Seismic Analysis and Design of Multistoried Steel Structure Using IS 1893:2016

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Abstract - *Indian Standard codes are regularly updated at regularly after any updation require for safety of buildings. Recently Indian Standard seismic code IS: 1893:2002 revised in year 2016 after 14 years. To improve ductility and lateral load resistant capacity of structure many equations and values are changed. Again till now steel buildings are not so much focused, because they are not so much popular in India.*

In this dissertation work, performance of steel multistoreyed buildings has been evaluated by using both codes IS – 1893:2002 and IS-1893:2016. For comparison purpose G+11 and G+6 buildings are selected. Sufficient bracing system is incorporated to control deflections. Performances of these models are studied and compared. Linear static analysis i.e. equivalent static analysis is carried out on the entire mathematical 3D models using the finite element software ETABS Version 15.

According to this study one can concluded that response of structure according to IS-1893:2016 is approx. 20% is higher than a structure analyzed according to IS-1893:2002.

1. INTRODUCTION

1.1 SEISMIC ANALYSIS

Seismic Analysis is a subset of structural analysis and is the calculation of the response of a building structure to earthquakes. It is part of the process of structural design, earthquake engineering or structural assessment and retrofit in regions where earthquakes are prevalent. The most important earthquakes are located close to the borders of the main tectonic plates which cover the surface of the globe. These plates tend to move relative to one another but are prevented by doing so by friction until the stresses between plates under the epicenter point become so high that a move suddenly takes place. This is an earthquake. The local shock generates waves in the ground which propagate over the earth's surface, creating movement at the bases of structures. The importance of waves reduces with the distance from the epicenter. Therefore, there exists region of the world with more or less high seismic risk, depending on their proximity to the boundaries of the main tectonic plates besides the major earthquakes which take place at tectonic plate boundaries, others have their origin at the interior of the plates at fault lines. Called intra plates earthquakes, these less energy, but can still be destructive in the vicinity of the epicenter. The action applied to a structure by an earthquake is a ground movement with horizontal and vertical components. The horizontal movement is the most specific feature of earthquake action because of its strength and because structures are generally better designed to resist gravity than horizontal forces. The vertical component of the earthquake is usually about 50% of the horizontal component, except in the vicinity of the epicenter where it can be of the same order. Steel structures are good at resisting earthquakes because of the property of ductility. Experience shows that steel structures subjected to earthquakes behave well. Global failures and huge numbers of casualties are mostly associated with structures made from other materials. There are two means by which the earthquake may be resisted:

- **Option 1** structures made of sufficiently large sections that they are subject to only elastic stresses
- **Option 2** structures made of smaller sections, designed to form numerous plastic zones.

A structure designed to the first option will be heavier and may not provide a safety margin to cover earthquake actions that are higher than expected, as element failure is not ductile. In this case the structure's global behavior is brittle. In a structure designed to the second option selected parts of the structure are intentionally designed to undergo cyclic plastic deformations without failure, and the structure as a whole is designed such that only those selected zones will be plastically deformed. The structures global behavior is ductile. The structure can dissipate a significant amount of energy in these plastic zones, For this reason, the two design options are said to lead to dissipative and non dissipative structures. A ductile behavior, which provides extended deformation capacity, is generally the better way to resist earthquakes. One reason for this is that because of the many uncertainties which characterize our knowledge of real seismic actions and of the analyses we make, it may be that the earthquake action and / or its effects are greater than expected. By ensuring ductile behavior, any such excesses are easily absorbed simply by greater energy dissipation due to plastic deformations of structural components. The same components could not provide more strength (a greater elastic resistance) when option 1 is adopted. Furthermore, a reduction in base shear V (V reduced < V elastic) means an equal reduction in forces applied to the foundations, resulting in lower costs for the infrastructure of a building.

1.2 STEEL STRUCTURES

During the recent decades, our society has been continuously experimenting with newer materials and construction alternatives. Sometimes it is to solve a problem, often to derive benefits like monetary savings, occasionally to strive for a greener future or could be to explore a personal thought. Not all have led to replicable ideas, but this impulse to explore is important to us today. Sometimes, we have simply tried out a foreign practice, like concrete technology, which came from Europe in a big way after our independence. Within half a century, it has swept across India, shifting the way we built for centuries.

Fig 1.1: Steel building in India

Among such imported ideas, building with steel is trying to find a foothold in India today. While it is very common to see a public building with structural steel in the U.S. and Europe, we hardly see them here with the exceptions of industries and temporary shelters, despite India being the third largest producer of steel in the world. Of course, we use steel in the construction process, as in reinforced concrete or an occasional beam but the whole building is not made with structural steel columns, beams, floor plates, staircase supports and such others.

Once finished with infill walls, external cladding, flooring materials, paint finish, doors and windows, only a subject expert may identify a steel building. As a technology, it is much faster than any other existing approaches, offering a wide choice of material finishes. The material gives it greater fire safety, while making it easy for future maintenance and alterations. Yet, why are steel buildings not common in India?

The primary reason is cost, where all the above advantages come at a price not always worth, unless we are building in a congested city centre a commercial property with high site value. Return of investment is emerging as an overriding criterion in our construction industry. Steel structures demand greater precision than those built with masonry or concrete frame, which cannot be guaranteed by all contractors. Uninterrupted power supply, ease of transporting long steel sections to sites, large storage space for site materials and such others are related prerequisites for building with steel.

In the Indian context, can we term steel structures as eco-friendly? They come with some green parameters including the few cited above, but on overall count, steel buildings tend to fall short. The embodied energy consumed by steel buildings is high mainly due to steel itself and partly due to increased use of manufactured and transported materials. Construction demands lot of electricity, produces wastage or joining multiple materials may not get done well affecting occupancy performance.

There could be more arguments against steel buildings, but in the urbanising India, there would be more of them in future, especially where factors weighing against them like cost and energy may appear less important than site value or project period. All that we can hope for is as steel buildings get more common, the steel technology gets greener.

Steel structures are particularly good at providing an energy dissipation capability, due to:

- The ductility of steel as a material
- The many possible ductile mechanisms in steel elements and their connections
- The effective duplication of plastic mechanisms at a local level
- Reliable geometrical properties
- Relatively low sensitivity of the bending resistance of structural elements to the presence of coincident axial force
- Variety of possible energy dissipation mechanisms in steel structures, and the reliability of each of these possibilities, are the fundamental characteristics explaining the excellent seismic behavior of steel structures. Furthermore, steel structures tend to have more reliable seismic behavior than those using other materials, due to some of the other factors that characterize them: guaranteed material strength, as result a of controlled production designs and constructions made by professional

1.3 OBJECTIVES

- To study the clauses provided in IS 1893 (Part1): 2016, & compare them with clauses provided in IS 1893 (Part1): 2002.
- To highlight the revised clauses in IS 1893 (Part1): 2016 which will help designers to understand new code in simple & quick manner.
- To motivate the designers to use latest seismic codes so as to generate valuable data for

research regarding provisions made in new seismic codes.

