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Comparative Analysis of Seismic Design Standards for Structures and Safety Standards for High-rise Concrete Building Structures

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Abstract: *The core of this study is the comparative analysis of I S. 1893 (Part One): 2016 Edition (Code for Seismic Design of Structures) and I S. 16700:2017 (Code for Safety of High rise Concrete Building Structures). In addition, the study aims to uncover the key factors that contribute to poor performance of buildings in earthquakes, with the aim of improving the safety performance of structures in earthquakes in the future. As a research case, we selected a specific reinforced concrete moment shelving frame (SMRF) building at Jabalpur Airport. The building structure was modeled and analyzed using SAPpro V20i software. According to software calculations, we obtained the time history analysis results of the structure in two directions and ensured that they comply with the two Indian standards mentioned above. Subsequently, by comparing the structural responses under the two standards, we evaluated the significant differences in foundation shear force, displacement, and mass participation. The research results indicate that compared to I S. 1893 (Part One): 2016, following I S. The performance of the 16700:2017 structure in earthquakes is relatively poor.*

Keywords: Seismic Analysis, I.S 16700:2017, I.S 1893(Part I):2016, Base shear, Displacement

1. Introduction

Natural calamities such as earthquakes, Tsunamis and floods causes' severe damage and suffering to human being by destroying structures, transport system, navigation system, animals hazards etc. However, civil engineers play an important role for minimizing the damages by proper designing, maintain or provision against earthquake structures. This includes the knowledge about the earthquakes, behavior of materials as well as structural elements in seismic load to which structural engineers make use of information for proper designing of structures made in reinforcement concrete.

An earthquake is the shaking of the surface of the earth resulting from the sudden release of energy in the lithosphere that creates seismic waves. For reducing the earthquake effect or forces which is in lateral direction by shear wall or Special Moment Frame. Special Moment Frames a rectilinear assemblage of beams and columns which resist lateral forces by rigid frame members and joints. Twist in building called Torsion, due to torsion more damages are observed in frames as well as wall. Many building have been severely affected by this excessive torsional behavior during past earthquakes. It cannot be completely avoided but it can be minimize by doing special design calculations which are provided in standard codes for each country according to their geometry, seismic zone and soil type. In India, IS 1893(Part I):2016 (Criteria for Earthquake Resistant Design of Structures) and I.S.16700:2017(Criteria for Structural Safety of Tall Concrete Buildings) used. Seismic building codes are guidelines to design and construct the buildings and civil engineering works in seismic regions which is to protect human lives from damages are happened during earthquake.

2. Objectives

The chosen standards are IS: 1893(Part I):2016 and IS16700: 2017; A comparative analysis was performed in terms of Base shear, Displacement. To bring out the main contributing factors which lead to poor performance during earthquake.

3. Literature Review

Urunkar S.S and Bogar V.M both are studied the comparison in between IS 1893(Part I):2012 and IS 1893(Part I):2016. In this clauses provided in seismic code for designers improve the behavior of structures during an earthquake. This work mainly focuses on the revised codal provisions in IS 1893(Part I):2016.[1] Sergio Hampshire De C. Santos and Luca Zanaica are presents a comparative evaluation among some International, European and American seismic design standards. A model for standard reinforcement concrete building has been developed in SAP 2000 and SFiSFiK and subjected to seismic input according to each code and result will be compared.[2] Mehul J. Bhavsar and Kavita N. Choksi are compared Indian and Euro standards under seismic forces by using a residential building with G+7 in ETABS software and results mainly compared with storey drift. [3] Prakash Channappagoudar and Vineetha Palankar are deals with a building in Pune is taken into consideration for analysis with respect to wind load for different number of floors by using both IS 875(Part III):1987 and IS 875(Part III):2015 with newly revised code as well as includes IS 16700:2017 for tall building structures.[4]

Amit Anwade and Shubham Aher are presenting a residential building of G+10, G+15, G+20 and G+25 with (SMRF) is taken and modeling done on STAAD pro V8i and parametric analysis and study done by using IS code, IBC and Canada code.[5] Angelo Masi and Marco Vona are doing parametric study on reinforcement concrete frame by using European seismic code (EC8-3) for different analysis method. The results are compared to understand the

4. Methodology

1) Literature survey for basic information against analysis as well as comparison of standard codes.
2) Study the IS 1893 (Part I) : 2016 and IS 16700:2017.
3) Model generation using SAP2000vi20.
4) Analyzing the model by each code for different conditions.
5) Plotting the graph according to displacement, base shear as well as mass participation
6) Evaluation of result.
7) Conclusion.

