis method. Again the forces in lower storeys are more when computed by modal analysis method. The base shear values obtained as per IS:

1893-2002, by response spectrum method and modal analysis method are found to be equal. The seismic load values obtained by later version again found to be significantly higher.

Table 4 -Lateral load and base shear in nine-storey building as per IS: 1893-1984 and IS: 1893 - 2002

Floor Level	Seismic Coefficient Method IS: 1893-1984	Response Spectrum Method		Modal Analysis Method	
		IS: 1893- 1984	IS: 1893 -2002	IS: 1893 - 1984	IS: 1893 - 2002
Roof	358 kN	214 kN	753 kN	125 kN	431 kN
9	342 kN	205 kN	721 kN	139 kN	290 kN
8	268 kN	161 kN	565 kN	126 kN	347 kN
7	203 kN	122 kN	428 kN	118 kN	327 kN
6	147 kN	088 kN	310 kN	120 kN	335 kN
5	100 kN	060 kN	211 kN	129 kN	364 kN
4	062 kN	037 kN	131 kN	139 kN	391 kN
3	033 kN	020 kN	070 kN	138 kN	390 kN
2	013 kN	008 kN	028 kN	120 kN	339 kN
1	000	000	001 kN	001 kN	001 kN
Base Shear	**1527 kN**	**916 kN**	**3215 kN**	**1155 kN**	**3215 kN**

6. CONCLUSIONS

Analytical study is carried out to investigate the effect of changes in latest revision of IS: 1893 on lateral load calculations for multistorey buildings. Though the number of buildings analyzed is a few to make generalized conclusions about the effect of revisions yet some important conclusions have been arrived. The significant conclusions that emerge from the study are as follows:

1. The seismic design approach, in both the versions, is based on designing a strong and ductile structure, which can take care of the inertial forces generated by earthquake shaking. Unlike previous version of 1984, the latest 2002 version clearly reflects that design seismic force is much lower than what can be expected during strong shaking.
2. In IS:1893-1984 version, seismic coefficient method yields higher values of base shear relative to response spectrum and modal analysis method.
3. Seismic forces in upper storeys of buildings obtained by modal analysis method are significantly less.
4. Forces obtained as per IS:1893-2002 are significantly higher than that computed as per recommendations of IS:1893-1984.
5. Relative difference in the design seismic forces as per the two versions varies with the building properties and therefore existing buildings designed as per earlier code should be analyzed on individual basis so as to assess the vulnerability for future shocks.

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