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Analysis and Comparison of Seismic Performance of RC Building Using Earthquake Codes IS:1893 (Part-1): 2002 and IS:1893 (Part -1):2016

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Abstract: The sixth revision of IS 1893 (Part 1): 2016, "Criteria for Earthquake Resistant Design of Structures" has been published by Bureau of Indian Standards recently in December 2016. In this new code many changes have been included considering standards and practices prevailing in various countries including India. The Indian seismic code IS: 1893 has been revised after a gap of 14 years. This work aims at studying the revisions in various clauses of the new IS 1893 (Part 1): 2016 and comparing it with the earlier version. The method of analysis and design of multi-storey residential buildings G+3, G+14 and G+24 located in zone III, IV and V under different soil conditions in both static and dynamic method with old and new IS: 1893. The newly revised code has introduced a clause for effect of Unreinforced masonry (URM) infill walls in buildings, minimum width of column has changed into 300 mm and modifications done on response spectra. These are the primary provisions considered in analysis of these buildings. The effects of diagonal strut provided in various locations in buildings with different conditions were analysed in the clause for URM infill walls. This project aims at understanding the relevance of the Indian standard codes that are used for design of various building elements using Staad Pro software under seismic load and wind load acting on the structure and investigating sufficient changes in the seismic performance of building while considering both the codes. If considerable variations in results are identified between the both codes, then the currently existing buildings that had been constructed before implementing the revision in 2016 needs to be modified by suitable retrofitting schemes.

Index Terms* - *Staad Pro, IS:1893-2002, IS:1893-2016, Seismic performance, response spectra, equivalent static method, time history method, URM infill walls.

I.INTRODUCTION

The effective design and construction of an earthquake resistant structure have great importance have all the world. India shows that 54% of the land-living is unsafe to earthquake. This Project presents Seismic Analysis and Comparison of Is 1893 (Part-1) 2002 and 2016 of Residential Building G+3, G+14 and G+24 in zone III, IV and V under different soil conditions using Staad Pro V22 software. In many countries, RC frame buildings are infilled by brick masonry and solid concrete block panels, although infill panel significantly increases the both stiffness and strength of the RC frame. The urge needs for the functional or for the architectural requirements, it is inevitable to provide the openings in the infill wall, however it will be increasing the lateral strength of the structures. Further if the openings are provided in the infill walls of the soft storey building, it proves to be critical condition. Reduction of the lateral strength of the structure due to the presence of the openings in the infill walls depends upon the various factors such as percentage of opening, aspect ratio and the location of the opening in the infill wall. Analysis and design of the structure without considering the reduction of the lateral strength due to the presence of the openings in the infill wall, and considering the stiffness of the whole infill wall could lead to a circular condition during the earthquake.

In the Indian seismic code IS 1893 (part 1): 2002 there is no provision regarding the stiffness and openings in the masonry infill wall. So as per old code the modelling of brick infill was not incorporated in the code and because of this the designers used the empirical formula which is conservatively written for all the RCC structures. Hence the modelling of brick infill by equivalent Strut represent the actual stiffness distribution of structure as a whole thus the time period calculation will be closer to realistic condition of Building Structure.

In 1893-2016 new clause of RC Framed Building with Unreinforced Masonry Infill walls: cl. 7.9 is added. This clause discusses the calculation of EQ loads when infill is considered. A detail procedure for URM infill by Equivalent diagonal strut method has been given in cl.7.9.2.2 As per IS 1893-2016 New code, Modelling with URM infill consider the stiffness of the infill in analysis thus, sizes of columns/shear walls may Increase or decrease as per the stiffness distribution of brick infill in the Structure. The efficiency of newly added clause is the main clause considered in this study.

II. METHODOLOGY

Based on type of external action and behaviour of structure, the analysis can further classify as linear static analysis, linear dynamic analysis, non- linear static analysis, or non-linear dynamic analysis. Non-linear dynamic analysis is also known as Time history analysis, linear dynamic analysis is known as Response spectra analysis and linear static analysis is known as Equivalent static analysis. The response spectrum analysis is the preferred method because it is easier to use. The time-history procedure is used if it is important to represent inelastic response characteristics or to incorporate time-dependent effects when computing the structure’s dynamic response

In this study each building is analysed in Equivalent static, response spectrum and time historic methods in different zones and different soil conditions by using both old and new seismic codes and comparing the deflection of each building in both codes. The effect of new clause URM is the main condition considered in this study. In this study dead load, live load and wind load are applied on the basis of IS:875(Part-1)-1987, IS 875 (Part 2)–1987 and IS 875 (Part 3) -1987 respectively.

