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Seismic Analysis of Reinforced Concrete Building with Infill Wall and Overhead Water Tank

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***Abstract:** Infill walls are typically treated as non-structural elements in building design and assessment, and they are ignored in analysis methods because they are assumed to be non-beneficial to response of a structure. Reinforced concrete framed buildings with infill walls are typically analysed as bare frames, with strength and stiffness contributions of the infills ignored. In this study an attempt is be made to find the effect of overhead water tank load on RC building with unreinforced infill wall. From the study it has been found that water tank load makes RC building more vulnerable against lateral loads, but proper incorporation of unreinforced infill walls can enhance storey stiffness, storey drift and other structural deformations parameters.*
***Keywords:** Equivalent Strut, Lateral Loads, Unreinforced Infill walls, Water Tank, Seismic Analysis, Seismic vulnerability*

I. INTRODUCTION

Masonry infills are always made in simple contact with RC frames, without any joint or link that ensures a reliable connection with beams and columns for simplicity and economic construction. Such infills are extremely prone to shaking during earthquakes, as demonstrated by seismic incidents. On the positive side, it has been discovered that they enhance the strength and stability of this type of construction during such catastrophes. Even the infill with perforations considerably increases the resistivity of such constructions. Thus, infills with or without openings carry prime importance in the seismic performance of RC structures. Long-term analysis and research have shown that the availability of infill significantly affects how RC structures performance. The supporting frame's strength and stiffness can be significantly changed by infills. They improve the combined structural system's stiffness, particularly under lateral loads, which decreases the system's ductility and natural period. Even the infill with openings has proven to be able to withstand lateral loads with enough strength. Infills can result in irregularities in elevation, thereby compromising a proper structural arrangement, in addition to enhancing stiffness and strength. The building's torsion, soft storey mechanism, and captive column development can all be considerably influenced by them. When the infills apply significant shear loads to the adjacent frame, they can also induce premature collapse of the frame's structural components. The interaction between the frame and infill must be accurately studied because it could be dangerous to ignore infill involvement in the design. In countries like India, where the terrain is prone to seismic activity, R.C.C frames with masonry infill walls are standard practise. Masonry infill walls are typically treated as non-structural elements in structural analysis, and only their mass contribution is considered. Their structural characteristics, such as strength and stiffness, are typically ignored. Nevertheless, it makes a considerable contribution to the lateral rigidity of the frame constructions. There are no such specific references to infill walls in the Indian seismic standard (IS 1893:2002), but in IS 1893: 2016, now it is proposed to use infill walls as equivalent strut cl. 7.9. Sloshing is among the most prominent effects in elevated water tanks.

The dynamic behavior of vital water storage tanks in the event of an earthquake is one of the engineering challenges associated with sloshing. The performance and dynamic stability of Structures are directly impacted by these characteristics. Sometimes a sloshing-induced hydrodynamic load can have a negative impact on the structural integrity and dynamic performance of the liquid storage tank. Investigating the effects of the dynamic response of rigid rectangular liquid storage tanks on the building's unreinforced infill walls is the main objective of this discussion. On the seismic vulnerability of low-rise residential RC buildings, researchers present comparative seismic vulnerability for various analysis instances in terms of fragility functions using four analysis scenarios. The overall picture of the observations shows that low-rise RC buildings are damage state sensitive to the effects of infills and soil-structure interaction. In the meanwhile, because some performance criteria are more sensitive than the total fragility, design considerations will be severely impacted. In the case of low-rise RC buildings, we also noticed that the analytical fragility models significantly overstate the real seismic fragility[1]. The findings demonstrate that infills alter the floor response spectra and peak floor accelerations. The OOP accelerations for infills are always 1.2-2 times greater than those for PFA. The acceleration response spectra of the infill do not alter as the building height rises [2].

