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Seismic Analysis of RCC Multistoried Building by IS 1893:2016 and it's Comparison with IS 1893:2002

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Abstract: *The sixth revision of IS 1893 (Part 1): 2016, "Criteria for Earthquake Resistant Design of Structures" and first code of tall building IS 16700: 2017, "'Criteria for Structural Safety of Tall Concrete Buildings" have been published by Bureau of Indian Standards recently. In this new code many changes have been included considering standards and practices prevailing in different countries and in India.In this study, performance of RCC buildings with G+12 and G+16 storeyhas been evaluated by both equivalent static analysis and response spectrum analysis method. Performances of these building models are studied for zone II, II, IV and V and compared. Entire mathematical 3D models using the finite element software ETABS.*
Key Word*: Seismic loads, IS1893:2016, IS 1893:2002, RC Framed Buildings, Tall Buildings*

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I. Introduction

In overhauling world, infrastructures have become omnipresent and it is inevitable to imagine today's world without it. Buildings made from concrete is one of the basic form of infrastructures which can be seen everywhere. Process of construction of a building entails different department such as architects, structure designer, contractors etc. with all the help of these departments, building is being erected such that it can withstand vigorous vertical loads and ground motion which is the result of earthquakes. Designer has to be very careful while considering these forces as little miscalculations will lead to failure of the structure because ground motions, being the complex concept, needs to be analyzed in a very scrutinized manner. Therefore, the resistance of a building and its design as per the guidelines of seismic codes has become an important research area. Sometimes, addition of members other than beams and columns are required to resist these produced lateral forces.

IS: 1893-2016, being the latest Seismic Indian Code, provides amendments regarding the design of the earthquake resistant building. Various amendments and new guidelines were introduced in this code but the major one was related to the dynamic seismic analysis. It stated that dynamic seismic analysis shall be adopted for all the buildings other than regular buildings lower than 15 m in height in seismic zone II.

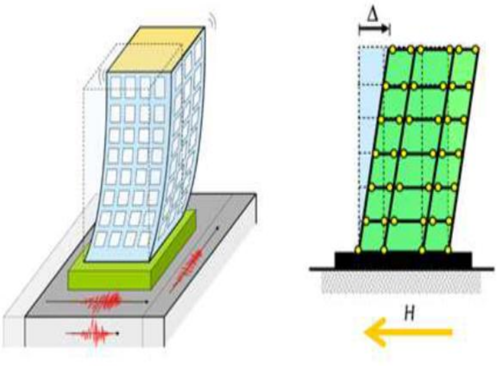

Figure no. **1**: Ground Motion during Earthquake

Previously, dynamic seismic analysis shall on be adopted if the height of regular building exceeds 40m, otherwise static seismic analysis shall be used. Therefore, while keeping both the codes (new and old version of earthquake code), a comparative study of static analysis (as per is: 1893-2002) & dynamic analysis (as per is: 1893-2016) in seismic zone V has been carried out. Various seismic parameters are to be considered while designing earthquake resistant building such as type of structure, material which is being used for construction, type of foundation soil etc. Two different methods, which are being used for making the structures earthquake resistant, are:

1. Equivalent Static Seismic Analysis
2. Dynamic Seismic Analysis.
   i. Response Spectrum Method
   ii. Modal Time History Method
   iii. Time History Method

II. Comparison of IS 1893:2002 and IS 1893:2016

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. 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 revisions 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.

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.

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.

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.

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.

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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.

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.

i. Steel Buildings with OMRF – 3.0
ii. Steel Buildings with SMRF – 5.0

iii. Buildings with ordinary braced frame having concentric braces – 4.0
iv. Buildings with special braced frame having concentric braces – 4.5
v. Buildings with special braced frame having eccentric braces – 5.0
vi. Unreinforced masonry with horizontal RC seismic bands – 2.0
vii. 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
viii. Confined masonry – 3.0
ix. Buildings with ductile RC structural walls with RC OMRFs – 4.0
x. 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 /m^2. 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. Aw is total effective area in m^2 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 m^2, Lwi is length of structural wall i in the first story 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.

III. Building Description

The study is carried out on RCC moment resisting buildings. The buildings considered is the commercial building having G+12 storeys and G+16 storeys . Height of each storey is 3.2m. The building has plan dimensions 16m x 16m as shown in the Figure 1. Other relevant data is tabulated in table no.1. In the analysis special moment-resisting frame (SMRF) are considered.

IV. Modeling of Building

The building is modeled using the finite element software ETABS Version 17. 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 node 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 node shell element with six DOF at each node. In the modeling, material is considered as an isotropic material. The 3D building model generated in ETABS is shown in figure 2 and 3.