5. Location, Description and Plan of Structure

5.1 Passenger Terminal Building (PTB)

Jabalpur is a tier 2 city in the state of Madhya Pradesh (MP), India. It is one of the most famous cities of Madhya Pradesh. This report covers the structural design basis for Proposed Development at Jabalpur Airport, Jabalpur, MP. Said proposed development consists of Passenger Terminal Building (PTB).

Total area equals to 9431 m^2 and will consist of Level 0, Level1 and Level2. Roof system provided for PTB Building consists of RCC beams spanning between the main columns and having span of 22m approximately. Said beams are aligned in diagonal fashion to support four modules of roof slab panel.

Each roof module is having hyperbolic parabolid geometry which facilitates sun light acting as a north light. It would be constructed in RCC and would have periphery edge beam which would act not only as stiffening member but will also act as gutter. A Hyperbolic Paraboloid is an infinite surface in three dimensions with hyperbolic and parabolic cross section.

Above figure shows the plan of Passenger Transport Building (PTB) in SAP 2000 vi20.This table shows the description of structure in tabular form:

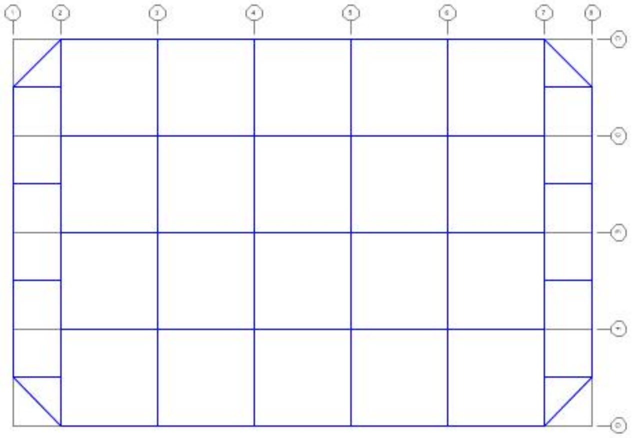

Figure 1: Plan of Structure

Table 1: Description of structure

Parameters	Dimension/ Type
Plan Dimension	100 x 90 m
No. of Stories	G
Height of Each stories	17m
Grade of Concrete	M30
Grade of Steel	HYSD Fe 500
Frame Type	Special Moment Frame (SMRF)
Zone	I
Soil Type	Hard Soil
Inner Wall	200mm
Outer Wall	300mm
Slab Thickness	150mm
Unit Weight of Concrete	25kN/m^3
Unit Weight of Steel	78.5 kN/m^3
Shear Wall Thickness	200mm
Beam Size	200 x 600, 350 x 750, 200 x 450 mm
Column Size	900D, 450 X 600, 300 X 300 mm
Roof Type	Hyperbolic Parabolid

5.2 Study of Standard Codes

a) IS1893 (Part I): 2016 primarily deals with earthquake hazard assessment for earthquake-resistant design of building, bridge, retaining wall.
b) IS 16700: 2017 primarily deals with earthquake hazard assessment for high rise building which is 50m height greater but less than or equal to 250m. This standard may also be used for design of buildings of height equal to or less than 50m.
c) New IS 1893(Part I) have same stiffness modifiers for SLS (unfactored loads) and ULS (factored Loads) as per clause 6.4.3.1. There are different stiffness modifiers for SLS and ULS in IS 16700:2017 code as per clause 7.2 (table7)
d) Clause 1.3 of IS 16700:2017 code states that buildings below 50m can also be designed using tall building code to add value to the design.
e) Stiffness modifiers for ULS are almost same in both codes. However, That for SLS is more in IS 16700:2017 code. For Structural analysis, the moment of inertia and area shall be taken as :