III. BUILDING MODELLING AND ANALYSIS

For this study four, fifteen and twenty-five buildings having same plan area of 30 m x 30 m is considered. The architectural drawing of these buildings is attached on Appendix-A. The floor height of every building is 3 m. M25 concrete and Fe 500 steel are used. The slab thickness of is taken as 120 mm. the different soil conditions taken are hard, medium and soft. Different zone considered are zone III, IV and V. The wind speed conditions in every zone is same for that the selected cities are Trivandrum (zone III), Shimla (zone IV) and Mandi (zone V).and the wind speed is each city is 39 m/s.

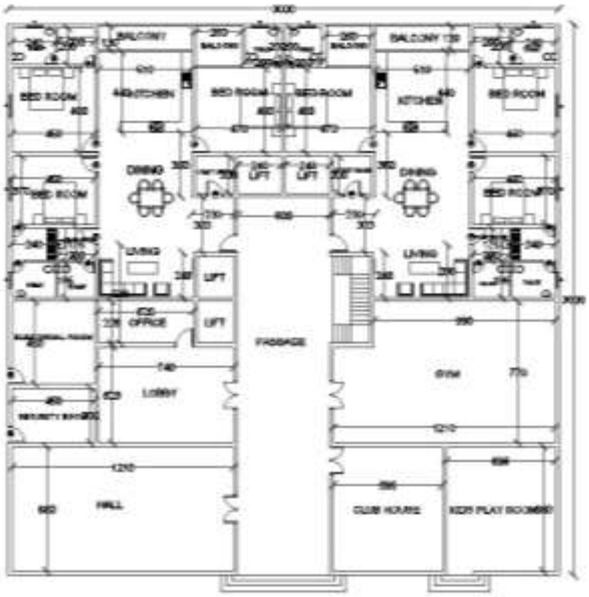


Figure 3.1: Ground floor plan

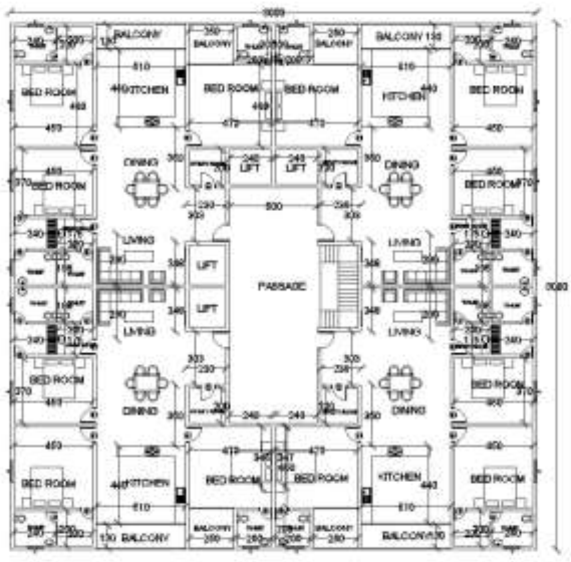


Figure 3.2: Typical floor plan

3.1. Building modelled using IS:1893-2002

Table 3.1: Dimension of beam & column as per IS:1893-2002

Building	Plinth beam size (mm)	Other floor beam size (mm)	Column size(mm)
G+3	200 x 450	200 x 400	200 x 450
G+14	200 x 450	200 x 400	200 x 900
G+24	200 x 450	200 x 400	200 x 1200