- To analyze steel multistoreyed buildings by using IS 1893 2016.
- To compare the seismic performance of steel building with IS 1893:2002 and IS 1893: 2016.

2. METHODOLOGY

2.1 GENERAL

Worldwide different types of RC and steel structures with various floor systems are being used for multistory buildings. In the past, masonry structures were widely used for building construction. Day by day technology has developed. Later, steel structural systems were started for multistory buildings.

The main objective of this study is to compare seismic response of steel multistoreyed buildings analyzing them by using IS 1893:2002 and IS 1893:2016. For analytical study two types of multistoreyed buildings are considered one is G+11 storey and second is G+6 storey.

2.2 COMPARISION BETWEEN IS 1893:2002 AND IS1893:2016

The seismic codes are prepared with consideration of seismology of country, accepted level of seismic risk, properties of construction materials, construction methods, and structure typologies etc. Furthermore, the provisions given in seismic codes are based on the observations, experiments & analytical case studies made during past earthquakes in particular region. In India, IS 1893 (Part1) Criteria for Earthquake Resistant Design of Structures is used as code of practice for analysis & designing of earthquake resistant buildings. In the last decade, the detailed & advanced research, damage survey was carried out by the Earthquake Engineering Sectional Committee of Bureau of Indian Standards. As a result, the huge data regarding behaviour of various types of structures during earthquake was collected which gained the knowledge. This continuous effort has resulted in revision of IS 1893 (Part 1): 2002 [1]. Hence the sixth revision of IS 1893 (Part 1) was published in 2016. The revision in major clauses has been presented below:

- As per the clause 1.2 & 1.3, the parking structures, security cabins, ancillary structures, scaffolding, temporary excavations are need to be designed for seismic forces.

- The clause 6.1.3 expects to design the structures for at least the minimum design lateral force specified in Table 7 of standard, which is newly added in latest version of code. The clause 6.3.1.1 from latest code expects to adopt provisions for earthquake resistant design, ductile detailing & construction related to seismic conditions as per the standard even when load combinations that do not contain seismic effects but indicate larger demand than combinations including the seismic effects.

- As per the clause 6.3.3.1, the structures located in seismic zone IV or V, structures which has plan or vertical irregularity, structures founded on soft soils, bridges, structures with long spans or with large lateral overhangs of structural members are required to consider the effects due to vertical earthquake shaking in load combinations. The load combinations for three directional earthquake ground shaking are mentioned in clause 6.3.4.

- When seismic forces are considered, net bearing pressure in soils can be increased, depending upon type of foundation & type of soil. To determine the type of soil for this purpose, soils are divided into four types which are mentioned in Table 2 of the new standard.

- In IS 1893 (Part1): 2016, the design spectra are defined for natural period up to 6 seconds & separate for equivalent static method & for response spectrum method. The Fig. 2 in the standard shows these graphs of design acceleration coefficient corresponding to 5% damping. Hence, the clause 6.4.2 mentions the expressions for determination of design acceleration coefficient (Sa /g) for use in equivalent static method as well as use in response spectrum method. The table 4 in new standard deals with the classification of type of soil on which structure can be founded. It is used to be in the determination of correct spectrum, to calculate the Sa /g.

- As per the clause 6.4.3.1, for structural analysis, the moment of inertia shall be taken as 70% of gross moment of inertia of columns & 35% of gross moment of inertia of beams in case for RC & masonry structures. The gross moment of inertia can be considered for columns & beams in case of steel structures.

- The Table 5 in the standard deals with the definitions of plan irregularities with respect to clause 7.1. This table states the limits on irregularities for seismic zone III, IV & V. According to this, the building is said to be torsionally irregular when the ratio of maximum lateral displacement at one end & the minimum lateral displacement at other end is in the range of 1.5 to 2. If it is more than 2 the building configuration shall be revised. The code states to carry out three dimensional dynamic analysis for buildings with re-entrant corners. In buildings with Out of Plane Offsets in vertical elements, the lateral drift shall be less than 0.2% in the storey having the offset & in the storey below.

- The Table 6 in the standard deals with the definitions of vertical irregularities with respect to clause 7.1. According to this, the soft storey is a storey whose lateral stiffness is less than that of the storey above. Also when the seismic weight of any floor is more than 150% of that of the floors below, the mass irregularity shall be considered to exist. The vertical geometric irregularity considered to exist when the horizontal dimension of lateral load resisting system in any storey is more than 125% of the storey below. The In-plane discontinuity in vertical elements resisting lateral load shall be considered to exist when in-plane offset of lateral force resisting elements is more than 20% of the plan length of those elements. The buildings with in-plane discontinuity are not permitted in seismic zone III, IV & V. The code states that features like floating columns & stub columns are undesirable & prohibited if it is the part of primary lateral load resisting system.

- The code expect to ensure that the first 3 modes together contribute at least 65% mass participation factor in each principal plan direction & the fundamental natural periods of the building in the two principal plan directions are away from each other by at least 10% of the larger value, to avoid the irregular modes of oscillation in two principal plan directions.

- In IS 1893 (Part1): 2016, Table 8 enlists the values of Importance factor depending upon the use, occupancy & service provided by the structures. The important factor value "1.2" is introduced for residential or commercial buildings with occupancy more than 200 people.

- The Table 9 in code deals with Response Reduction factor R for various lateral load resisting systems. Five types of lateral load resisting system & their respective R values are mentioned in the table which are, Moment Frame systems, Braced Frame Systems, Structural Wall systems, Dual systems, and Flat slab – structural wall systems. According to the code, followings are the revised & newly added types of load resisting systems & their respective R values.