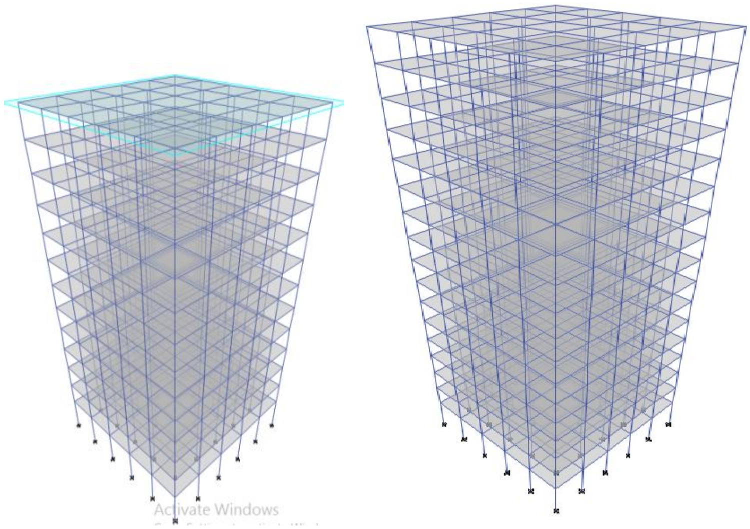

Figure no. **2 and 3:** 3D Model of building generated in ETABS (G+12) and (G+16)

Table no.1: Analysis Data

Sr. No.	Descriptions	Details
01	Plane dimensions	16x16 m
02	Total height of building	43.1m(G+12) & 55.9m(G+16)
03	Height of each storey	3.2m
04	Height of parapet	1m
05	Depth of foundation	1.5m
06	Size of beams	300x600mm
07	Size of columns	500x500mm (G+12) 750x750mm (G+16)
08	Thickness of slab	125 mm
09	Thickness of external walls	230 mm
10	Thickness of internal walls	115mm
11	Seismic zone	II, III, IV, V
12	Soil condition	Hard
13	Response reduction factor	5
14	Importance factor	1, 1.2
15	Floor finishes	1.5 kN/m^2
16	Live load at all floors	3 kN/m^2
17	Grade of Concrete	M35
18	Grade of Steel	Fe500
19	Density of Concrete	25 kN/m^3
20	Density of brick masonry	20 kN/m^3

To compare the seismic performance of G+12 and G+16 storey buildings, four building models are generated using ETABS. Brief description of all these models is given below.

a) RCC building with G+12 Storey

Model I: G+12 storey building analyzed with IS 1893:2002 with Zone II
Model II: G+12 storey building analyzed with IS 1893:2002 with Zone III
Model III: G+12 storey building analyzed with IS 1893:2002 with Zone IV
Model IV: G+12 storey building analyzed with IS 1893:2002 with Zone V
Model V: G+12 storey building analyzed with IS 1893:2016 with Zone II
Model VI: G+12 storey building analyzed with IS 1893:2016 with Zone III
Model VII: G+12 storey building analyzed with IS 1893:2016 with Zone IV
Model VIII: G+12 storey building analyzed with IS 1893:2016 with Zone V

b). RCC building with G+16 Storeys

Model I: G+16 storey building analyzed with IS 1893:2002 with Zone II
Model II: G+16 storey building analyzed with IS 1893:2002 with Zone III
Model III: G+16 storey building analyzed with IS 1893:2002 with Zone IV
Model IV: G+16 storey building analyzed with IS 1893:2002 with Zone V
Model V: G+16 storey building analyzed with IS 1893:2016 with Zone II
Model VI: G+16 storey building analyzed with IS 1893:2016 with Zone III
Model VII: G+16 storey building analyzed with IS 1893:2016 with Zone IV
Model VIII: G+16 storey building analyzed with IS 1893:2016 with Zone V

V. Model Analysis

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 they 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.