The findings also showed that infilled walls have a good impact on the rigidity, strength, energy dissipation, and ductility of RC frames. Additionally, it was discovered that the response modification factor is dependent on the geometry of the frame[3]. So, the objective is to conduct a study on seismic analysis of RC building with unreinforced infill considering water tank load.

II. METHODOLOGY

A. Model

In this study 12 storey building having 3m storey height is taken for study. The geometry of the building is rectangular. The buildings are modelled on Etabs 2018 software. The code used for designing these buildings is IS 456:2000 "Code of practice for plain and reinforced concrete", IS 1893:2002 "Criteria for earthquake resistant design of structures". Following models and nomenclature have been used in the model to categorise different models used in this study.

1) *BWS:* 12 storey building considering water tank at top and without strut shown in fig. 2
2) *BS:* 12 storey building considering water tank at top and strut at external face of the building along X and Y direction shown in fig. 3.

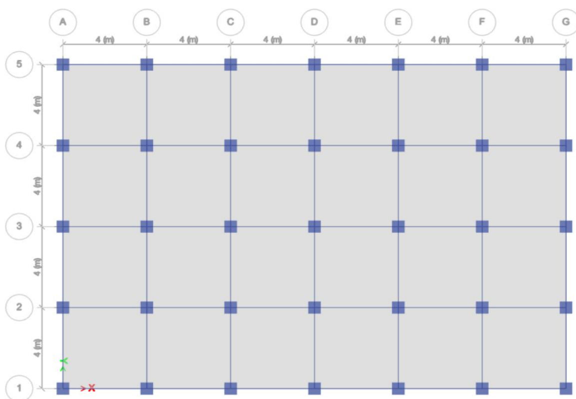
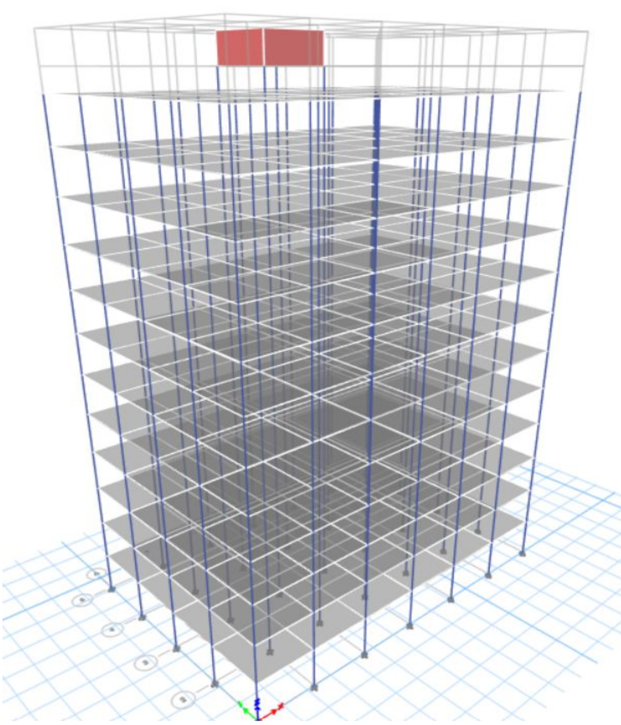