  - Steel Buildings with OMRF – 3.0
  - Steel Buildings with SMRF – 5.0
  - Buildings with ordinary braced frame having concentric braces – 4.0
  - Buildings with special braced frame having concentric braces – 4.5
  - Buildings with special braced frame having eccentric braces – 5.0
  - Unreinforced masonry with horizontal RC seismic bands – 2.0
  - Unreinforced masonry with horizontal RC seismic bands & vertical reinforcing bars at corners of rooms & jambs of opening (with reinforcement as per IS 4326) – 2.5
  - Confined masonry – 3.0
  - Buildings with ductile RC structural walls with RC OMRFs – 4.0
  - Flat Slab- Structural Wall - 3.0

- The clause 7.3.5 & 7.3.6 states that, in regions of severe snow loads & sand storms exceeding intensity of 1.5 kN /m2, 20% of uniform design snow load or sand load shall be included in the estimation of seismic weight. In buildings with interior partitions, the weight of these partitions on floors shall be included in the estimation of seismic weight & this value shall not be less than 0.5 kN /m2. In case the minimum values of seismic weights corresponding to snow loads or sand storms or partitions given in IS 875 are higher, the higher values shall be used.

- The clause 7.6.2 gives newly added equations for calculation of approximate fundamental natural period,

For Bare steel MRF building, Ta = 0.085 h 0.75

For Building with RC Structural Walls

$$T_a = \frac{0.075h^{0.75}}{\sqrt{A_w}}$$

Where h is the height of building as defined in clause 7.6.2, in meters, d is base dimension of building at plinth along considered direction of seismic, in meters. A_w is total effective area in m2 of walls in first storey of building which is given by,

$$A_w = \sum_{i=1}^{N_w}\left[A_{wi}\left\{0.2+\left(\frac{L_{wi}}{h}\right)^2\right\}\right]$$

Where Awi is effective cross sectional area of wall i in first storey of building in m2, Lwi is length of structural wall i in the first storey in the considered direction of seismic force in meters, Nw is number of walls in the considered direction of seismic force. The value of Lw / h to be used in the equation shall not exceed 0.9.

- In the IS 1893: 2016, Fig. 5 explains the definition of Height & Base width of buildings, which is newly introduced.

- As per the clause 7.6.4, a floor diaphragm shall be considered to be flexible, if it deforms such that the maximum lateral displacement measured from the chord of the deformed shape at any point of diaphragm is more than 1.2 times average displacement of the entire diaphragm.

- The clause 7.7.1 expects to perform linear dynamic analysis to obtain design seismic base shear & its distribution at different levels along height of building, for all buildings other than regular buildings lower than 15 m in seismic zone II.
- The newly added recommendations regarding RC frame buildings with unreinforced masonry infill walls are given as clause 7.9. These provisions are made to estimate the in-plane stiffness & strength of URM infill walls in the structures. Also the design equations are provided along with the clauses.
- The clause 7.10.3 states that RC structural walls must be designed so as the lateral stiffness in open storey is more than 80% of that in the storey above & lateral strength in open storey is more than 90% of that in the storey above & RC structural wall must not increase torsional irregularity in plan than that already present in the building.
- As per the clause 7.12.3, the compound walls shall be designed for design horizontal coefficient Ah of 1.25Z, that is, with I =1, R =1, &Sa /g = 2.5.
- The Annex F in IS 1893:2016 deals with simplified procedure for evaluation of liquefaction potential which is newly added.

2.2.1 BUILDING DESCRIPTION

The study is carried out on sreel moment resisting setback buildings. The buildings considered is the commercial building having G+11 storeys and G+6 storeys . Height of each storey is 3.15m. The building has plan dimensions 16m x 12m as shown in the Figure 3.1 and having setback in elevation at various heights. Other relevant data is tabulated in table 3.1. In the analysis special moment-resisting frame (SMRF) are considered.

Table 2.1: Analysis data for example building

Plane dimensions	16x12 m
Total height of building	43.8 m(G+11) & 22.5m(G+6)
Height of each storey	3.15m
Height of parapet	1m
Depth of foundation	1.5m
Size of beams	ISMB550 – G+11 ISMB450 – G+6
Size of external brace	ISMB350
size of columns	ISMB600 – G+11 ISMB550 – G+6
Thickness of slab	125 mm
Thickness of external walls	230 mm
Seismic zone	III
Soil condition	Medium
Response reduction factor	5
Importance factor	1 / 1.2
Floor finishes	1.8 kN/m^2
Live load at all floors	3 kN/m^2
Density of brick masonry	20 kN/m^3

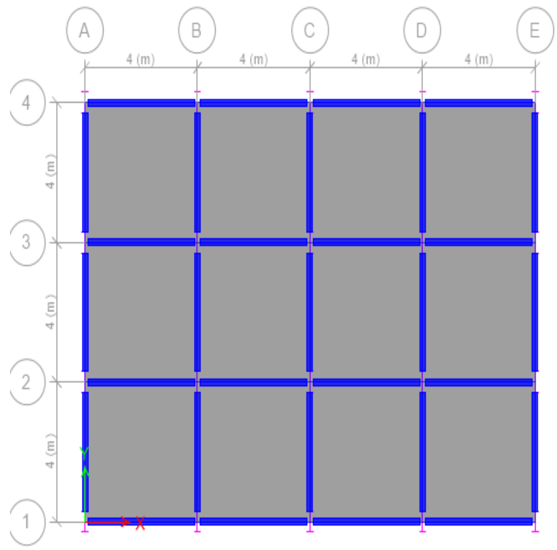


Figure 2.1: Plan of building

2.2.2 MODELING OF BUILDING

The building is modeled using the finite element software ETABS Version 15. The analytical models of the building include all components that influence the mass, strength, stiffness and deformability of structure.

The building structural system consists of beams, columns, slab, and foundation. The non structural elements that do not significantly influence the building behavior are not modeled. Beams and columns are modeled as two noded beam element with six DOF at each node.

The floor slabs are assumed to act as diaphragms, which insure integral action of all the vertical load resisting elements and are modeled as four noded shell element with six DOF at each node.

In the modeling, material is considered as an isotropic material and for controlling lateral deflections X braces aremodelled at appropriate locations. The 3D building model generated in ETABS is shown in figure 2.2.

