**Review of IS 1893:2016 with IS 1893:2002 for high rise structure with irregularities**

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***Abstract –*** *The national building code of India(NBC)2015 was released by bureau of Indian standards during December 2016/january2017. The various sections of this NBC have undergone changes as per latest technologies and user requirements. It is necessary to identify the performance of the structures to withstand against disaster for both new and existing one. The paper discusses the performance evaluation of RC (Reinforced Concrete) Buildings with various irregularities. Structural irregularities are important factors which decrease the seismic performance of the structures. This study as a whole makes an effort to evaluate the effect of various irregularities on RC buildings using IS 1893:2002 and IS 1893:2016 in terms of dynamic characteristics.*

***Keywords-*** *Seismic performance, Plan, vertical, mass, stiffness, weak storey irregularities, IS 1893:2002, IS1893:2016.*

**INTRODUCTION**

**E**arthquake is known to be one of the most destructive phenomenon experienced on earth. It is caused due to a sudden release of energy in the earth’s crust which results in seismic waves. When the seismic waves reach the foundation level of the structure, it experiences horizontal and vertical motion at ground surface level. Due to this, earthquake is responsible for the damage to various man-made structures like buildings, bridges, roads, dams, etc. It also causes landslides, liquefaction, slope-instability and overall loss of life and property.

During an earthquake, failure of structure starts at points of weakness. This weakness arises due to discontinuity in mass, stiffness and geometry of structure. The structures having this discontinuity are termed as Irregular structures. Irregular structures

contribute a large portion of urban infrastructure. Vertical irregularities are one of the major reasons of failures of structures during earthquakes. For example structures with soft storey were the most notable structures which collapsed. So, the effect of vertically irregularities in the seismic performance of structures becomes really important. Height-wise changes in stiffness and mass render the dynamic characteristics of these buildings different from the regular building.

IS 1893 definition of Vertically Irregular structures: The irregularity in the building structures may be due to irregular distributions in their mass, strength and stiffness along the height of building. When such buildings are constructed in high seismic zones, the analysis and design becomes more complicated.

There are two types of irregularities-

1. Plan Irregularities

2. Vertical Irregularities.

Vertical Irregularities are mainly of five types

i a) Stiffness Irregularity — Soft Storey-A soft storey is one in which the lateral stiffness is less than 70 percent of the storey above or less than 80 percent of the average lateral stiffness of the three storeys above.

b) Stiffness Irregularity — Extreme Soft Storey-An extreme soft storey is one in which the lateral stiffness is less than 60 percent of that in the storey above or less than 70 percent of the average stiffness of the three storeys above.

ii) Mass Irregularity-Mass irregularity shall be considered to exist where the seismic weight of any storey is more than 200 percent of that of its adjacent storeys. In case of roofs irregularity need not be considered.

iii) Vertical Geometric Irregularity- A structure is considered to be Vertical geometric irregular when the horizontal dimension of the lateral force resisting system in any storey is more 2 than 150 percent of that in its adjacent storey.

iv) In-Plane Discontinuity in Vertical Elements Resisting Lateral Force-An in-plane offset of the lateral force resisting elements greater than the length of those elements.

v) Discontinuity in Capacity — Weak Storey-A weak storey is one in which the storey lateral strength is less than 80 percent of that in the storey above.

**METHODOLOGY**

RCC Frames with G+10 is considered in the study. Fundamental period of vibration of the frame with fixed support using codal formula in IS 1893(Part I):2002 and IS 1893(Part I):2016 and model analysis is evaluated. In order to understand the effect of irregularities in structures, modeling is done using STAAD.Pro software. Response spectrum method of seismic analysis of the models are performed using STAADPro.

**PROBLEM STATEMENT**

The building is analyzed is G+10 R.C framed building of symmetrical rectangular plan configuration. Complete analysis is carried out for dead load, live load & seismic load using STAAD-Pro software. Response Spectrum Method of seismic analysis is used. All combinations are considered as per IS 1893-(part I).

