INTER-RELATIONSHIP OF VARIOUS TYPES OF INFILL WALLS AND GEOMETRICAL PARAMETERS OF RC FRAME BUILDING

A DISSERTATION

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Submitted by:
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CERTIFICATE

I hereby certify that the Project Dissertation titled “Inter Relationship of various types of infill walls and geometrical parameters of RC Frame building” which is submitted Ankit Singh Panwar, Roll No. 2K20/STE/03 Department of Civil Engineering (Structural Engineering), Delhi Technological University Delhi in partial fulfilment of the requirement for the award of the degree of the Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere. Only the candidate would be responsible for any aspect connected to this report, whatsoever including any issue related to plagiarism, legally or otherwise.

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ABSTRACT

The infill wall serves as the supporting wall that closes the perimeter of a three-dimensional framework structure-built building. In designs for calculating the seismic behaviour of RC frames, the infill is not treated as a structural element but just as a load providing element, resulting in erroneous conclusions and an incorrect prediction of the real seismic behaviour of the structure. The current study investigates the changes of various seismic characteristics of bare frame and brick infill using the equivalent diagonal strut technique (FEMA 356 and IS code 1893:2016), with a focus on the differences in seismic parameters between the various approaches. The fluctuation of differences is investigated by reducing densities and Young's modulus E in the same proportion. This research will look at a G+4 residential structure and use ETABS software to compute seismic characteristics namely storey shear, base shear, and storey drift. The results are graphically represented and reveal that the fluctuations of storey drift and storey displacement in infill walls calculated using IS 1893:2016 and in infill walls modelled using FEMA 356 are almost same whereas the fluctuations of storey shear and base shear in infill walls calculated using IS 1893:2016 are greater than in infill walls modelled using FEMA 356. Also, when the densities and Young’s Modulus are reduced till 60%, storey displacement and storey drift are found to be increased and storey shear are found to be decreased.

ACKNOWLEDGEMENT

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CHAPTER 1

INTRODUCTION

1.1 INFILL WALLS

Buildings constructed with a three-dimensional framework structure generally include an infill wall as part of the perimeter. In this sense, the structural frame provides the bearing function, and the infill wall fills up the outer frame boxes, separating the inner and outer space. Infill framed structures are common in all parts of the world. These can be both decorative and functional. They provide a good finish and add a lot of functionality. Infill walls bear their own weight, so they are unique in this way. These walls are a type of externally visible, opaque closure. Comparing infill walls with other types of walls, we see that they differ from partitions that serve to separate two interior spaces and from the load bearing wall. These walls perform the same functions as the infill wall, namely hydrothermal and acoustical, as well as performing static functions.

1.2 TYPES OF INFILL WALLING

Concrete or steel buildings can incorporate infill walls spanning between floors with a variety of construction methods.

1.2.1 Masonry Infill Wall

The traditional way of building infill walls involves using clay bricks and concrete blocks. Nevertheless, block-work infill walls have become less common due to messy and time-consuming site operations, which require extensive material handling. Providing structural strength to large window openings is important from a design standpoint, because the masonry around these openings is not sufficiently strong to resist high wind loads. Density of masonry infill walls is in the range of 19 to 22 KN/m^3 [28].

1.2.2 Concrete Infill Walls

Concrete infill walls are usually constructed as large precast concrete panels that are storey high and often width-determined by the spacing between the columns. Top-hung or bottom-supported panels are typically used. They are typically bolted to the structure on the above or below level, and then bear onto the floor slab through a boot arrangement.

Other materials can be used to cover integrated panels (usually stone is used to cover concrete panels).

Panel widths of 3-9m and heights of 3.5 to 4.2m are typical, with panels weighing about 300kg/m^2. Panel sizes are limited by transportation, as well as crane lifting capacity (on site and in the concrete plant). Maximum weights for precast concrete panels are typically 15 to 20 tonnes. [28]

Concrete infill walls can also be used as concrete blocks which has a density of roughly around 17.6 KN/m^3.

1.2.3 Timber Framed Infill Walls

Infill timber walls span between floors in the range of 2.4 to 3.6m and are like steel infill walls in shape and form. Each section of wood is cut to length and configured at a 400 mm or 600 mm spacing. Timber has several disadvantages in comparison to steel, such as the fact that it is not as strong, and it cannot be used in walls that have large openings or tall walls [28].