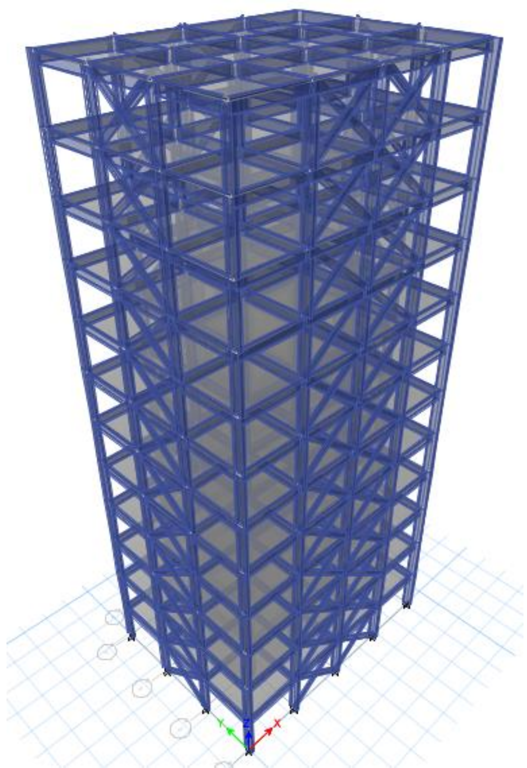
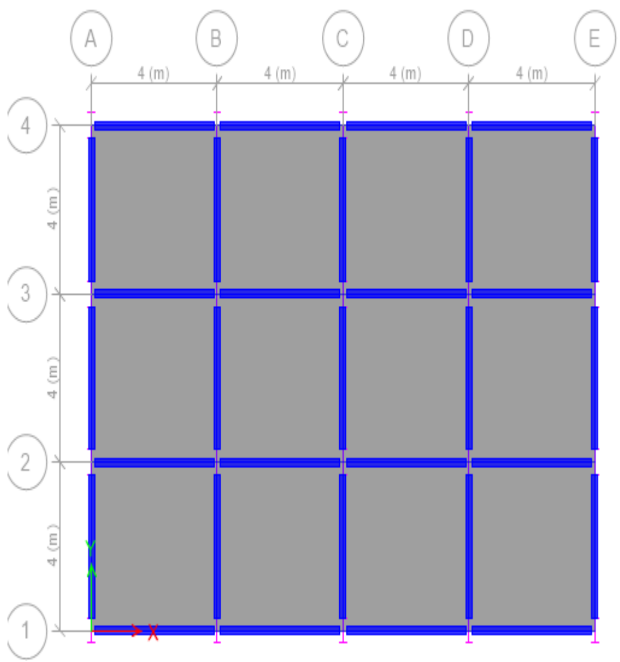


Figure 2.2: 3D Model of building generated in ETABS

To compare the seismic performance of G+11 and G+6 storey buildings, four building models are generated using ETABS. Brief description of all these models is given below.

Model I: G+11 storey building analyzed with IS 1893:2002 as shown in figure 2.3

Model II: G+11 storey building analyzed with IS 1893:2016 as shown in figure 2.3



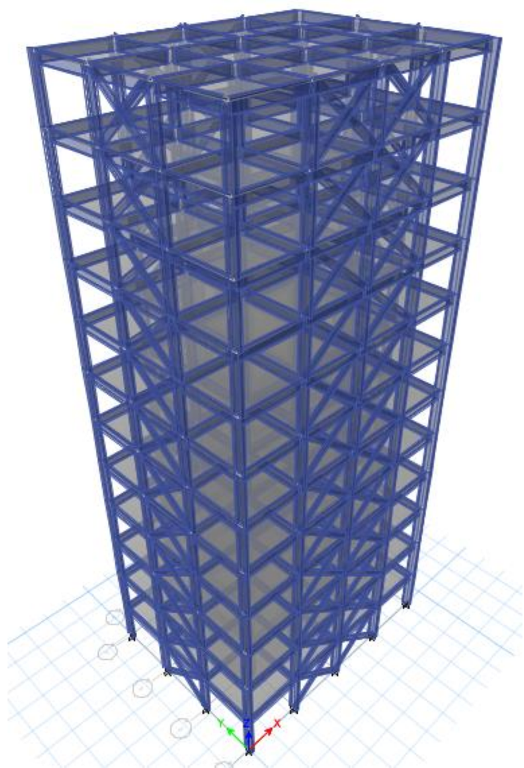
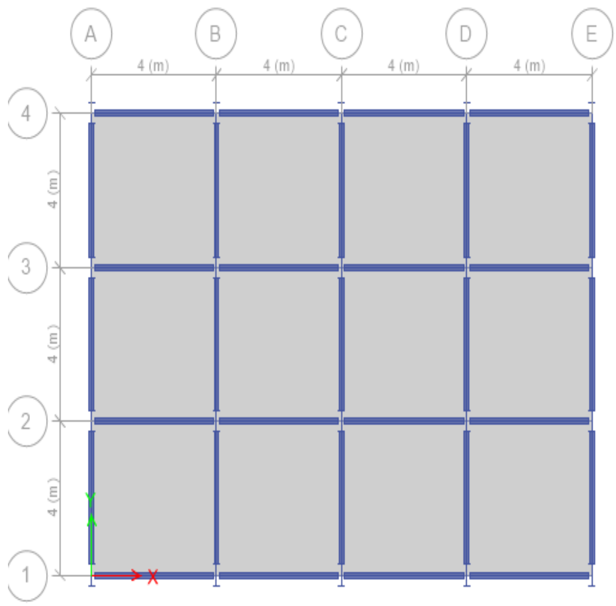


Figure 2.3: Plan and 3D view of G+11 Building

Model III: G+6 storey building analyzed with IS 1893:2002 as shown in figure 3.4

Model IV: G+6 storey building analyzed with IS 1893:2016 as shown in figure 3.4



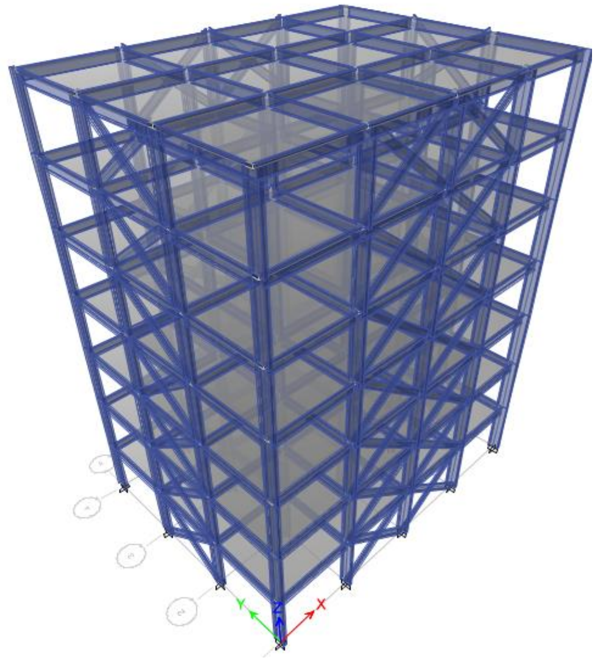


Figure 3.4: Plan and 3D view of G+6 Building

2.2.3 Analysis of Building

Seismic codes are unique to a particular region or country. In India, Indian Standard Criteria for Earthquake Resistant Design of Structures IS 1893 (Part-I): 2016 is the main code that provides outline for calculating seismic design force. This force depends on the mass and seismic coefficient of the structure and the latter in turn depends on properties like seismic zone in which structure lies, importance of the structure, its stiffness, the soil on which it rests, and its ductility. The code recommends following methods of analysis.