Site Properties:

Details of building:: G+10 RC framed structure

Plan Dimension:: 35m x 20m , 5m span in each direction.

Outer wall thickness:: 230mm

Inner wall thickness:: 230mm

Floor height ::3 m

Parking floor height :: 3m

Material Properties

Material grades of M35 & Fe500 is used for the design.

Loading on structure

Dead load :: self-weight of structure

Weight of 230mm wall :: 13.8 kN/m²

Live load:: Floor:: 2.5 kN/m²

Roof :: 1.5 kN/m²

Seismic load:: Seismic Zone IV

Table 1- Preliminary Geometric & Seismic data

|  |  |  |
| --- | --- | --- |
|  | As per IS 1893:2002 | As per IS 1893:2016 |
| Column size | 850mmX400mm | 950mmX400mm |
| Beam size | 600mmX300mm | 600mmX300mm |
| Slab thickness | 120mm | 120mm |
| Seismic Zone Z | IV=0.24 | IV=0.24 |
| Importance factor I | 1.0 | 1.2 |
| Response Reduction factor R | 5 | 5 |

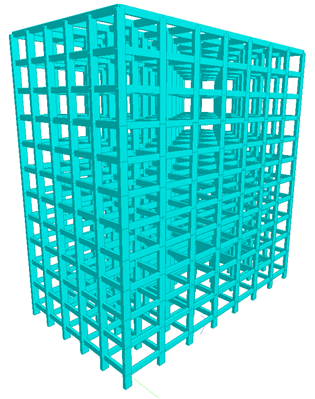
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Fig.1- 3D view of G+10 RC building

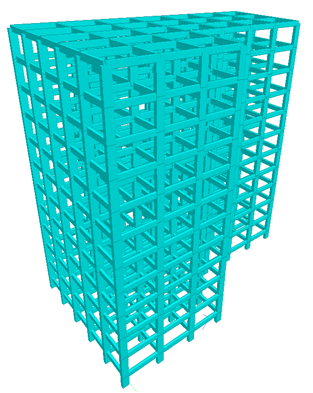
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Fig.2- 3D view of G+10 RC building with plan irregularity

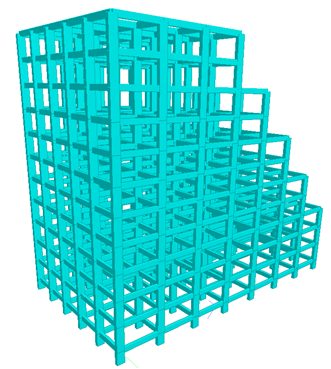
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Fig.3- 3D view of G+10 RC building with vertical irregularity

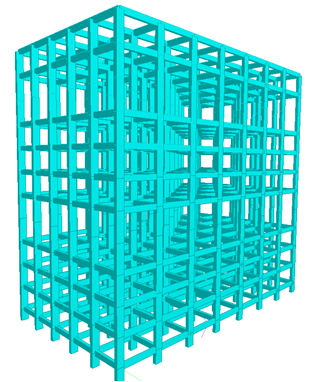
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Fig.4- 3D view of G+10 RC building with stiffness irregularity

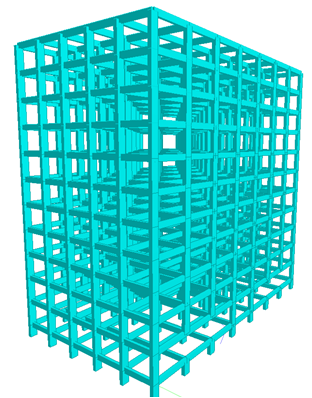
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Fig.5- 3D view of G+10 RC building with weak storey irregularity