1.3 FAILURE MODES OF INFILL WALLS

Previous earthquakes have caused different types of damage to masonry walls in RC frame construction. These failure modes were-

- Due to low bond strength, cracks developed along the block/mortar interface. Large cracks even led to collapse of some infill walls. Infill walls failed mainly because of frame drifts within levels. Several of the lower floors were affected by a bigger drift, causing more damage to the lower floor infill walls. The cracks that form in an X shape were the most noticeable. After the earthquake struck, the walls collapsed due to the forces exerted by the earthquake [29].

- There were problems with the way the infill walls were fixed to the frame, causing the walls to collapse out of plane unsatisfactorily. As a result of faulty service lines within the walls, some walls collapsed. Those wall shapes with arch-shaped shapes were more easily damaged because the horizontal forces caused additional bending moments out of plane [29].

1.4 EVALUATION PROCEDURES

1.4.1 Equivalent Diagonal Strut Method

One of the most common ways proposed in seismic codes to mimic infill panels in the frames is equivalent diagonal strut method. Material qualities, thickness, and breadth of corresponding struts determine the mechanical parameters of infilled frames, such as strength and stiffness. The contact length between the infill and the frame determines the strut width. There are many approaches by which researchers have used this method. In this method 2 approaches have been used. One is using IS 1893 and other is using FEMA 356.

1.4.2 ETABS

ETABS is a multi-story structure design and analysis software application. The grid-like geometry peculiar to this form of construction is reflected in modelling tools and templates, code-based load recommendations, analysis methodologies, and solution strategies. In this study dynamic analysis has been done using ETABS software

1.5 NEED OF PROPOSED STUDY

Infills are not considered to be bonded to frames in the design. Although, whenever an infill panel is subjected to lateral forces, it interacts with the frame. A structure's seismic response is known to be affected by the placement of MI walls and partition walls. The MI walls in structure protect it from the external environment. As per the modern designs, when calculating the seismic behaviour of RC frames, the infill is not considered as a structural part and only used as a load-bearing element. Thus, inaccurate results are obtained, leading to a poor estimation of seismic behaviour. Despite considering them to be non-structural, researchers must learn how infill walls perform during earthquakes.

1.6 OBJECTIVES

- To study the variations of various seismic parameters in bare frame and brick infill using equivalent diagonal strut method (FEMA 356 and IS code 1893:2016).
- Note down the difference of the seismic parameters between different methods (FEMA 356 and IS code 1893:2016).
- Study the variations and note down the differences by reducing the densities and Young’s modulus E in the same proportion (until 60%).

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Using dynamic response data of RC framed masonry walls and non-masonry walls, the present study examines both scenarios and a comparative study between different types of infill walls is also done. The general philosophy of different types of analysis of RC Frames with infill walls is available in literature.

2.2 LITERATURE REVIEW

A longitudinal study conducted by Dolsek and Fajfar examined the structural effects of masonry infill walls on a four-storey RC frame and observed that the presence of walls distributed consistently throughout the structure was satisfactory for the integrity of the structure, and columns would not be damaged [1].

Hemant B. Kaushik and Sudhir K. Jain after conducting several field investigations during the 23 December 2004 Sumatra earthquake, concluded that buildings experience soft storey damage, out of plane collapses, in plane collapses, and shear failures due to inadequate infill walls and improper packing gaps between RC frames and MI walls [2].

Korkmaz et. al studied the earthquake response of these 3-story R/C frame structures with different amounts of masonry infill walls. Regarding with the paper's results of the pushover analyses, especially, infill walls have very important effects on structural behaviour [3].

Based on his analysis of the dominant parameters affecting fundamental period of RC buildings including infill walls, Mehmat Matin concluded that infill walls can shorten the fundamental period by 5–10% when compared to the reduction of walls without infill [4].

Mosalam et. al conducted experimental analysis and concluded that RC frames with URM infill commonly have inferior tensile strength and that brick absorption rate affects it as well. In addition, the tensile strength of the frame is dependent on how fast the masonry units absorb moisture. Building strength is determined by the spacing between the MI-RC frames [5].

Yu and Tan studied that CAA and TCA are significantly affected by the axial and rotational constraints at beam ends [6].

RC frames's seismic performance was assessed by Meng et al. in 2013. Three ground motions were used in the analysis of two four-story RC buildings. The walls were determined to contribute significantly to the structural performance during a seismic event. Additionally, the researchers found that the infill walls increased stiffness and ductility, and that plastic hinges were fewer when the walls collapsed [7].

RC structures with one-storey, single-bay, were tested seven times by Jiang et al. in 2015. Of the seven tests, five involved the use of flexible connections for masonry walls, one involved rigid connection for walls and one did not include walls. Rigid connections are stronger in lateral strength, stiffer, and have greater capacity to dissipate energy, however their displacement ductility is lower than flexible connections. Furthermore, a reversal of the trend is seen with flexible connections [8].