1. Equivalent static analysis

2. Dynamic Analysis

a. Response spectrum Analysis

b. Time History Analysis

Here the explained 3D building models are analyzed using equivalent static method (linear method). This method is briefly described in next section. The lateral loads are calculated and then distributed along the height of the building as per the empirical equations given in the code. The building models are then analyzed by the software ETABS. Different parameters such as base shear, drift, displacements and time period are studied for all the models.

2.2.4 Equivalent static analysis

Equivalent static analysis is performed on all the models. Brief description of which is given below.

1) The weight of all the floors and the roof is calculated and total seismic weight of the building is found out.

$$W = \sum W_i$$

2) The approximate fundamental natural period of vibration (T_α), in seconds of all buildings, including moment-resisting frame buildings with brick infill panels, is estimated by empirical expression :

$$T_\alpha = \frac{0.09h}{\sqrt{d}}$$

3) The design horizontal seismic coefficient A_h for a structure is determined by the following expression :

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

4) The total design lateral force or design seismic base shear is determined by the following expression.

$$V_B = A_h XW$$

5) The design base shear computed as above is distributed along the height of building as per the following expression.

$$Q_{1h} = V_B X \frac{W_i h_i^2}{\sum W_i h_i^2}$$

2.2.5 Load combinations

For the analysis, following seven load combinations specified by the IS 1893: 2016 as are used.

1. 1.5 (DL + LL)
2. 1.2 (DL + LL ± EL)
3. 1.5 (DL ± EL)
4. 0.9 DL ± 1.5EL

3. RESULT AND DISCUSSION

3.1 INTRODUCTION

A steel building will be the common type of building structures of future India. From the available literature it is found that implication of newly revised IS 1893:2016 was not studied on steel buildings so far. In this study an attempt is made to compare seismic performance of multistoreyed steel buildings analyzed by using both old and new IS 1893. For this, different building models with different number of storeys i.e. G+11 and G+6 are considered. The 3D analysis of building is carried out for earthquake zone III. The equivalent static analysis is carried out on all the mathematical 3D models using the software ETABS. The results obtain from the analysis are discussed in next sections.

3.2 SEISMIC PERFORMANCE OF G+11 BUILDING

As discussed in section 3.2 of previous chapter, there are total two models under consideration, out of which first model is analyzed using IS 1893: 2002 and other model is alalyzed by using IS 1893:2016. For comparison purpose, lateral displacement, storey drift, time period and base shear is studied

3.2.1 Comparison of results for G+11 building

Equivalent Static analysis is carried out on all the models. The results are presented in the form of graphs. Results in the tabular form are given in appendices.

3.2.1.1 Lateral Displacement

A graph is plotted taking floor level as the abscissa and the displacement as the ordinate for different models in the longitudinal and transverse direction as shown in figure 3.1 and figure 3.2.

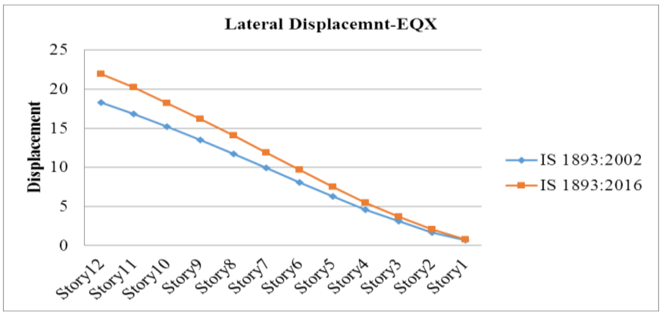


Figure 3.1: Displacement profile in longitudinal direction for G+11 building

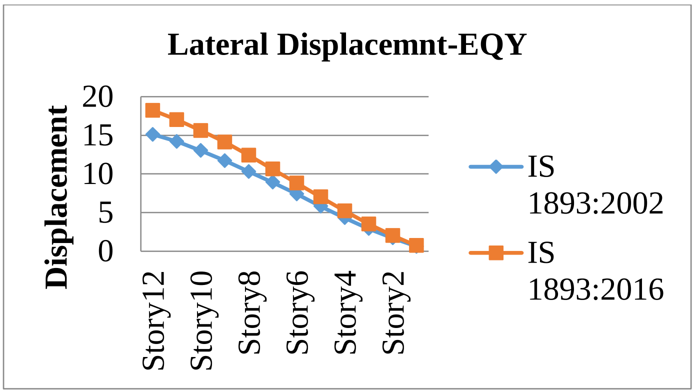


Figure 3.2: Displacement profile in transverse direction for G+11 building

From the displacement profile it is observed that after analyzing building by IS 1893: 2016, lateral displacement increases by 20% and 21% for longitudinal direction and for transverse direction respectively.

3.2.1.2 Storey Drift

A graph is plotted taking floor level as the abscissa and the storey drift as the ordinate for different models in the longitudinal and transverse direction as shown in figure 4.3 and figure 3.4.

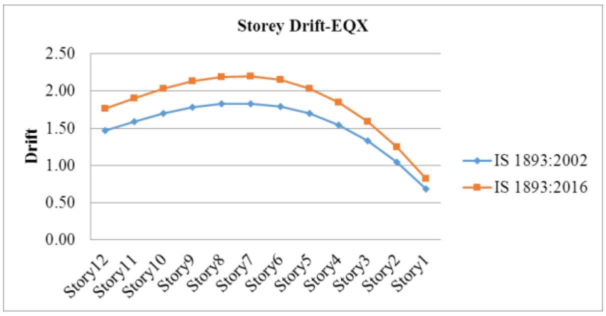


Figure 3.3: Drift profile in longitudinal direction for G+11 building

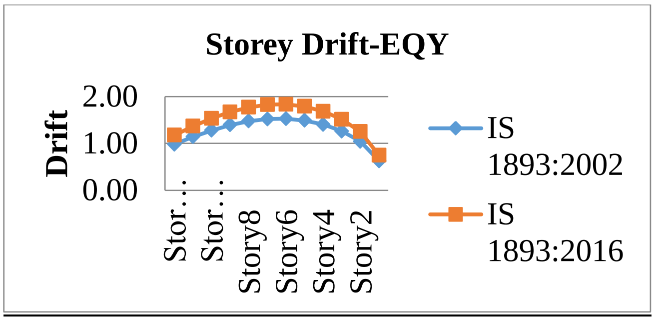


Figure 3.4: Dift profile in transverse direction for G+11 building

From the drift profile it is observed that after analyzing building by IS 1893: 2016, storey drift increases by 20% for longitudinal direction and for transverse direction.