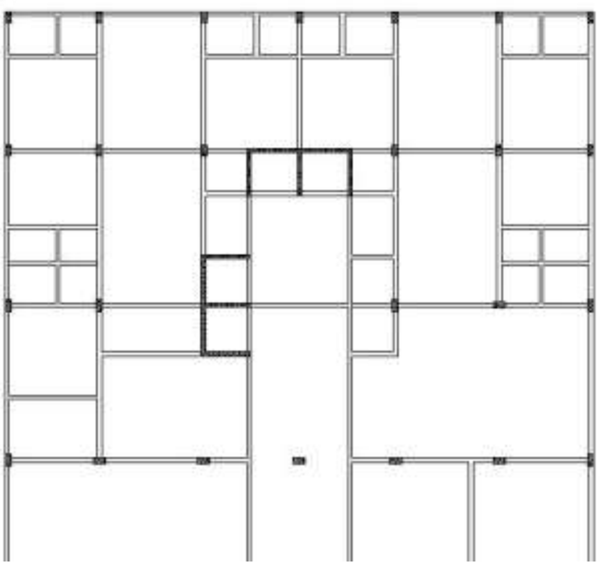


Figure 3.3: Ground floor beam-column layout as per IS:1893-2002

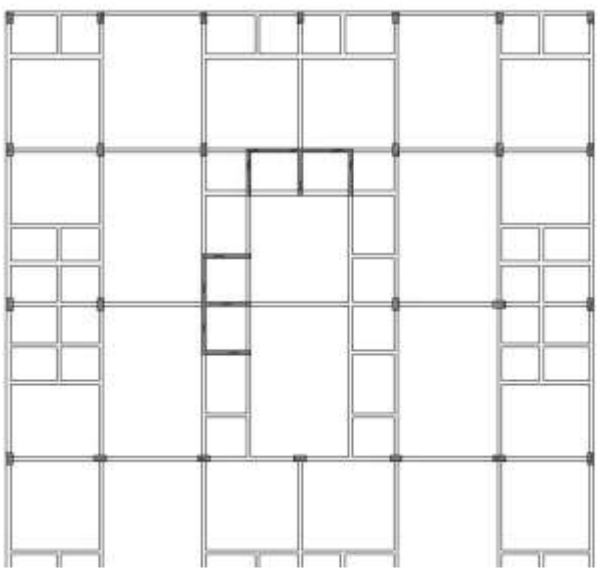


Figure 3.4: Typical floor beam-column layout as per IS:1893-2002

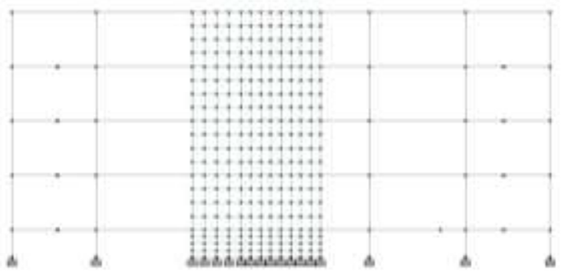


Figure 3.5: Elevation of G+3 model as per IS:1893-2002

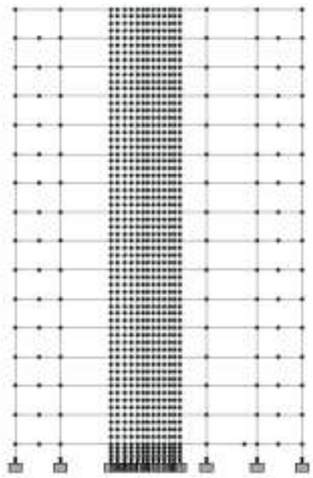


Figure 3.1: Elevation of G+14 model as per IS:1893-2002

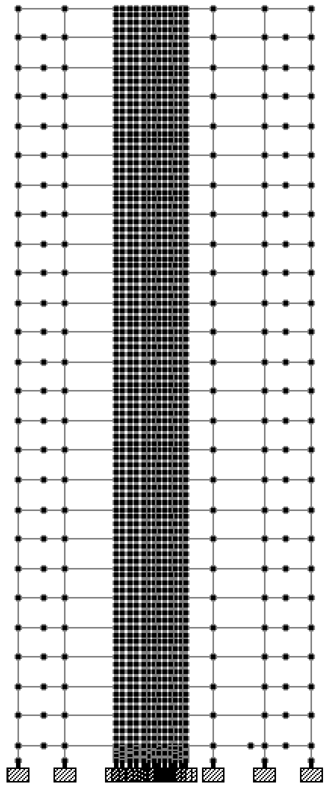


Figure 3.7: Elevation of G+24 model as per IS:1893-2002

In this study of IS:1893-2002 code factors consider for seismic analysis are: Zone factors 0.16,0.24 and 0.36 for Zone III, Zone IV and Zone V respectively. Response reduction factor is 5, Importance factor 1 and damping ratio is 0.05.

3.2. Building modelled using IS:1893-2016

In this study of IS:1893-2016 code factors consider for seismic analysis are: Zone factors 0.16,0.24 and 0.36 for Zone III, Zone IV and Zone V respectively. Response reduction factor is 5, Importance factor 1.2 and damping ratio is 0.05.