Table 2: Parameters according to IS 1893(PartI):2016

According to I.S.1893(Part I):2016 (clause 6.4..1)	
Beams	$0.35\ I_{gross}$
Columns	$0.7\ I_{gross}$

Table 3: Parameters according to IS 16700:2017

According to I.S.16700:2017 (clause 7.2)				
Structural Elements	Unfactored Loads		Factored Loads	
	Area	Moment of Inertia	Area	Moment of Inertia
Slabs	$1.0A_g$	$0.35I_g$	$1.0A_g$	$0.25I_g$
Beams	$1.0A_g$	$0.7\ I_g$	$1.0A_g$	$0.35\ I_g$
Columns	$1.0A_g$	$0.9\ I_g$	$1.0A_g$	$0.7\ I_g$
Walls	$1.0A_g$	$0.9\ I_g$	$1.0A_g$	$0.7\ I_g$

6. Results

1) Result obtained for Mass Participation

The Mass Participation Factors associated with each mode represents the amount of system mass participating in that mode. Therefore, a mode with a large effective mass is usually a significant contributor to the system's response. For comparing purpose we took 5 node points.

Table 4: Results obtained by Mass Participation in Case I

Case I : I.S.1893:2016(Part I)				
Node	Frequency	Sum U_x	Sum U_y	Sum U_z
1	0.42064	0.70867	7.56E-09	9.12E-13
2	0.442194	0.70867	0.88132	2.8E-05
3	0.537104	0.8826	0.88132	2.8E-05
4	1.73521	0.8826	0.88221	0.00347
5	1.897177	0.88262	0.88221	0.00347

Table 5: Results obtained by Mass Participation in Case II

Case II : I.S.16700:2017 (Factored Load)				
Node	Frequency	Sum U	Sum U	Sum U
1	0.450656	x [illegible]	y [illegible]	z [illegible]
2	0.450656	0.70361	0.88048	1.5E-05
3	0.550065	0.88137	0.88048	1.5E-05
4	1.845662	0.88137	0.88122	0.00451
5	2.001978	0.88138	0.88122	0.00451

Table 6: Results obtained by Mass Participation in Case III

Case III : I.S.16700:2017(Unfactored Load)				
Node	Frequency	Sum U_x	Sum U_y	Sum U_z
1	0.571174	0.71211	4.2E-09	4.61E-13
2	0.620431	0.71211	0.85743	1.94E-05
3	0.74092	0.858	0.85743	1.94E-05
4	2.415943	0.858	0.8576	0.08696
5	2.522641	0.858	0.8582	0.10855

2) Result obtained for Base Shear

Base shear is the maximum expected lateral force that will occur due to seismic ground acceleration at the base of the structure.

Table 7: Results obtained by base shear

Cases	I.S.1893:2016 (Part I) kN	I.S.16700:2017 (Factored Load) kN	I.S.16700:2017 (Unfactored Load) kN
In X direction	5597.77	6010.334	5713.12
In Y direction	5590.75	6011.298	5612.45
In Z direction	8023.44	8999.822	8123.732

3) Result obtained for Displacement

The difference between the initial position of something (such as a body or geometric figure) and any later position. For comparing purpose we took 5 node points which on slab.

Table 8: Results obtained by displacement in Case I

Node	CASE I : I.S.1893(Part I):2016	
	In X direction(m)	In Y direction(m)
70	0.086986	0.074999
71	0.084129	0.074887
72	0.084807	0.074856
73	0.085503	0.07483
74	0.086217	0.074817
Maximum	0.120259	0.01518
Minimum	0.062004	0. 010583

Table 9: Results obtained by displacement in Case II

Node	CASE II : I.S.16700:2017 (Factored Load)	
	In X direction (m)	In X direction (m)
70	0.084302	0.084302
71	0.081508	0.081508
72	0.082181	0.082181
73	0.082867	0.082867
74	0.083563	0.083563
Maximum	0.107329	0.013962
Minimum	0.054569	0

Table 10: Results obtained by displacement in Case III

Node	CASE III : I.S.16700:2017 (Unfactored Load)	
	In X direction (m)	In X direction (m)
70	0.049815	0.049815
71	0.048265	0.048265
72	0.048635	0.048635
73	0.049014	0.049014
74	0.0494	0.0494
Maximum	0.062453	0.041105
Minimum	0.033837	0.039562

7. Discussion

Comparison in between three cases shows by graphical representation:

1) On Mass Participation

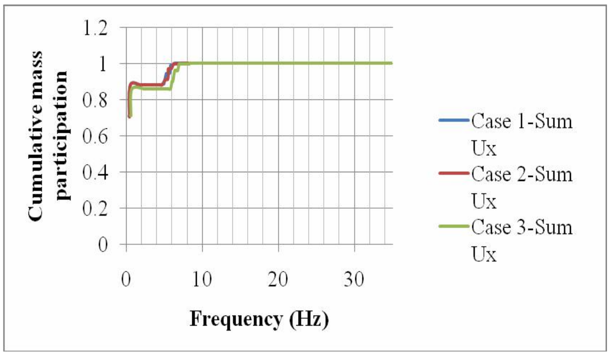

Figure 2: Mass Participation graph in X direction

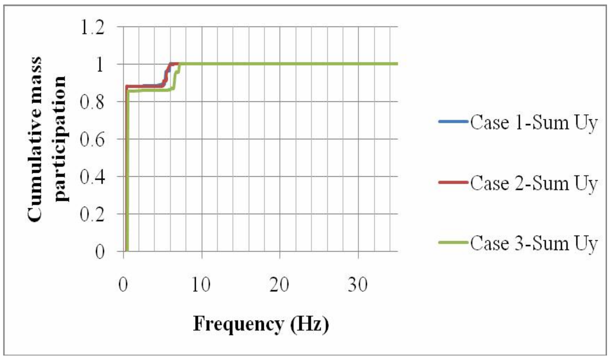

Figure 3: Mass Participation graph in Y direction

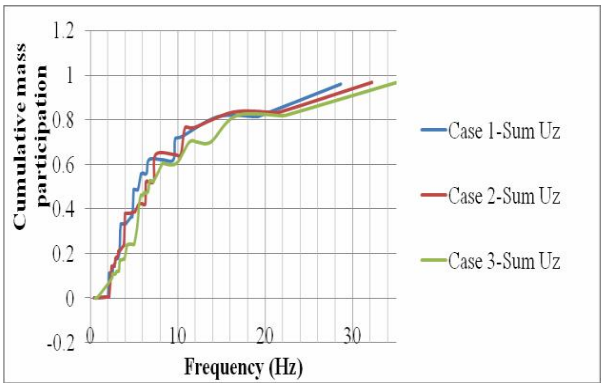

Figure 4: Mass Participation graph in Z direction

2) On Base Shear

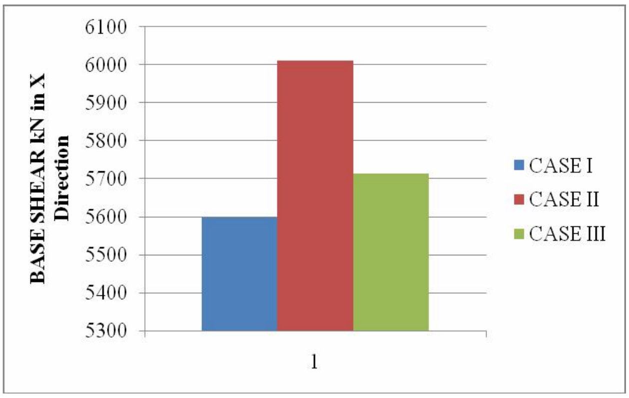

Figure 5: Base shear graph in X direction

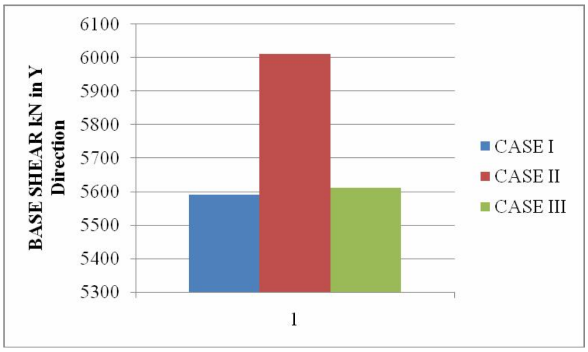

Figure 6: Base shear graph in Y direction

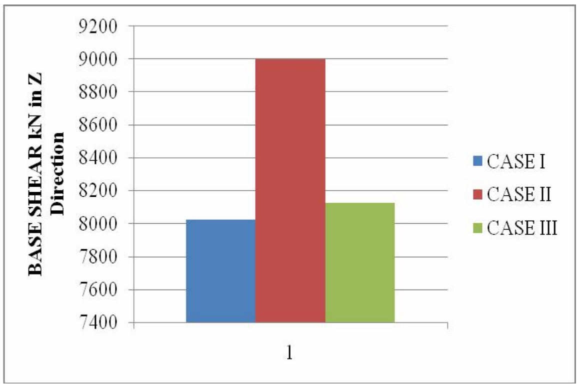

Figure 7: Base shear graph in Z direction

3) On Displacement

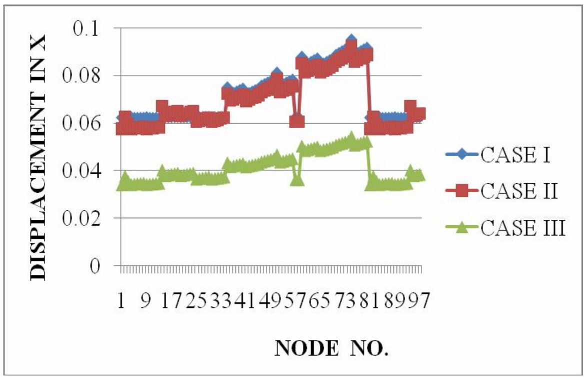

Figure 8: Displacement graph in X direction

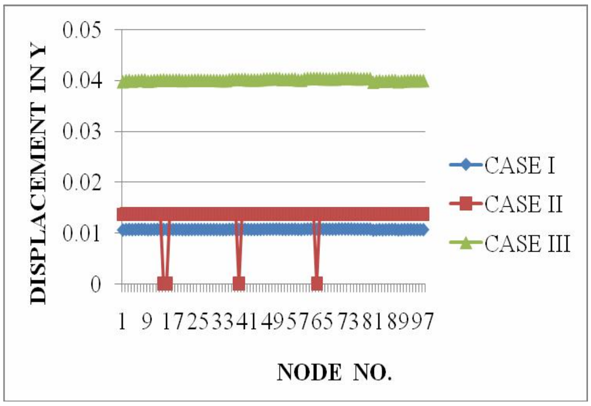

Figure 9: Displacement graph in Y direction

8. Conclusion

1) Conclusions for Mass Participation

Calculation of Mass Participation is taken for checking the how elements are behave in analysis. If its showing the same behaviour then IS 1893 used for designing purpose and IS16700 used for displacement and deflection checking purpose. Here, it shows different behaviour. Thus, we conclude below.

2) Conclusions for Base Shear

- Calculated base shear in X-direction shows, 8.19% more according to I.S.16700:2017 as compared to I.S.1893 (Part I):2016.
- Calculated base shear in Y-direction shows, 8% more according to I.S.16700:2017 as compared to I.S.1893 (Part I):2016.
- Calculated base shear in Z-direction shows, 11% more according to I.S.16700:2017 as compared to I.S.1893 (Part I):2016.

3) Conclusions for Displacement

Displacement as per I.S.16700:2017 shows 8.4% less as compared to I.S.1893 (Part I):2016 in both directions.

Thus, if a building (below 45m) is designed using IS 16700:2017 (Criteria for Structural Safety of Tall Concrete Buildings) for earthquake resistant structures which give good results as compared IS 1893(Part I):2016(Criteria for Earthquake Resistant Design of Structures)

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