3.2.1.3 Base shear

The base shear for different building models in both longitudinal and transeverse directions is shown in figure 3.5.

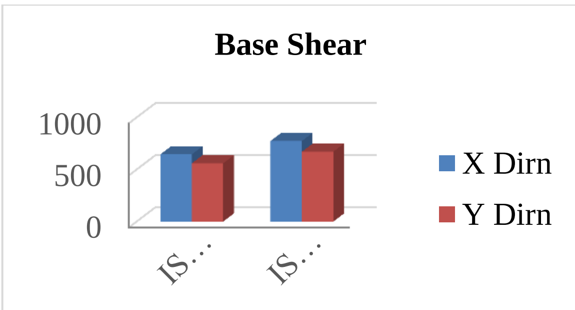


Figure 3.5: Base shear in longitudinal and transverse direction for G+11 storey building

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From the bar chart it is observed that after analyzing building by IS 1893: 2016, storey drift increases by 20% for longitudinal direction and for transverse direction.

3.2.1.4 Time period

A graph is plotted taking modes on the X axis and time period in second on Y axis for all the building models as shown in the figure 3.6 below.

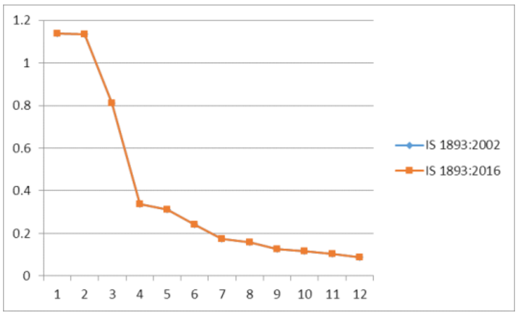

Figure 3.6: Comparison of time period for G+11 storey building

It is observed that the time period of vibration is same for both models since geometry of building is same.

3.2.1.5 Critical Column Forces

For comparison of column forces, three critical columns is selected as shown in below Fig. 4.7 and moment and axial forces of ground floor of the same is compared.

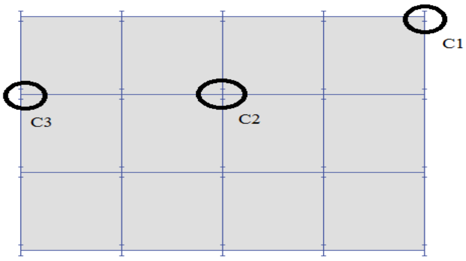

Figure 3.7: Critical columns location

4.2.1.5.1 Critical Column Moments

The critical column moments for different building models is shown in figure 3.8.

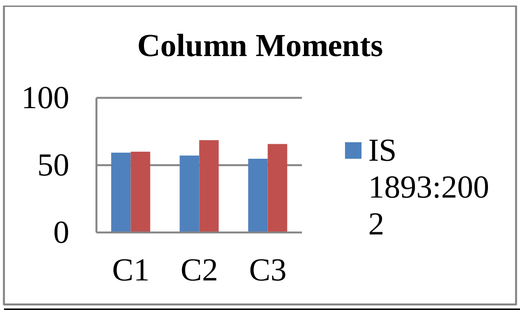

Figure 3.8: Critical column moments for G+11 storey building

From the bar chart it is observed that after analyzing building by IS 1893: 2016, column moment increases by 20% for biaxial moment column and 20% for axial and uniaxial moment column.

3.2.1.5.2 Critical Column Axial Force

The critical column axial force for different building models is shown in figure 4.9.

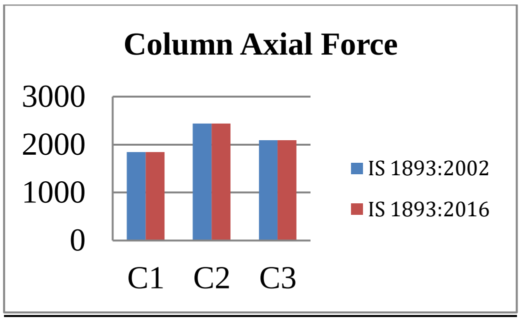

Figure 3.9: Critical column axial force for G+11 storey building

From the bar chart it is observed that after analyzing building by IS 1893: 2016, column axial forces are similar as compared to IS 1893: 2002.

3.3 SEISMIC PERFORMANCE OF G+6 BUILDING

As discussed in section 2.2 ,there are total two models under consideration, out of which first model is analyzed using IS 1893: 2002 and other model is alalyzed by using IS 1893:2016. For comparison purpose, lateral displacement, storey drift, time period and base shear is studied

3.3.1 Comparison of results for G+6 building

Equivalent Static analysis is carried out on all the models. The results are presented in the form of graphs. Results in the tabular form are given in appendices.

3.3.2.1 Lateral Displacement

A graph is plotted taking floor level as the abscissa and the displacement as the ordinate for different models in the longitudinal and transverse direction as shown in figure 3.10 and figure 3.11.

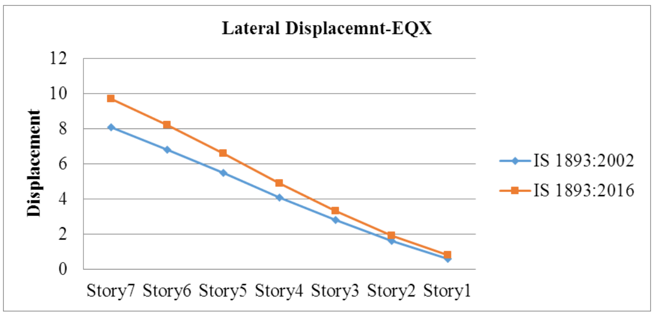

Figure 3.10: Displacement profile in longitudinal direction for G+6 building

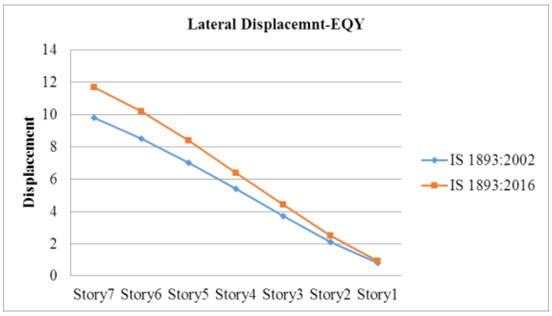

Figure 3.11: Displacement profile in transverse direction for G+6 building

From the displacement profile it is observed that after analyzing building by IS 1893: 2016, lateral displacement increases by 20% and 19% for longitudinal direction and for transverse direction respectively.