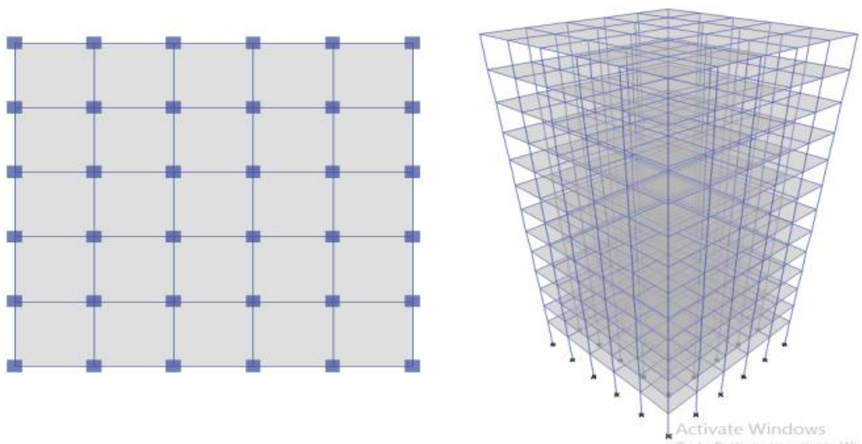

Figure no. **4**: Plan and 3D view of G+12 Building

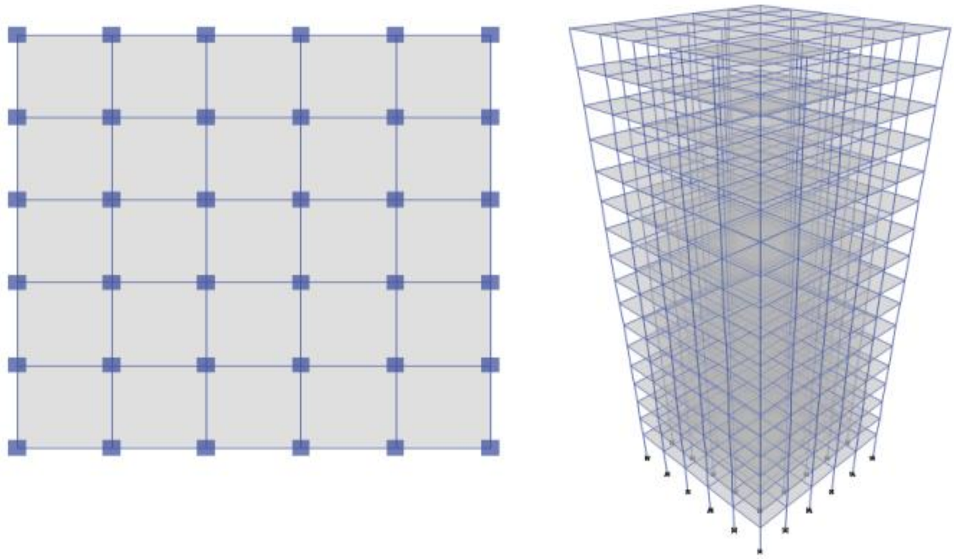

Figure no. **5**: Plan and 3D view of G+16 Building

VI. Results

As the continuous analysis and efforts put by researchers to study the behavior and performance of structure during past earthquake leads to development and advancement in designing earthquake resistant structure. Therefore, it is required to revise the seismic code time to time. IS: 1893-2016 revised after 14 years in year 2016. And first tall building code IS 16700-2017 has been developed. In this study an attempt is made to compare seismic performance of multistoreyed RCC buildings analyzed by using both IS 1893-2002 and IS 1893-2016. For this, different building models with different number of storeys i.e. G+12 and G+16 are considered. The 3D analysis of building is carried out for earthquake zone II, III, IV and V.

VII. Conclusions

In the dissertation work, entitled "Seismic response of RCC multistoried buildings by using new code IS 1893:2016, IS 16700:2017 and its comparison with IS 1893:2002", analytical study is carried out on a G+12 and G+16 storey building. The 3D analysis of building is carried out for earthquake zone III. The main objective of the study was to compare seismic performance of RCC multistory building following provisions of IS 16700:2017, after analyzing them by new code IS 1893-2016. The comparisons parameter considered were lateral displacement, storey drift, time period and base shear.

All the above building models are generated using the finite element software ETABS 17 and are analyzed using equivalent static method and response spectrum method.Based on the analysis results following conclusions are drawn;In general, there is considerable increase in response of building after analyzing by new code IS 1893:2016 as compared to IS 1893:2002 for both equivalent static and response spectrum analysis.Storey shear and base shear increased by 20% after analyzing by new code IS 1893:2016 as compared to IS 1893:2002 for both equivalent static and response spectrum analysis. It is due to change in importance factor for multi storey residential buildings. It 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.

Response spectra for Equivalent Static Method and Response Spectrum method are given separately, in both cases Sa/g values will change. It will change the values of Ah and VB.In old IS 1893-2002 full section, i.e. full M.I. of columns and beams is considered. In new code IS 1893-2016, cracked section with 70% MI of columns and 35 % MI of beams is considered. As cracks may develop in structure after some period, MI of sections may reduce and hence for safety it is more reasonable to consider cracked section properties in analysis.Due to change in MI, there is reduction in displacement observed, this reduction is upto 134% for G+12 Building and upto 170% for G+16 Building.

As per new IS 1893-2016 Equivalent static analysis shall be applicable for regular buildings with height < 15m in seismic Zone II. So Dynamic analysis is compulsory for almost all buildings in all zones.It is observed that there is significant increase in the lateral drift and displacement demand which ultimately increases the member forces, and design.Time Period of building is also increased by 40% for G+12 building and 51% for G+16, this is again may be due to reduction in moment of inertias of structural elements for IS 1893:2016 as compared to IS 1893:2002. For G+12 storey building, there is increment in storey drift by nearly

156% by using IS 1893:2016 as compare to IS 1893:2002 for response spectrum analysis. For G+16 storey building, there is increment in storey drift by nearly 188% by using IS 1893:2016 as compare to IS 1893:2002 for response spectrum analysis.

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