Fig. 1 Plan of 12 Storey Building



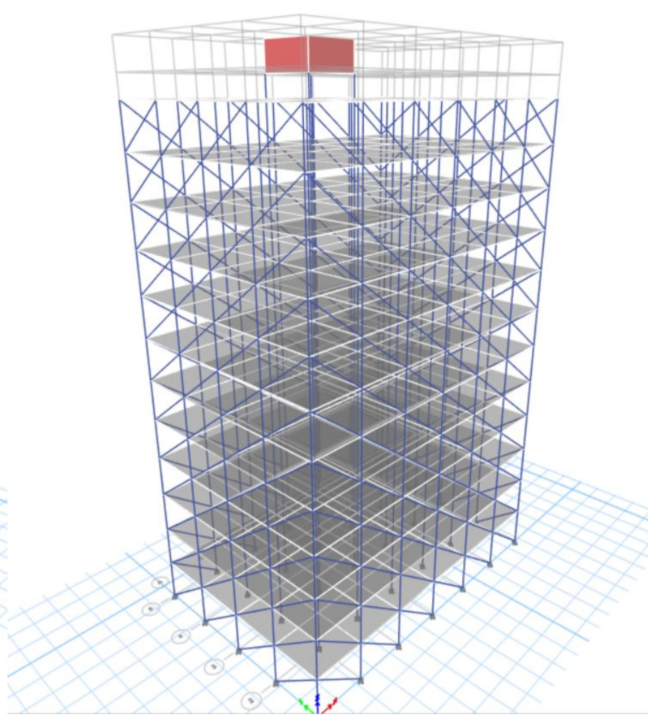


Fig. 2 12 storey building considering water tank at top and without strut (BWS) Fig. 3 12 storey building considering water tank at top and without strut (BS)

B. Geometrical Properties

The geometric parameters of structures considered for study consist of the geometric plan structure height, storey height, span & floor area of structures. The geometric details are given in table 1. The beam sizes, column sizes and water tank walls are determined by the hit and trial method until the safe design is achieved.

Table 1. Element Properties

S.No.	Description	Specification
1	Number of stories	12
2	Story height	3 m
3	Length of building	24 m
4	Width of building	16 m
5	Spacing between grids	4 m
6	Grade of the concrete	M30
7	Size of beam	350 mm x 600 mm
8	Size of column	600 mm x 600 mm
9	Thickness of Slab	200 mm
10	IS Code	IS 456:2000, IS 1893:2002

C. Loading

The designing criteria given in IS13920:2016 were followed for current work. Thus, the criteria given for selecting a grade of concrete and grade of steel has also been followed and as per clause 5.1 of IS 13920:2016 the grade of material given in table. 2. The loads applied on the structure were floor finish load and live load where live load on the roof and floor level are same.

Table 2. Loading Properties

S.No.	Parameter	Details
1	Floor Finished Load at Stories	1.2 kN/m^2
2	Exterior Periphery Wall	12.14 kN/m^2
3	Interior Wall	8 kN/m^2
4	Roof Floor Finish Load	3.3 kN/m^2
6	Roof Live Load	1.5 kN/m^2
7	Live Load on other levels	3 kN/m^2
8	Density of Masonry Wall	20 kN/m^2
9	Density of RCC	25 kN/m^2
10	Grade of Concrete	M30
11	Grade of Steel	HYSD 500

The Indian standard code 1893:2016 (Part I) gives information of seismic parameters that are required in analysis of structures for the considered seismic zone. Zone 4 has been considered for this study.

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D. Water Tank Modelling

The dimensions of water tank and elements are shown in table 3. Water tank is modelled in ETABS using FEM method. After deducting free board of 500 mm, water pressure at base slab of water tank is 15 kN/m^2.

Table 3. Water Tank Specification

S.No.	Description	Specification
1	Length	4 m
2	Width	4 m
3	Height	2 m
4	Outer Wall	200 mm
5	Bottom Slab	200 mm

E. Unreinforced Wall Modelling

As per IS 1893(Part – 1):2016 unreinforced infill walls shall be modelled by using equivalent diagonal strut in which width of the of equivalent diagonal strut has been given. Width of the equivalent strut is taken as 590 mm. Equivalent strut has been modelled using section designer available in ETABS in which the density of the strut has been taken same as masonry and thickness of the strut is 230 mm.

III. RESULTS AND DISCUSSION

The linear static analysis was carried out on 12 storeys building with and without unreinforced infill considering water tank at top for zone IV. The sizes are obtained after number of trials of analysis and design process. The results are so obtained that were influenced by seismic load are discussed and compared to understand the effects of unreinforced infill wall designed as strut on building with water tank at top under different seismic parameters. All models are compared for storey drift, storey stiffness, roof displacement, Time Period, and shear forces in water tank wall.