Table 3.2: Dimensions of beam and column as per IS:1893-2016

Building	**Plinth beam size (mm)**	**Other floor beam size (mm)**	**Column size(mm)**
G+3	200 x 450	200 x 400	300 x 450
G+14	200 x 450	200 x 400	300 x 900
G+24	200 x 450	200 x 400	300 x 1200

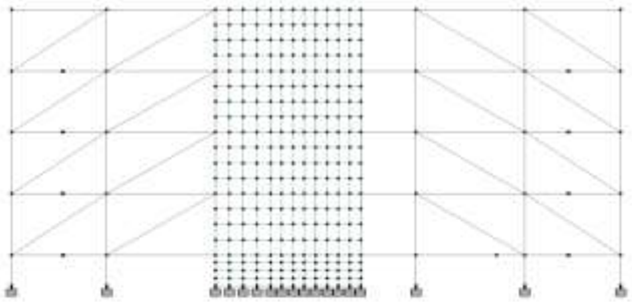


Figure 3.8: Elevation of G+3 model as per IS:1893-2016

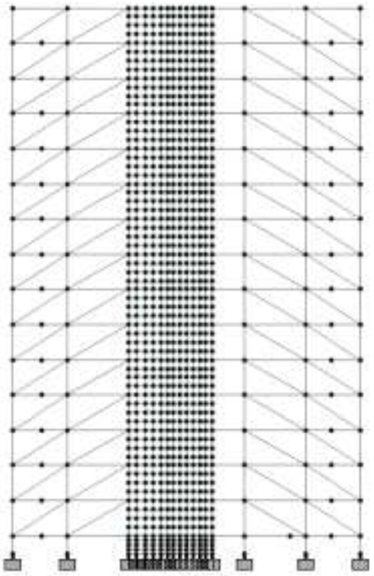


Figure 3.9: Elevation of G+14 model as per IS:1893-2016

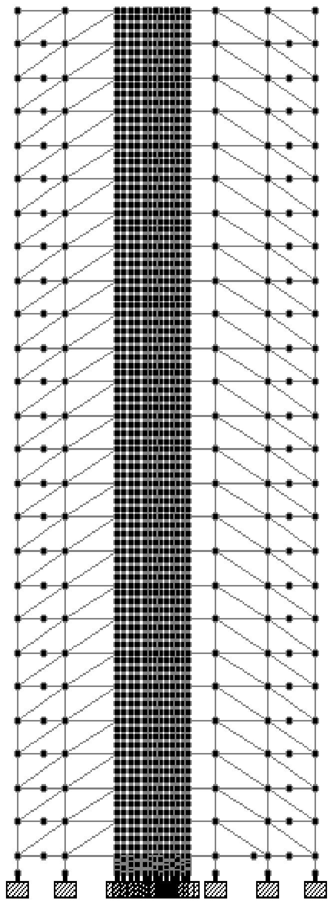


Figure 3.10: Elevation of G+24 model as per IS:1893-2016

3.3. Calculation of diagonal strut width

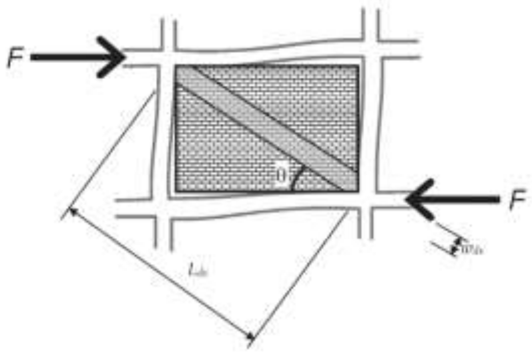


Figure 3.11: Equivalent diagonal strut of URM infill wall

As per newly revised code IS 1893 (Part 1)-2016 size of diagonal strut is calculated as:
Width of diagonal strut
$w_{ds} = 0.175\ \alpha_h^{-0.4} L_{ds}$ = 0.175 x $3.73^{-.04}$x 7631.06 =788.62 mm
Where,

$$\alpha_h = h\left(\sqrt[4]{\frac{E_m t \sin 2\theta}{4 E_f I_c h}}\right) = 3.73$$

Modulus of elasticity of masonry infill wall $E_m = 550 f_m$= 9678.17 MPa
Compressive strength of masonry prism $f_m = 0.433 f_b^{0.64} f_{mo}^{0.36}$ = 17.6 MPa
Compressive strength of brick f_b=35 MPa
Compressive strength of mortar f_{mo} =53 MPa
Modulus of elasticity of RC MRF $E_f = 5000\sqrt{f_{ck}}$ =25000 MPa
Moment of inertia of adjoining column $I_c = \frac{bd^3}{12} = \frac{300\ x\ 450^3}{12}$ =2.28 x $10^9\ mm^4$
Thickness of infill wall t= 200 mm

Angle of diagonal strut θ = 24.38

Clear height h = 3120 mm

Providing the depth of diagonal strut as 600mm instead of 786.62 mm depending upon practical considerations. So, size of diagonal strut is 200 mm x 600 mm.

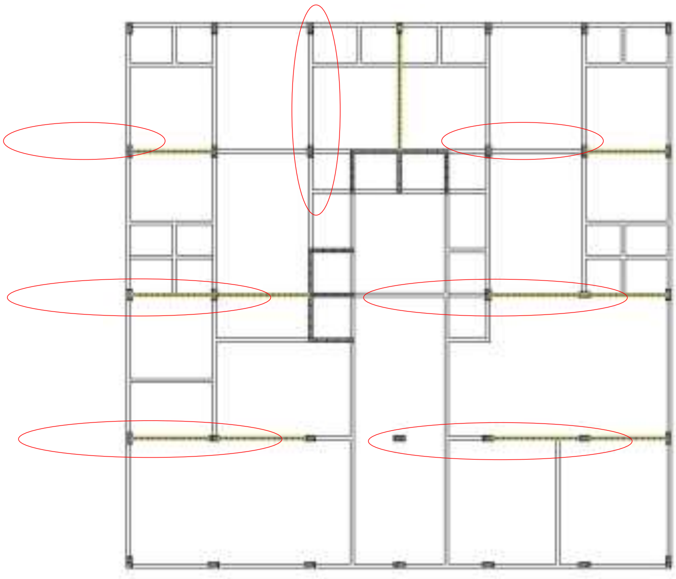


Figure 3.12: Location of diagonal strut in ground floor

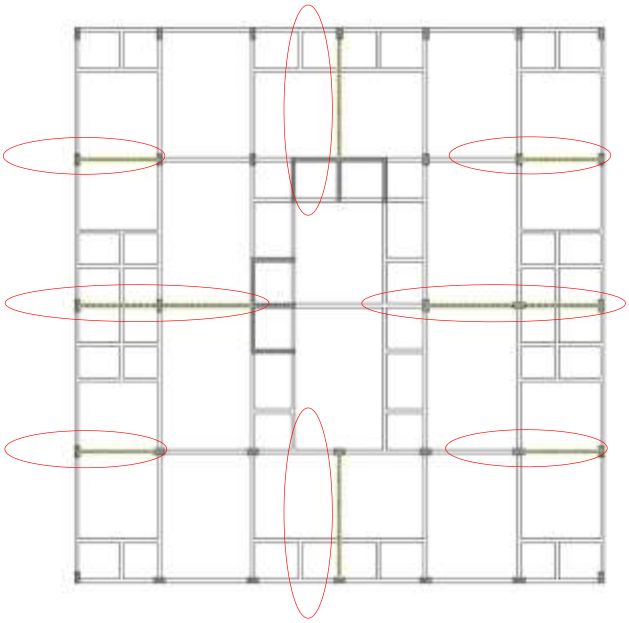


Figure 3.13: Location of diagonal strut in typical floor

IV. RESULTS AND COMPARISION

From analysis of 114 building models the maximum deflection of buildings in different condition is found out. And the comparisons of those building deflections are shown in figures 4.1-4.7.

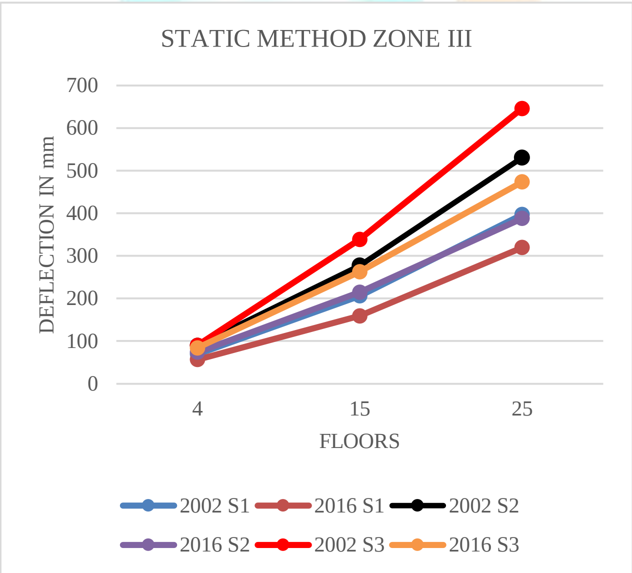


Figure 4.1: Deflection of buildings in Equivalent static method in zone III

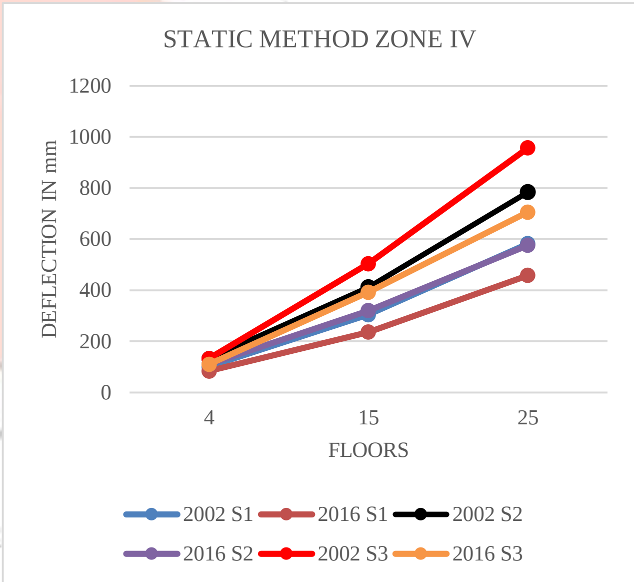
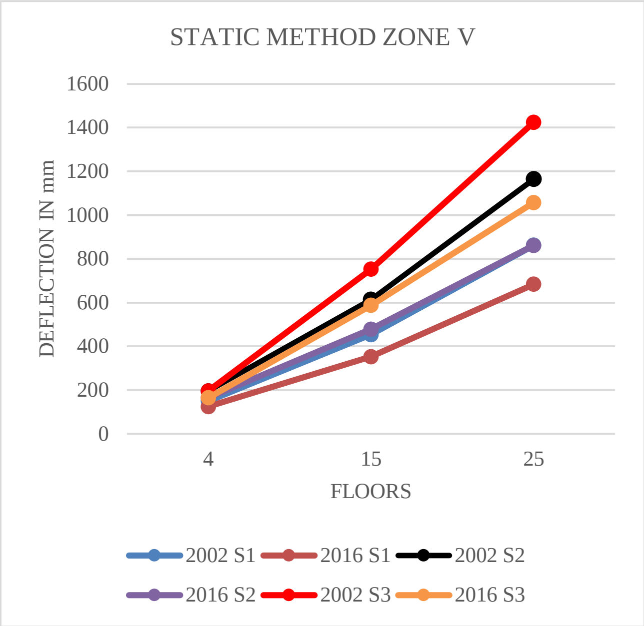


Figure 4.2: Deflection of buildings in Equivalent static method in zone IV



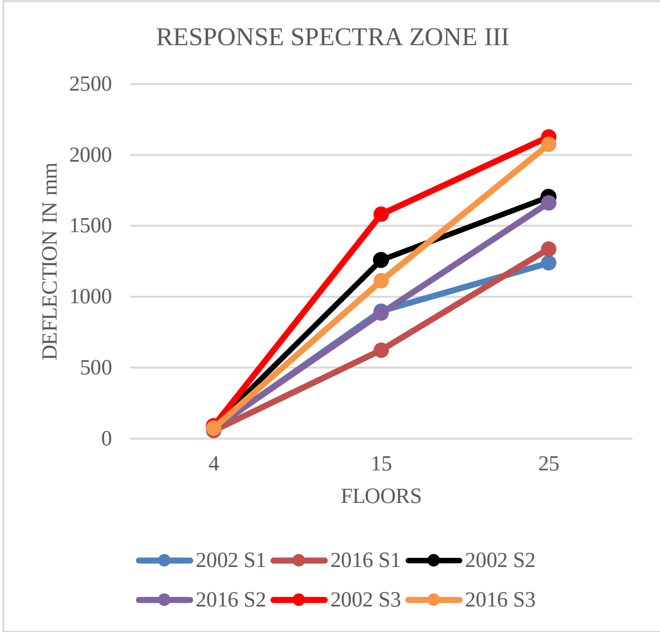


Figure 4.3: Deflection method in zone V

Figure 4.7: Deflection of buildings in Time history method

gs in Response spectra method in zone III

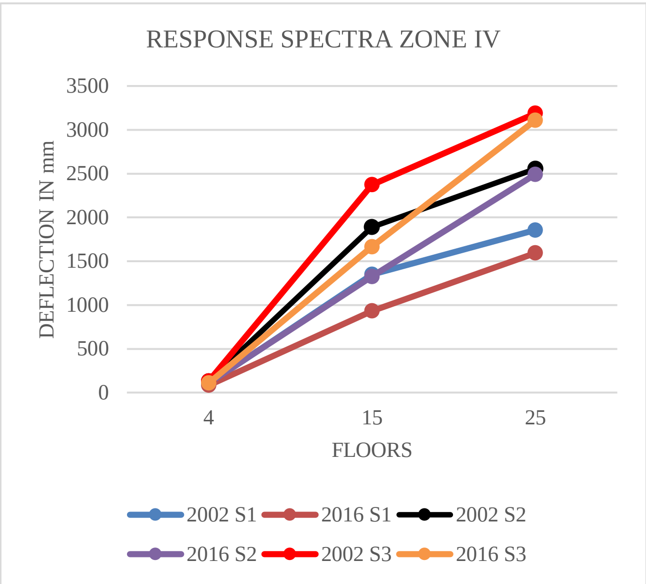


Figure 4.5: Deflection of buildings in Response spectra method in zone IV

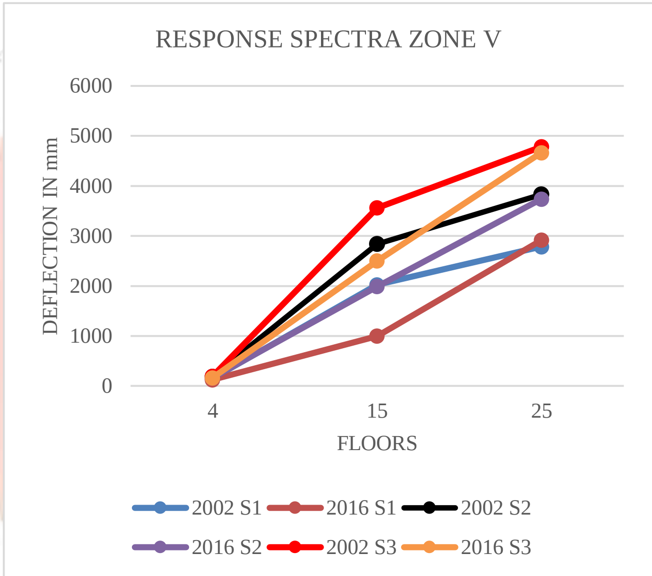


Figure 4.6: Deflection of buildings in Response spectra method in zone V

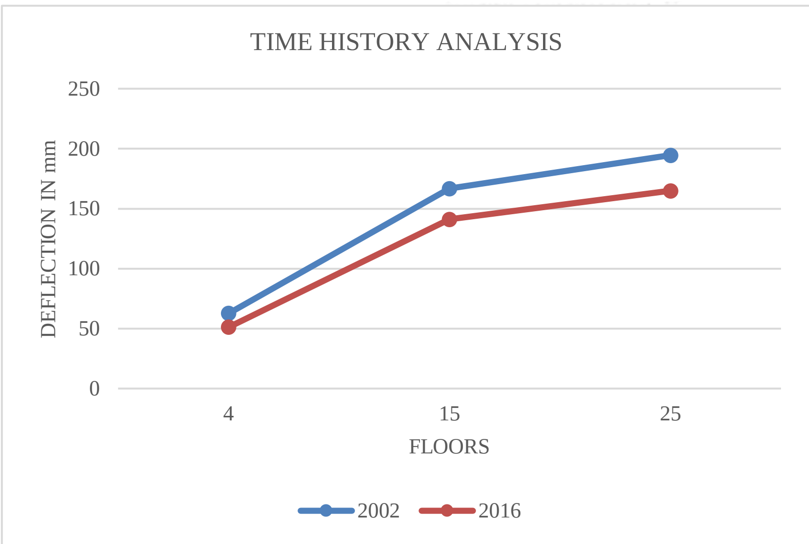


Figure 4.1-4.7 illustrates the compassion of deflection of building models modelled as per two seismic codes in three zone conditions and three soil conditions analysed under equivalent static, response spectra and time historic method. In these charts S1 means hard soil, S2 means medium soil and S3 means soft soil. From these studies it is clear that zone 5 and soft soil having maximum deflection in all methods and all building height so it is selected as critical criteria in cost analysis and base shear study.

In general, it is found that deflection of building increases from hard to soil zone and zone III to Zone V in all method of analysis. While comparing both seismic codes IS:1893-2016 have lower deflection values than IS:1893-2002. Some of reasons for less deflection in IS:1893-2016 minimum width of column is maintained as 300 mm, Increase in Importance factor from 1 to 1.2 and use of diagonal strut in URM infill walls which make stiffer.

From the study while comparing both seismic codes in Equistatic method of analysis, For G+3 building model have 19.4% reduction in deflection in critical condition. For G+14 building model it is 28.13% and for G+24 building model it is 34.77%. It is obtained as an average 27.43% reduction for deflection in Equistatic method while using IS:1893-2016 instead of IS:1893-2002. While comparing both seismic codes in Response Spectra method of analysis, For G+3 building model have 19.4% reduction in deflection in critical condition. For G+14 building model it is 42.43% and for G+24 building model it is 2.52%. 2.52% is a small difference it is due to column size for building modelled as per 2016 code is insufficient if increases the column size deflection will reduce but for comparing results in this study size of column is fixed (only change in width its due to code recommendations). It is obtained as an average 21.45% reduction for deflection in Response spectra method while using IS:1893-2016. While comparing both seismic codes in Time historic method of analysis, For G+3 building model have 28.08% reduction in deflection. For G+14 building model it is 18.12% and for G+24 building model it is 17.93%. It is obtained as an average 21.38% reduction for deflection in Time historic method while using IS:1893-2016.

It is clear that almost 23.42% average reduction in deflection of building while modelled using IS:1893-2016. This is mainly due to provision of diagonal strut in building. To confirm the effect of diagonal strut extra 3 buildings are modelled using IS:1893-2016 without diagonal strut and analysed in Response spectra method under critical criteria that is zone V and soft soil conditions and those results are shown in figure-4.8.

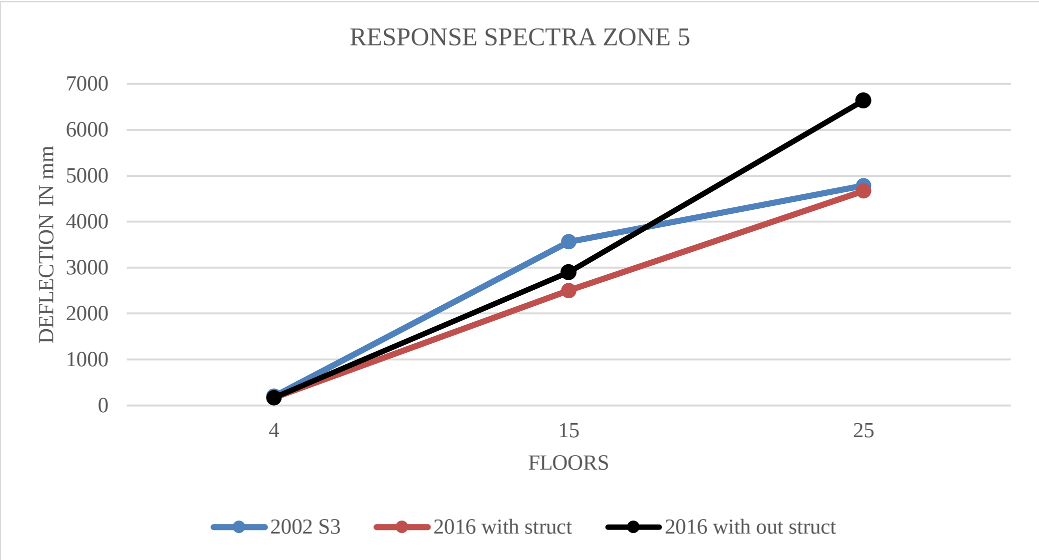


Figure 4.8: Deflection comparison of building with and without diagonal struct

From figure-4.8 by comparing building modelled using IS;1893-2016 with and without diagonal strut it is found that deflection of building increases while removing diagonal struct. For G+3 building deflection increases by 0.42% when diagonal strut removes. For G+14 building deflection increase by 15.8% and for G+24 deflection increases by 42.18%. So almost 19.67% increases in deflection while building modelled without diagonal struct. So, which indicates the effect of diagonal struct, the use of diagonal structs increase the stiffness of building thus reduce deflection in structure and also help in reduction of column size.

V. CONCLUSION

Purpose of this study is to compare the effect of new seismic code IS:1893-2016 over IS:1893-2002. The change in importance factor, minimum width of column 300mm and new clause of URM infill wall, etc. in IS:1893-2016 affect different features of building. From comparison of deflection of G+3, G+14 and G+24 buildings under different soil and zone conditions and under different analysis methods, it is found that response spectra analysis is critical in high raised building there is no much difference in response and static method in G+3 building. And deflection of building modelled using IS:1893-2016 is less than buildings modelled using IS:1893-2002 in all cases and all three method of analysis. In this study 10 diagonal strut are provided in each storey of buildings, the introduction of 10 diagonal strut reduces approximately 20% deflection of building than IS:1893-2002. So, addition of more diagonal structs in the URM infill wall by reducing the openings and full glass panels in the exterior portion of building makes the structure stiffer and thus reduces the deflection of building.

From the study it is evident that buildings designed by IS:1893-2016 is more resistance towards lateral force and less deflection than IS:1893-2002. But buildings designed as per IS:1893-2002 still exist now, so those buildings require some modifications or retrofit method for increase the stiffness of building to resist earthquake or reduce the damage in building in future.

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