3.3.2.2 Storey Drift

A graph is plotted taking floor level as the abscissa and the storey drift as the ordinate for different models in the longitudinal and transverse direction as shown in figure 3.12 and figure 3.13.

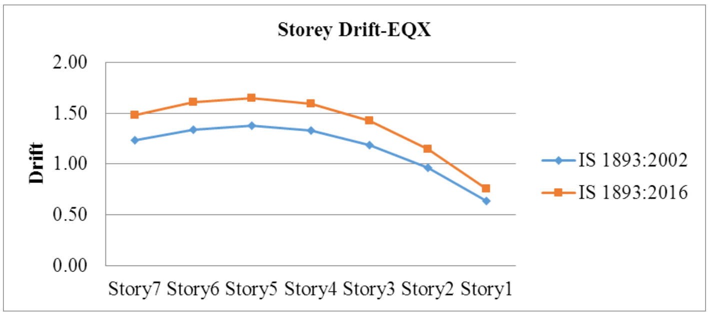

Figure 3.12: Drift profile in longitudinal direction for G+6 building

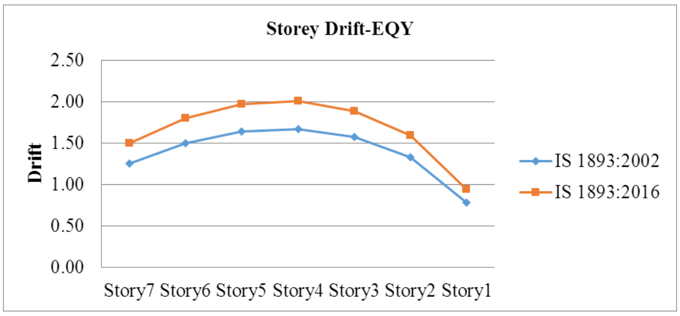

Figure 3.13: Drift profile in transverse direction for G+6 building

From the drift profile it is observed that after analyzing building by IS 1893: 2016, storey drift increases by 20% for longitudinal direction and for transverse direction.

3.3.2.3 Base shear

The base shear for different building models in both longitudinal and transeverse directions is shown in figure 3.14.

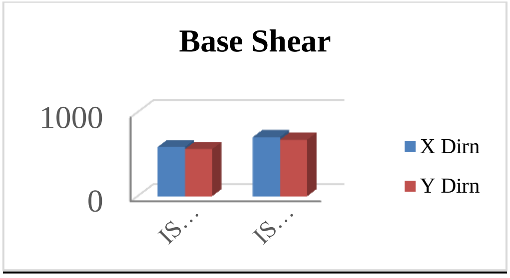

Figure 3.14: Base shear in longitudinal and transverse direction for G+6 storey building

From the bar chart it is observed that after analyzing building by IS 1893: 2016, storey drift increases by 20% for longitudinal direction and for transverse direction.

3.3.2.4 Time period

A graph is plotted taking modes on the X axis and time period in second on Y axis for all the building models as shown in the figure 4.15 below.

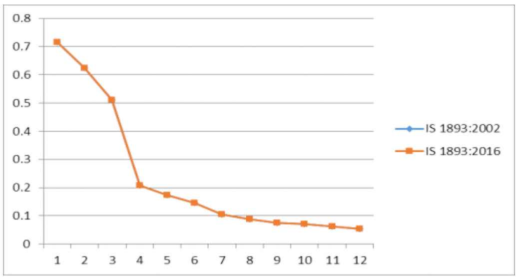

Figure 3.15: Comparison of time period for different modes for G+6 storey building

It is observed that the time period of vibration is same for both models since geometry of building is same.

3.3.2.5 Critical Column Moments

The critical column moments for different building models is shown in figure 3.16.

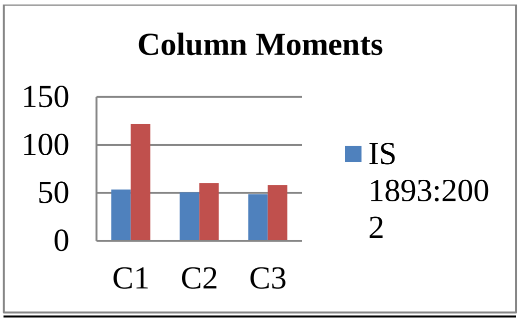

Figure 3.16: Critical column moments for G+6 storey building

From the bar chart it is observed that after analyzing building by IS 1893: 2016, column moment increases by 128% for biaxial moment column and 20% for axial and uniaxial moment column.

3.3.2.6 Critical Column Axial Force

The critical column axial force for different building models is shown in figure 3.17.

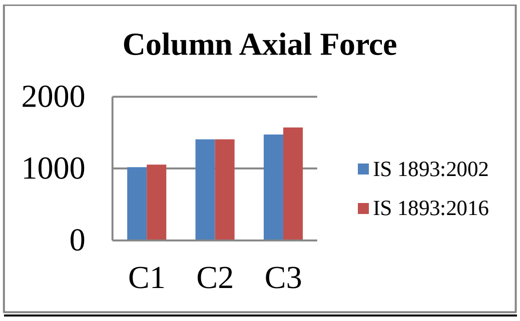

Figure 3.17: Critical column axial force for G+6 storey building

From the bar chart it is observed that after analyzing building by IS 1893: 2016, column axial forces are similar as compared to IS 1893: 2002.

4.0 CONCLUSIONS

Based on the analysis results following conclusions are drawn;

- It is observed that there is significant increase in the lateral drift and displacement demand which ultimately increases the member forces, and design.
- Importance factor for multi storey residential and commercial buildings has been changed from 1.0 to 1.2. As I increases, Ah will increase and therefore Base shear VB will increase. This may lead to increase in size of lateral load resisting members and reinforcement. Ultimately structure cost may increase.
- There is increment in lateral displacement by nearly 20% by using IS 1893:2016 as compare to IS 1893:2002.
- Seismic weight of building will remain same for both IS 1893:2016 and IS 1893:2002.
- Time Period of building will remain same for both IS 1893:2016 and IS 1893:2002 since stiffness of building is not changing.
- There is increment in storey drift by nearly 20% by using IS 1893:2016 as compare to IS 1893:2002.
- There is increment in base shear by nearly 20% by using IS 1893:2016 as compare to IS 1893:2002.
- It can be concluded that, Seismic response of building will increase by 20% by using new code IS 1893:2016. If equivalent static analysis is used.
- For multistoreyupto G+11, increment in seismic forces is about 20% as compared to IS 1893:2002.
- For multistorey building G+6, increment in column moments is about 20% as compared to IS 1893:2002.
- For multistorey building G+6, increment in column moments is about 128% for biaxial moment column and 20% for axial and uniaxial moment column as compared to IS 1893:2002.
- For multistorey building G+6, increment in column axial forces are similar as compared to IS 1893:2002.
- For multistorey building G+11, increment in column moments is about20% for biaxial moment column and 20% for axial and uniaxial moment column as compared to IS 1893:2002.
- For multistorey building G+11, increment in column axial forces are mostly similar and varying only by 4 to 7% as compared to IS 1893:2002.