**RESULTS**

Table 2- Base shear (kN) in X-direction

|  |  |  |
| --- | --- | --- |
| **Type of Model** | **IS 1893:2002** | **IS 1893:2016** |
| Regular | 5786.01 | 8307.57 |
| Plan Irregularity | 5465.6 | 6634.29 |
| Vertical Irregularity | 5084.51 | 6152.26 |
| Mass Irregularity | 6909.64 | 8389.46 |
| Stiffness Irregularity | 5657.1 | 6975.1 |
| Weak storey | 6769.97 | 8423.52 |

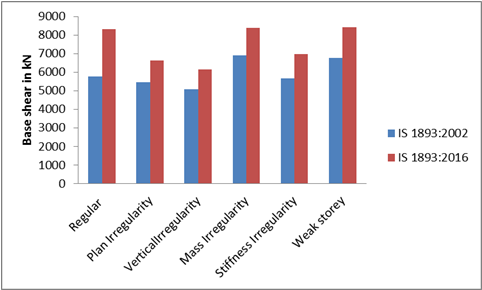
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Fig.6-Base shear (kN) in X-direction

Table 3- Base shear (kN) in Z-direction

|  |  |  |
| --- | --- | --- |
| **Type of Model** | **IS 1893:2002** | **IS 1893:2016** |
| Regular | 5722.98 | 6944.72 |
| Plan Irregularity | 5007.98 | 6062.15 |
| Vertical Irregularity | 4507.57 | 5651.94 |
| Mass Irregularity | 6319.35 | 7678.22 |
| Stiffness Irregularity | 5226.11 | 6365.39 |
| Weak storey | 6219.56 | 7640.47 |

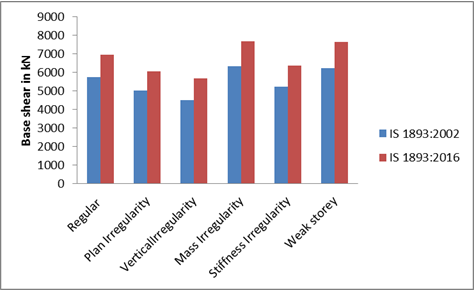
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Fig.7-Base shear (kN) in Z-direction

Table 4- Maximum Lateral Displacement (mm) in X-direction

|  |  |  |
| --- | --- | --- |
| **Type of Model** | **IS 1893:2002** | **IS 1893:2016** |
| Regular | 49.85 | 81.326 |
| Plan Irregularity | 49.863 | 84.244 |
| Vertical Irregularity | 42.462 | 73.704 |
| Mass Irregularity | 50.453 | 84.926 |
| Stiffness Irregularity | 54.486 | 92.734 |
| Weak storey | 53.037 | 93.968 |

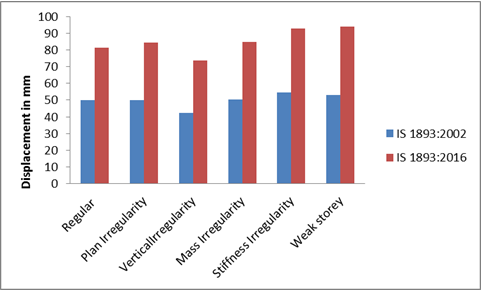
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Fig.8-Maximum Lateral Displacement (mm) in X-direction

Table 5- Maximum Lateral Displacement (mm) in Z-direction

|  |  |  |
| --- | --- | --- |
| **Type of Model** | **IS 1893:2002** | **IS 1893:2016** |
| Regular | 65.255 | 110.531 |
| Plan Irregularity | 72.907 | 128.677 |
| Vertical Irregularity | 81.001 | 136.697 |
| Mass Irregularity | 66.083 | 115.905 |
| Stiffness Irregularity | 81.426 | 146.157 |
| Weak storey | 89.414 | 170.734 |

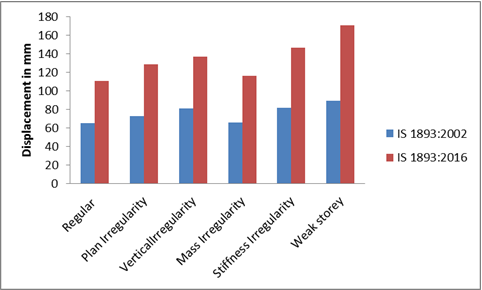
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Fig.9-Maximum Lateral Displacement (mm) in Z-direction