A. Time Period

Time period comparison is shown in fig. 4. It has been found that on incorporating water tank load on bare frame building, the time period increases due to mass redistribution at top floor but on incorporating strut in building with water tank at top time period reduces by 42%.

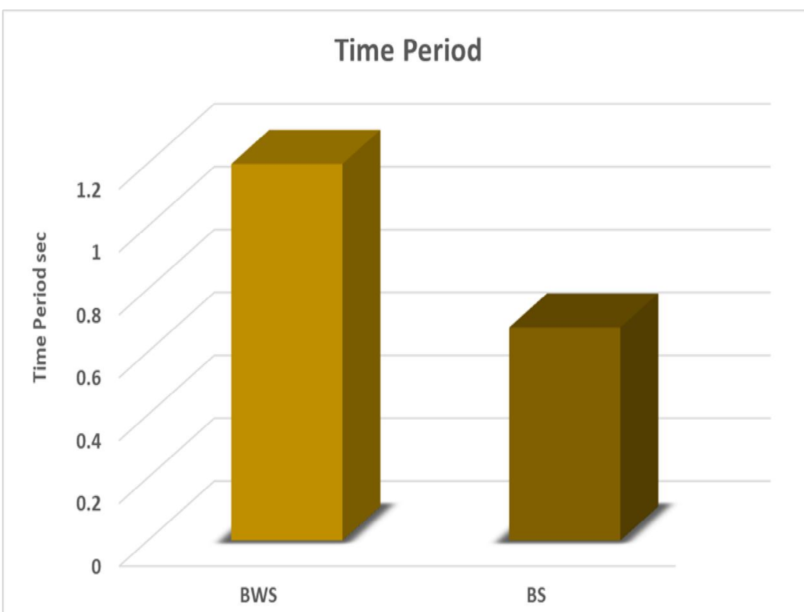

Fig. 4 Time Period Comparison

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B. Roof Displacement

Maximum storey displacement fig. 5. It has been found that on considering water tank load the time period increases due to mass redistribution at top floor but on incorporating strut in building with water tank at top, time period reduces by 75%.

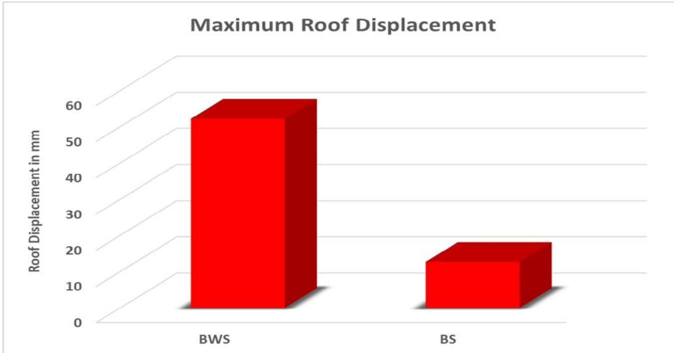

Fig. 5 Maximum Roof Displacement Comparison

C. Storey Drift

Storey drift has been compared as shown in fig. 6. Permissible storey drift as per IS1893 is 0.004-times height of storey. On considering water tank at top, storey drift is very large but on considering strut as unreinforced infill wall storey drift reduces and which means analysing building with proper unreinforced infill wall storey drift will be predicted more accurately.