4.1 FUTURE SCOPE

Within the limited scope of present study the broad conclusions drawn from this work. However, further study can be undertaken in following areas:

- In this dissertation, dynamic analysis has not been used, for further scope of study, response spectrum and time history analysis can be performed.
- In this dissertation comparisons are made on the basis of analysis results only. Designing of a steel building is necessary for checking the cost effectiveness of the structure.
- Various lateral load resisting elements such as shear wall braces can be used to again reduce response of structure.
- In present study soil interaction has not been taken into account, which has prominent effect on the design and construction of the building. This factor can also be taken into consideration for further scope of study.
- In present study, regular building analysis has been carried out. The study can be further extended using irregular buildings.
- Study can be further extended to various seismic zones.

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APPENDIXE

E-1: G+11 BUILDING

Table E-1: Displacement at floor levels in ongitudinal direction for G+11 building in mm

Storey	IS 1893:2002	IS 1893:2016
Story12	18.3	21.9
Story11	16.8	20.2
Story10	15.2	18.2
Story9	13.5	16.2
Story8	11.7	14.1
Story7	9.9	11.9
Story6	8.1	9.7
Story5	6.3	7.5
Story4	4.6	5.5
Story3	3.1	3.7
Story2	1.7	2.1

Table E-2: Displacement at floor levels in transverse direction for G+11 building in mm

Storey	IS 1893:2002	IS 1893:2016
Story12	15.1	18.2
Story11	14.2	17
Story10	13	15.6
Story9	11.7	14.1
Story8	10.3	12.4
Story7	8.9	10.6
Story6	7.4	8.8
Story5	5.8	7
Story4	4.3	5.2
Story3	2.9	3.5
Story2	1.7	2

Table E-3: Drift at floor levels in longitudinal direction for G+11 building

Storey	IS 1893:2002	IS 1893:2016
Story12	1.47	1.76
Story11	1.59	1.91
Story10	1.69	2.03
Story9	1.78	2.13
Story8	1.83	2.19
Story7	1.83	2.20
Story6	1.79	2.15
Story5	1.69	2.03
Story4	1.54	1.85
Story3	1.33	1.59
Story2	1.04	1.25

Table E-4: Drift at floor levels in transverse direction for G+11 building

Storey	IS 1893:2002	IS 1893:2016
Story12	0.98	1.17
Story11	1.14	1.37
Story10	1.28	1.53
Story9	1.39	1.67
Story8	1.47	1.77
Story7	1.52	1.83
Story6	1.53	1.83
Story5	1.49	1.79
Story4	1.40	1.69
Story3	1.26	1.51
Story2	1.04	1.25

Table E-5: Time period at different modes for G+11 building

Mode	IS 1893:2002	IS 1893:2016
1	1.138	1.138
2	1.135	1.135
3	0.812	0.812
4	0.337	0.337
5	0.313	0.313
6	0.242	0.242
7	0.174	0.174
8	0.157	0.157
9	0.127	0.127
10	0.116	0.116
11	0.104	0.104
12	0.086	0.086

Table E-6: Base Shear for G+11 building

Dirn	IS 1893:2002	IS 1893:2016
X Dirn	644.22	773.06
Y Dirn	558.76	670.51

Table E-7: Column axial forces for G+11 building

Column	IS 1893:2002	IS 1893:2016
C1	1843.31	1843.31
C2	2441.11	2441.11
C3	2089.87	2089.87

Table E-8: Column moments for G+11 building

Column	IS 1893:2002	IS 1893:2016
C1	59.25	60.02
C2	57.2	68.55
C3	54.86	65.81

F-1: G+6 BUILDING

Table F-1: Displacement at floor levels in longitudinal direction for G+6 building in mm

Storey	IS 1893:2002	IS 1893:2016
Story7	8.1	9.7
Story6	6.8	8.2
Story5	5.5	6.6
Story4	4.1	4.9
Story3	2.8	3.3
Story2	1.6	1.9
Story1	0.6	0.8

Table F-2: Displacement at floor levels in transverse direction for G+6 building in mm

Storey	IS 1893:2002	IS 1893:2016
Story7	9.8	11.7
Story6	8.5	10.2

Story5	7	8.4
Story4	5.4	6.4
Story3	3.7	4.4
Story2	2.1	2.5
Story1	0.8	0.9

Table F-3: Drift at floor levels in longitudinal direction for G+6 building

Storey	IS 1893:2002	IS 1893:2016
Story7	1.24	1.48
Story6	1.34	1.61
Story5	1.38	1.65
Story4	1.33	1.59
Story3	1.19	1.43
Story2	0.96	1.15
Story1	0.63	0.76

Table F-4: Drift at floor levels in transverse direction for G+6 building

Storey	IS 1893:2002	IS 1893:2016
Story7	1.26	1.51
Story6	1.51	1.80
Story5	1.64	1.97
Story4	1.68	2.01
Story3	1.58	1.89
Story2	1.33	1.59
Story1	0.78	0.94

Table F-5: Time period at different modes for G+6 building

Mode	IS 1893:2002	IS 1893:2016
1	0.716	0.716
2	0.624	0.624
3	0.511	0.511
4	0.207	0.207
5	0.173	0.173
6	0.145	0.145
7	0.106	0.106
8	0.089	0.089
9	0.075	0.075
10	0.071	0.071
11	0.063	0.063
12	0.054	0.054

Table F-6: Base Shear for G+6 building

Dirn	IS 1893:2002	IS 1893:2016
X Dirn	587.46	704.95
Y Dirn	560.66	672.8

Table F-7: Column axial forces for G+6 building

Column	IS 1893:2002	IS 1893:2016
C1	1020.89	1057.06
C2	1407.22	1407.22
C3	1472.59	1572.57

Table F-8: Column moments for G+11 building

Column	IS 1893:2002	IS 1893:2016
C1	53.37	121.46
C2	50.21	60.17
C3	48.31	57.97

BIOGRAPHIES

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