Rajashri A. Deshmukh and P.S. Pajgade studied an investigation of the analysis of RC frames with both AAC block and conventional clay brick infill subject to earthquake loads and at varying percentages of openings. It was observed that the base shear, lateral forces, and story shear and all the other parameters for the structure with AAC blocks was significantly less as compared with the structure infilled with brick masonry [9].

To minimize damages to RC frames and ensure ductility, Bolis et al proposed a method for increasing the flexibility of infill walls [10].

Bhavani Shankar and Anusha studied an attempt which was made to analyse the structure when the infill wall is modelled using interlocking blocks. It was observed that overall displacement of interlocking block wall was reduced when compared with frame without infill wall and with infill wall [11].

Karam Singh Yadav and Dr. Pratap Singh studied an attempt was made to analyse the performance of RCC frame with infills panels with and without openings. Study findings indicate that infill panels increase stiffness of the structure, whereas increasing the opening percentage decreases lateral stiffness of the infilled frame [12].

In 2017, Shawkat et al. studied seismic performance of RC frames with infill walls. Research modelled the behavior of a single-bay, 2-story frame with and without infill walls using the ABAQUS software. These results demonstrate that plastic hinges form faster, and lateral displacements are reduced by half when infill walls are absent [13].

The Gorkha earthquake and the subsequent aftershocks were investigated by Barbosa et al. in 2017 [14].

In 2017, Burton et al. studied earthquake-affected RC frames with infill walls. Several RC frames with two, four, six and nine stories had infill walls distributed along height in both complete and partial ways. Multiple earthquakes were simulated on the structures using the IDA method by OpenSees. RC frames with complete walls are affected by multiple earthquakes, resulting in soft and weak stories. Moreover, the ductility of the structures is less than when partial walls are added to the building [15].

Surana et al. We evaluated two structural building configurations, one uniformly infilled and one with an open ground floor, using the FEMA P695 far-field ground motion suite. Infilled RC frames show greater structural nonlinearity than bare RC frames, which is observed in the results of the research [16].

Sukrawa and Budiwati concluded that openings in infill walls have an impact on internal forces, reinforcement, wall stresses, and soft story mechanisms based on their findings in 2019. [17].

Priyanka et. al studied seismic response of reinforced concrete (RC) structure which was investigated analytically using response spectrum method (RSM) while considering and ignoring the effect of masonry. It was clear from results that MI contributes to overall strength and stiffness of the structure and leads to overestimation of base shear and underestimation of displacement [18].

Suryawanshi et. al studied the effect of infill in building and their behaviour in structure. According to them Displacement, Storey Drift and Storey shear of the structure with AAC block in all the three Model cases is found less than that of conventional brick masonry [19].

Infill walls were studied in the study of reinforced concrete (RC) frames with slabs for the effect on progressive collapse resistance. Planar frames could be made stiffer by installing an infill wall, which increased the initial load capacity of the frames [20].

Ali Jalaeefar and Malihe Hejazi investigated the seismic resistance of special steel moment resisting frames with different infills. Moreover, the analysis shows that infills are effective in reducing structural damages and increasing structural resilience depending on the degree of risk. The increase in risk level indicates that infills contribute to increasing the resilience index [21].

The paper by Pradhan et al reviewed the extensive literature on Out-of-Plane tests on infill walls based on different influencing parameters and compared the experimental results. According to dynamic tests, both infill walls and frames can be damaged as acceleration increases. This finding, however, may not be conclusive due to a limited number of dynamic tests [22].

An assessment of masonry infill walls in the linear range as well as the investigation of post peak behavior of RC buildings with open ground levels was conducted by Chandra et al. It has been observed that the location of the opening in the infill wall does not significantly affect the response of the building to displacement loads [23].

A new multi-platform simulation method is presented in a paper by Alex Brodsky and Xu Huang for modelling reinforced concrete infilled frames. A simulation of sudden column removal was shown to be almost five times faster without the steps before the column removal [24].

Kaipal Shankar Soni and Anjali Rai compared four building models for seismic behaviour by considering openings (10% of the area of the wall) at different locations in the infill walls. In comparison with models without openings, models with openings are more efficient [25].

2.3 LITERATURE GAP

All the papers which are studied no paper studied the relationship of RC frame with brick infill using equivalent diagonal strut method by methods of IS 1893:2016 and FEMA 356.