Table 6- Maximum axial force (kN) in columns

|  |  |  |
| --- | --- | --- |
| **Type of Model** | **IS 1893:2002** | **IS 1893:2016** |
| Regular | 4409.52 | 5452.28 |
| Plan Irregularity | 4524.18 | 5755.75 |
| Vertical Irregularity | 4450.9 | 5657.1 |
| Mass Irregularity | 4426.21 | 5563.72 |
| Stiffness Irregularity | 3674.96 | 4718.07 |
| Weak storey | 8721 | 11045.2 |

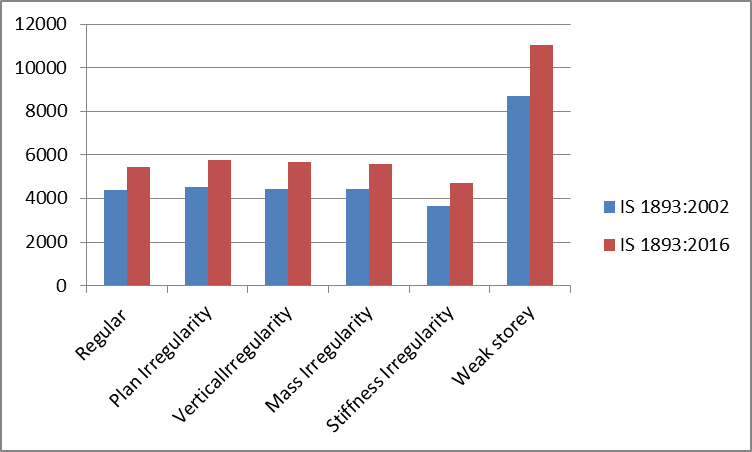


Fig. 10- Maximum axial force (kN) in columns

Table 7- Maximum shear force Y (kN) in columns

|  |  |  |
| --- | --- | --- |
| **Type of Model** | **IS 1893:2002** | **IS 1893:2016** |
| Regular | 244.721 | 432.068 |
| Plan Irregularity | 243.969 | 356.98 |
| Vertical Irregularity | 200.185 | 438.581 |
| Mass Irregularity | 248.922 | 375.499 |
| Stiffness Irregularity | 207.338 | 1080.05 |
| Weak storey | 801.195 | 423.661 |

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Fig.11-Maximum shear force Y (kN) in columns

Table 8- Maximum shear force Z (kN) in columns

|  |  |  |
| --- | --- | --- |
| **Type of Model** | **IS 1893:2002** | **IS 1893:2016** |
| Regular | 239.06 | 475.381 |
| Plan Irregularity | 255.938 | 531.566 |
| Vertical Irregularity | 302.143 | 445.811 |
| Mass Irregularity | 242.986 | 379.235 |
| Stiffness Irregularity | 201.316 | 904.912 |
| Weak storey | 455.708 | 666.208 |

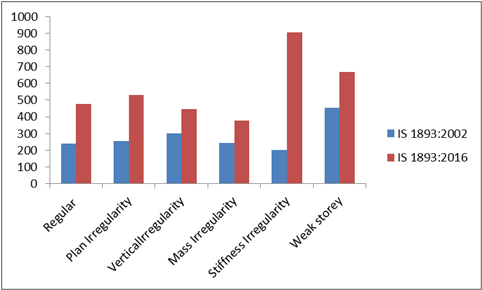
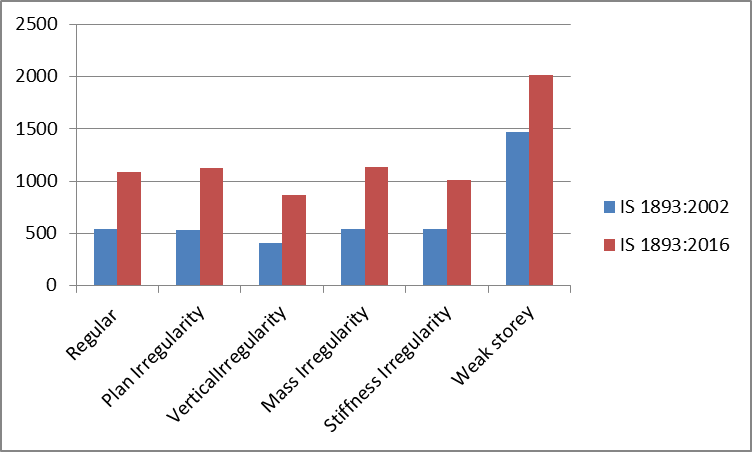
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Fig.12-Maximum shear force Z (kN) in columns

Table 9- Maximum moment Y (kNm) in columns

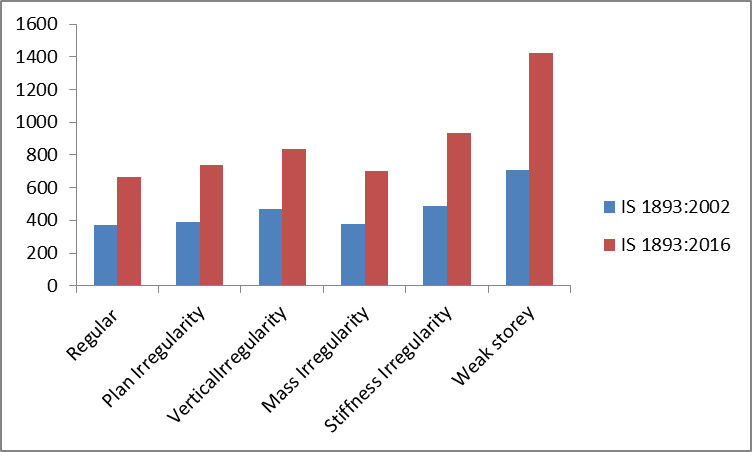
|  |  |  |
| --- | --- | --- |
| **Type of Model** | **IS 1893:2002** | **IS 1893:2016** |
| Regular | 370.935 | 666.208 |
| Plan Irregularity | 392.576 | 736.731 |
| Vertical Irregularity | 468.698 | 834.926 |
| Mass Irregularity | 377.129 | 701.31 |
| Stiffness Irregularity | 488.377 | 934.892 |
| Weak storey | 709.518 | 1423.33 |

Fig.13-Maximum moment Y(kNm) in columns

Table 10- Maximum moment Z (kNm) in columns

|  |  |  |
| --- | --- | --- |
| **Type of Model** | **IS 1893:2002** | **IS 1893:2016** |
| Regular | 537.995 | 1082.54 |
| Plan Irregularity | 536.513 | 1120.87 |
| Vertical Irregularity | 408.965 | 871.491 |
| Mass Irregularity | 546.83 | 1135.72 |
| Stiffness Irregularity | 545.523 | 1006.91 |
| Weak storey | 1466.03 | 2017.62 |

Fig.14-Maximum moment Z (kNm) in columns

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**CONCLUSIONS**

* Base shear for mass irregularity is highest. Approximately 20% increase in base shear is calculated after using IS 1893:2016.
* Storey shear and base shear in both the directions i.e. along X-direction and along Z-direction are increased by nearly same amount i.e. approximately 20% when using IS 1893:2016.
* Models using IS 1893:2016 shows 10% - 20% rise in axial force in columns when compared with models using IS 1893:2000.
* Models using IS 1893:2016 shows 15% - 25% rise in shear force in columns when compared with models using IS 1893:2000.
* Models using IS 1893:2016 shows 30% rise in moments in columns when compared with models using IS 1893:2000.

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