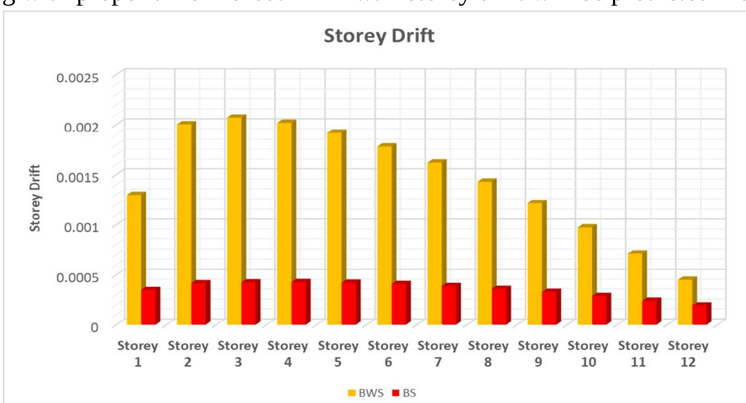

Fig. 6 Storey Drift Comparison

D. Storey Stiffness

Storey stiffness has been compared as shown in fig. 7. On using strut, storey stiffness enhances by about 200% in each floor. Storey stiffness results also validated the storey drift results discussed in previous section in which building without strut and water tank at top attracts more storey drift.

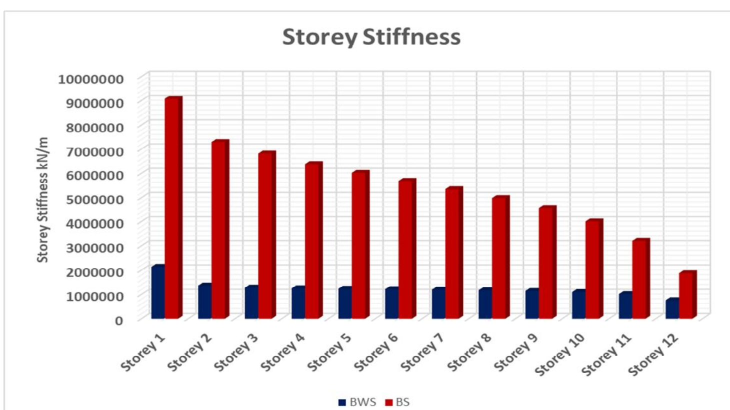

Fig. 7 Storey Stiffness Comparison

E. Shear Force in Water Tank Wall

The comparison of shear force on shear wall for all models has been shown in fig. 8. It has been found that on considering infill wall in the building the shear force in water tank wall reduces by 34%. Since shear force dominates the thickness of wall therefore on considering infill wall an economical design of water tank can be formulated.

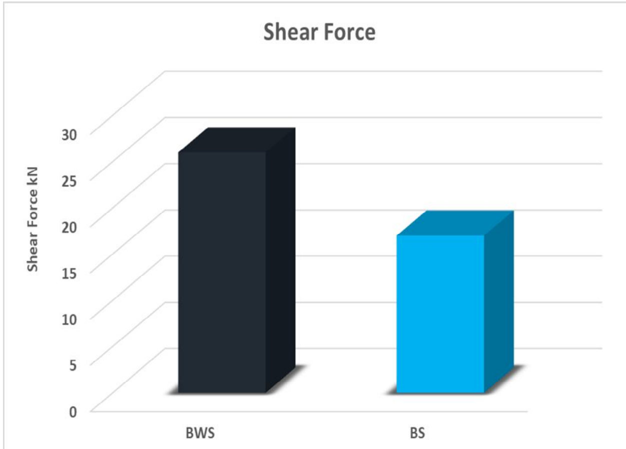

Fig. 8 Shear Force in Tank wall

IV. CONCLUSIONS

Following are the conclusions of the study –

1) Water tank on the top of the building increases natural time period of building but incorporation of strut as infill wall reduces time period significantly.
2) Building with unreinforced infill wall modelled as equivalent strut attract less storey drift as compared to building with water tank at top and without strut.
3) Unreinforced infill wall modelled as equivalent strut increases building stiffness by 200%. This increase in stiffness will be advantageous with respect to earthquake damage because it can reduce the deformation demands on a building.
4) Due to increase in stiffness of building maximum storey displacement reduces, which helps in less deterioration of partition wall.
5) From the study it is also concluded that designer should incorporate water tank load and unreinforced infill wall in the analysis as it will leads to more accurate and practical design parameters.

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