CHAPTER 3

METHODOLOGY

3.1 GENERAL

To carry out the seismic analysis of G+4 residential buildings of bare frame and RC frame with infill panel we have used E Tabs software. The purpose of this study was to find out the importance of infill panels and how they play an important role in seismic analysis by modelling the infill walls using 2 different approaches.

3.2 VALIDATION

3.2.1 GENERAL

To start off the analysis of the RC frame building with infill walls, first we need to confirm that results from ETABS Software are valid. To do this, we analyze model by Priyanka, Shobha Ram and Alok Verma's research paper of Seismic Performance of Masonry Infill Reinforced Concrete International Journal on Emerging Technologies 10(1): 01-03(2019). The IS code 1893 calculated lateral forces and base shear with for the residential buildings is also compared with results from ETABS Software.

3.2.2 DETAILS OF MODEL

A G+5 residential building. The building is with plan dimensions of 12.0 m in longitudinal direction and 12.0 m in the lateral direction. Building is assumed to be symmetrical in both X and Y-direction. Bay dimension is assumed to be 4m in both directions. Clear height of floor is taken as 3m, and all columns are assumed to be fixed condition. Building is considered with ordinary moment resisting frame. Cross section of beams –250mm X 400mm, cross section of columns –400mm X 400mm and thickness of slab –150mm.

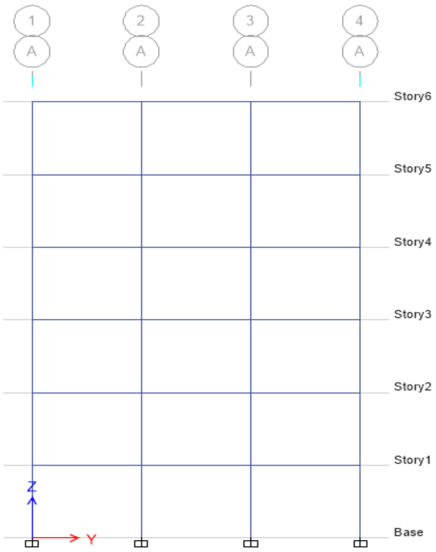


Fig 3. 1 Elevation of model

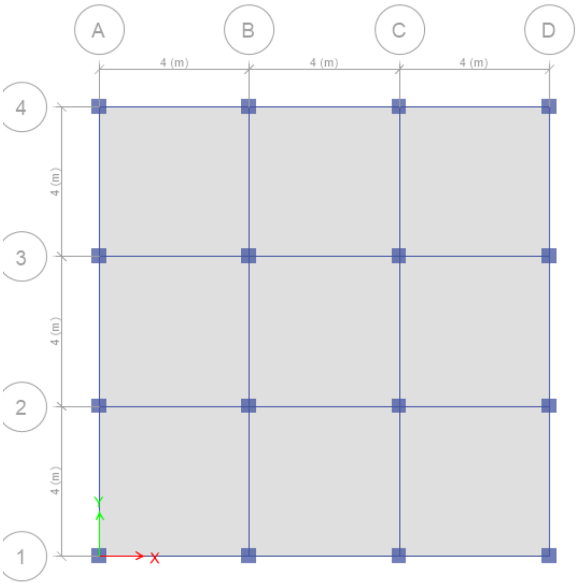


Fig 3. 2 Plan of Model

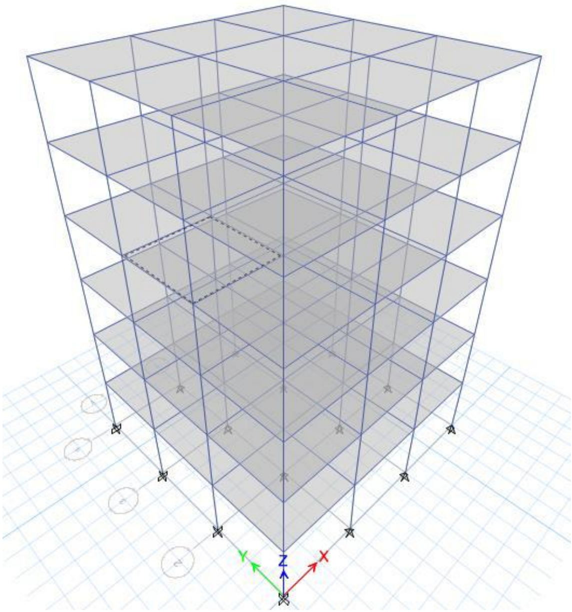


Fig 3. 3 Isometric View of model

3.2.3 ASSUMPTIONS OF VALUES

Dead Load of beam = 0.25×0.4×25=2.5*KN/m,* