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Seismic Analysis of Plan Irregular Multi-Storey Building Using IS 1893 (Part-1):2016 and its Comparison with IS 1893(Part-1):2002

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Abstract—*After a long time of 14 years, the Indian seismic code "Criteria for earthquake resistant design of structures" was revised in 2016. Main intention of this research is to highlight the various provisions and parameters in new code specially related with irregularity and dynamic analysis and also find out the performance of RC plan irregular multistory building with both old and new code. For this work G+15 RCC multi-story building with H, L and T shape is modeled and analyzed with IS 1893(Part-1):2002 and IS 1893(Part-1):2016 in zone III on medium soil to find out the effect of irregularity on RCC structures using ETABS 2017 software. In this study the parameters i.e. storey-drift, storey stiffness, overturning moment and model mass participation ratio for all models are considered and compared using Response spectrum method of analysis. The results shows higher values of storey drift, overturning moment in case of models analyzed with IS 1893(Part-1):2016 but the storey stiffness values are same from both the codes. The model mass participation ratio is greater than 65% and the L shape model shows more variation compared with other models.*

Keywords: *Storey drift, Storey stiffness, Overturning moment, Plan irregularity, Response spectrum analysis, IS 1893(Part-1):2002 and 2016.*

1. INTRODUCTION

Seismic code provides help to develop and improve the conduct of structure to the creator. So that, it can endure during earthquake impact and decrease loses. They are interestingly different for specific nation and district. The seismic codes are set up with keeping all factors like acknowledged degree of seismic hazard, thought of seismology of nation, properties of development materials, structure typologies, development strategies and so on. So, the clauses and specifications kept written in the seismic codes depend on the comprehension, tests and scientific contextual analysis made during past especially in seismic prone area. "Criteria for Earthquake Resistant Design of Structures" i.e. IS 1893(part-1) is utilized as code of training for examination and planning of quake safe structures in India. IS: 1893(part-1)2016, Being the latest revised Seismic Indian Code of the previous code IS 1893:2002, provides amendments regarding the design of the earthquake resistant building.

In the research we try to understand the changes in both codes by doing it with the help of software on a RCC building with irregular configuration. Since the Reinforced concrete building frames are most common types of construction in urban India. Due to the growing population and the demand we need to make the building in the limited space and also in multi-stories. For fulfilling the needs and providing the habitat to every individual we need to make the buildings in different shapes and also the high rise buildings are provided.

In this paper it was studied that the real structures are almost irregular and the perfect regular structure is only a myth it is practically not possible. The earthquake and wind forces are usually greater than the design base shear of the structure which results in extra shear and torsion of the irregular structure. Due to these extra shear and torsion, the seismic performance of the building decreases. The major issue is the lateral instability while designing a multistory building. Most of construction in recent time consist of poorly design and constructed building in urban areas. The older buildings may not comply with the more stringent specifications of the latest standards of IS 1893(Part-1):2016, even if constructed with the most popular code.

1.1 Changes in Latest IS 1893(Part-1):2016-

Various important changes for the analysis and design of earthquake resistant building are given below:

(i) For Regular buildings- The buildings found in zone III, IV and V having height more than 48m and those in zone II having height more than 70m adopted dynamic analysis method. But, buildings in zone III, IV and V having height less than 48 m and those in zone II having height less than 70 m adopted static equivalent method for analysis.

(ii) For Irregular building- Buildings in zone III,IV and V having height more than 12m and in zone II having height more than 48 m adopt dynamic analysis method.

(iii) The design spectra is extended upto 6 seconds and separate spectrum are defined for both static equivalent method and response spectrum analysis method. The Figures in code show these graphs of design acceleration coefficient corresponding to 5% damping. Hence, the clause 6.4.2 mentioned in code IS 1893(part-1):2016 gives the expression to determine the Sa /g value for equivalent static method as well as for response spectrum method. The table 4 in new code tells about the classification of different type of soil.

(iv) The cracked section is now added for structural analysis of RC and masonry structures because the equivalent moment of inertia is taken as 70% of gross M.I. for column and 35% of gross M.I. for beam. But, in case of steel structures, the equivalent M.I. is taken equal to gross M.I. for both columns & beams.

(v) In IS 1893 (Part1): 2016, Importance factor is now increased to 1.2 for building more than 200 person's occupancy. It will cause big problems for buildings which are of low cost having high density.

(vi) The new code included the URM wall in the structure it tells when and how to place URM wall. If plan density of unreinforced masonry infill wall is greater than 20% then URM wall is included in the design.

(vii) For stiffness irregularity the code is now become more disciplinary and rigid.

(viii) The building height h is defined excluding the basement storey when connected with ground floor deck and includes the basement storey when not connected with the deck.

(ix) The conditions for vertical earthquake loads are fully explained in the code.

(x) This code gives the criteria for building having flat slabs.

(xi) Now we got clarity regarding how to handle various kinds of irregularity in structural system.

(xii) Now in the analysis and design of RC buildings the effect of masonry infill wall has also been included. A new method is added to find out the approximate natural time period of building having irregularities i.e. step back structure, basements and building on hilly slopes.

(xiii) The Provisions on potential analysis of liquefaction and provision on torsion are simplified with simple methods.

In the paper, a multi-storey commercial building with plan irregularity is studied for earthquake forces with both the old and new codes of earthquake resisting structures using response spectrum analysis. The modeling and analysis is done in ETABs 2017. The building is located in zone III on medium soil. The response of the structure in terms of drift, stiffness and overturning moment is find out. The comparison charts of all the models are plotted for different parameters to have a clear view of the impact of irregular configuration on RC structures.

Hence, the objectives of this paper are-

1) To study changes and adaptation of new provisions and clauses in IS 1893 (Part-1): 2016 with respect to previous IS 1893 (Part-1): 2002 and their effect.
2) To analyze the RC Multi-storey building (G+15) having plan shape H, L and T with IS 1893(Part-1):2002 and IS 1893(Part-1):2016 in seismic zones III by using ETABs 2017 software.
3) To find the parameters like storey drift, storey stiffness, overturning moment with response spectrum method using both codes.
4) Plot the comparison charts of all the models presenting parameter resulted after analysis with both codes.

2. Problem statement

Consider G+15 RC special moment resisting frame multistory building of different shape (H, L and T) having re-entrant corners. Their 3D view are shown in figure below. Zone III is taken for the location of building. The soil is medium stiff and the building is commercial building.

Description of structure

1. Height of building = 48.5m
2. Bottom storey height = 3.5m
3. Floor height = 3mm
4. Size of external column = 450×550mm
5. Size of internal column=400×500mm
6. Size of external beam = 350×450mm
7. Size of internal beam=300×400mm
8. Thickness of slab = 130mm
9. Grade of concrete = M30(for columns)
10. Grade of concrete = M25(for beam and slabs)
11. Grade of steel= Fe 250 and HYSD 500

Load on structure:

Dead load-self weight of structure
Live load::3 KN/m^2
Load on External wall:: 14KN/m
Load on Partition wall:: 7KN/m

Table 1: Seismic data

1.	Earthquake Zone	III
2.	Zone factor(Z)	0.16
3.	Damping Ratio	5%
4.	Importance Factor(I)	1{as per IS 1893(Part1):2002} 1.2{as per IS 1893(Part1):2016}
5.	Response Reduction Factor (R)	5
6.	Type of soil	Medium soil

3. Structural Modeling

For the purpose of this study, three high rise models of RC frame irregular building (G+15) with H, L and T configuration having Re-entrant corner were selected to find out the seismic force resisting capacity of the structure. All the columns are taken restrain and fixed at the ground. 48.5m high building with base storey height 3.5 and floor height 3m.Figures 1, 2and 3 show the geometrical configuration like 3D view of the building. The no. of bays in X and Y direction are15.ETABs an FEM based software is used for modeling and analysis of the nodels. Study the seismic behaviour of multistorey irregular building in term of different the parameters like storey-drift,stiffness and overturning moment.The models with plan irregularity are taken as:

Model 1: G+15 H shape
Model 2: G+15 L shape
Model 3: G+15 T shape

The ETABs 2017 is used to model and analyse the structures. The steps in etabs are discussed below:-

1. Define the grid lines
2. Define the plan dimensions
3. Define the properties of members and material
4. Assign all loads and different load combinations
5. Define the function
6. Check model for any error
7. Run the analysis
8. Find out results and discussion

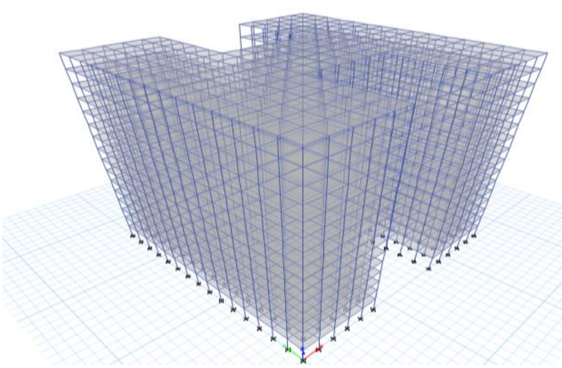

Fig. 1: 3D view (H shape)

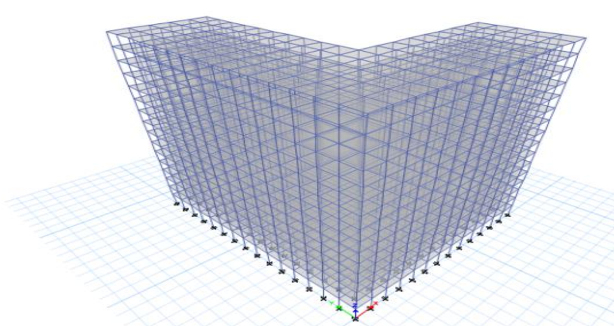

Fig. 2: 3D view(L shape)

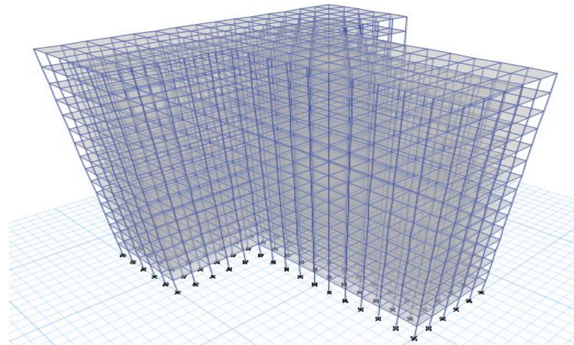

Fig. 3: 3D view (T shape)

4. Analysis

According to the new code, the dynamic analysis is carried out as the building is irregular having 48.5m height. There are three models of G+15 multi-story irregular building in shape H, L and T is modeled in ETABS 2017. These models are analyzed with the same software i.e. ETABS 2017. The loading and all other relevant considerations are same for all the shapes of buildings. According to the new code, the models are also analyzed for vertical earthquake load. The Dynamic analysis will be done in two cases with the Response spectrum analysis method as the method of analysis. The various parameters like storey drift, storey stiffness and overturning moment are find out. The results of the analysis are found out and discussed.

5. Result And Discussion

5.1 Storey Drift

The models analyzed with new code showing higher value of storey drift as compared with old code analysis. The tables and the graphs below are showing the maximum storey drift values of all models in X and Y direction with both the codes.

Table 2: Storey Drift (mm) comparison in X-direction

Model	IS 1893(Part-1):2002	IS 1893(Part-1):2016
1	1.348	1.618
2	1.218	1.724
3	1.504	1.805

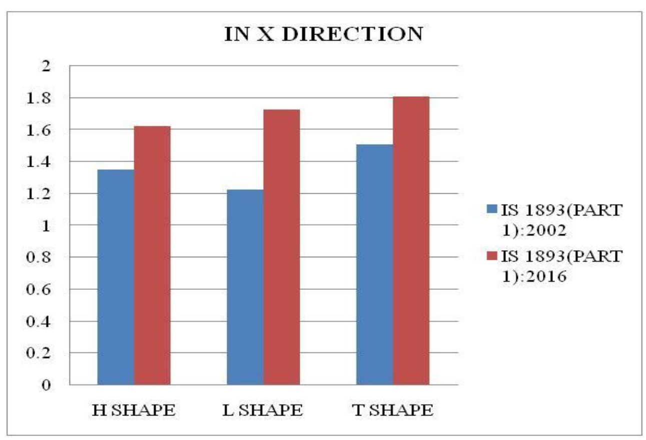

Fig. 4: Storey Drift (mm) comparison in X-direction

Figure 4 shows graphical representation between storey drift in X direction with plan irregularity by Response spectrum analysis using IS1893 (Part-1):2002 and IS 1893(Part-1):2016. It shows that the storey drift in X direction is increased by 20% in H shape, 42% in L shape and 20% in T shape but didn't exceed the permissible limit.

Table 3: Storey Drift (mm) comparison in Y direction

Model	IS 1893(Part-1):2002	IS 1893(Part-1):2016
1	1.412	1.694
2	1.293	1.774
3	1.426	1.71

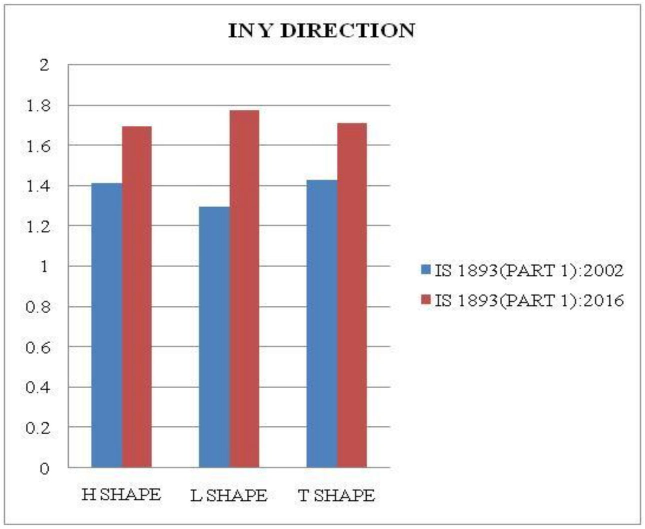

Fig.5: Storey Drift (mm) comparison in Y direction

Figure 5 shows graphical representation between storey drift in Y direction with plan irregularity by Response spectrum method using IS 1893:2002 and IS 1893:2016. It shows that the storey drift in Y direction is increased by 20% in H shape, 37% in L shape and 20% in T shape but didn't exceed the permissible limit.

5.2 Storey Stiffness

The models analysed with new code showing similar value of storey stiffness as compared with old code analysis. The tables and the graphs below are showing the maximum storey stiffness values which is at storey 1 of all models in X and Y with both the codes.

Table 4: Storey Stiffness (KN/m) comparison in X-direction

Model	IS 1893(Part-1):2002	IS 1893(Part-1):2016
1	3855014.4	3855014.4
2	2400263.01	2399343.5
3	2636953.4	2636105.7

Fig. 6: Storey Stiffness (KN/m) comparison in X-direction

Figure 6 shows graphical representation between storey stiffness in X direction with plan irregularity by Response spectrum analysis method using IS 1893(Part-1):2002 and IS 1893(Part-1):2016.

Table 5: Storey Stiffness (KN/m) comparison in Y-direction

Model	IS 1893(Part-1):2002	IS 1893(Part-1):2016
1	3124765.9	3124765.9
2	1984965.4	1984702.9
3	2218700.7	2218696.9

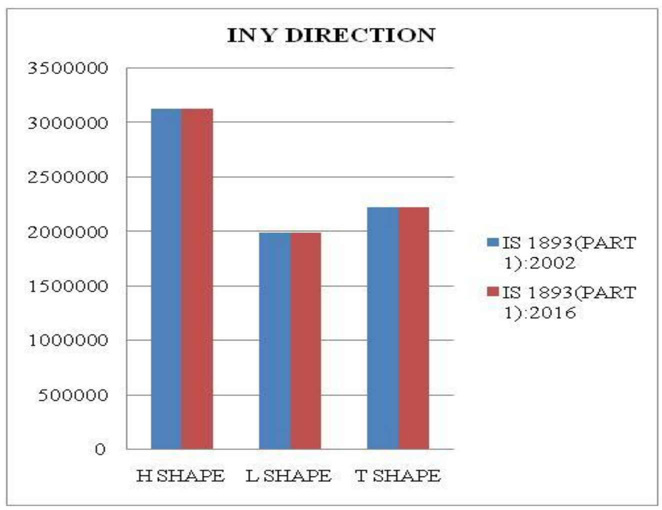

Fig. 7: Storey Stiffness (KN/m) comparison in Y-direction

Figure 7 shows graphical representation between storey stiffness in Y direction with plan irregularity by Response spectrum method using IS 1893(Part-1):2002 and IS 1893(Part-1):2016.

5.3 Overturning Moment

The models analyzed with new code showing similar value of overturning moment as compared with old code analysis. The tables and the graphs below are showing the maximum overturning moment values which are at the base of all models in X and Y direction with both the codes.

Table 6: Overturning moment comparison in X direction

Model	IS 1893(Part-1):2002	IS 1893(Part-1):2016
1	124464.717	149357.797
2	70089.957	96625.467
3	87216.939	105111.870

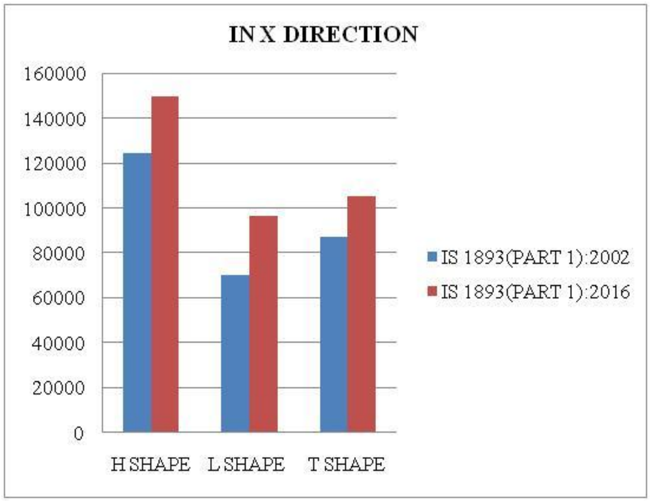

Fig. 8: Overturning moment comparison in X direction

Figure 8 shows graphical representation between overturning moment in X direction with plan irregularity by Response spectrum analysis method using IS 1893(Part-1):2002 and IS 1893(Part-1):2016. It shows that the overturning moment in X direction is increased by 20% in H shape, 38% in L shape and 21% in T shape.

Table 7: Overturning moment comparison in Y direction

Model	IS 1893(Part-1):2002	IS 1893(Part-1):2016
1	127359.422	152831.583
2	70902.645	100840.757
3	96444.097	116306.084

Figure 9 shows graphical representation between overturning moment in Y direction with plan irregularity by Response spectrum analysis method using IS 1893(Part-1):2002 and IS 1893(Part-1):2016. It shows that the overturning moment in Y direction is increased by 20% in H shape, 42% in L shape and 21% in T shape.

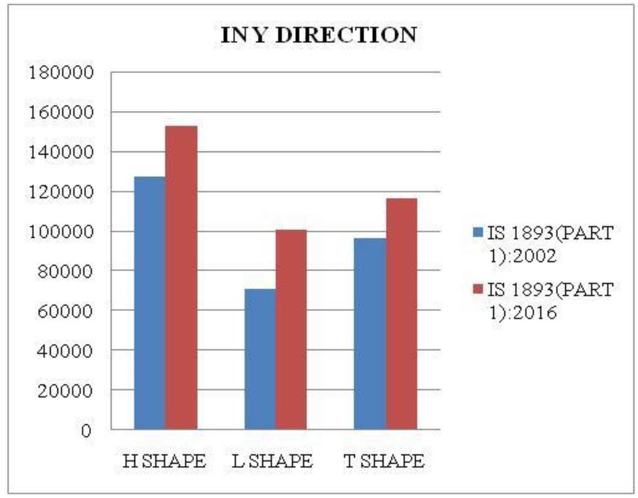

Fig. 9: Overturning moment comparison in Y direction

5.4 Model Mass Participation Ratio

According to the latest code to ensure safety against lateral storey irregularity the condition is mentioned, if the building is located in zone II and III, the first three modes should contribute at least 65% of the modal mass participation factor. In the research the first three modes contributes more than 65% for all the models and hence the structure is safe from lateral storey irregularity. Another condition is that the sum of all modes should be greater than 90% for the modes considered so here 12 modes are considered which satisfy this condition for all models.

6. Conclusion

From the study of both the codes, we come to conclusion in the following points:

- The value of time period, importance factor of building, the response reduction factor and the design acceleration coefficient have more realistic value in new code. Therefore, new code is more refined as compared to old code.
- For any type of irregularity in structural system, we got clarity in new code and got more realistic approach of analysis for regular and irregular buildings.
- New code proposed more fractional approach in seismic design depending upon occupancy and location. It gives the clarity for vertical earthquake load as compare to old code all conditions are specified in which vertical earthquake load come.
- The models analyzed as per the IS 1893(Part-1):2016 find out to be greater value of storey drift compared to when analyzed with IS 1893(Part-1):2002, this is due to reduction in moment of inertia. The percentage increase in storey drifts are approximately 20%, 40% and 20% of H, L and T model respectively when compared with is 1893:2002.

- Storey stiffness gives the same value when analyzed from both the codes for all the three models. Stiffness depends upon the time period and also on the height of structure. As the time period and height are same when analyzed with both codes.
- The models analyzed as per the IS 1893(Part-1):2016 showing approximately 20%,40% and 20% higher values of overturning moment in H, L and T shape respectively than the models analyzed as per IS 1893(PART 1):2002, due to the higher importance factor value considered in analysis with new code.
- The structure is safe in lateral storey irregularity because the first three modes have more than 65% of model mass participation factor. The sum of all modes is more than 90% for 12 modes.
- According to revised code the building is safe and not structurally deficient. Hence, there is no requirement of retrofitting this building to ensure safety against design seismic vibration.
- Form all the three models L shape model gives higher value of variation for all the parameters.

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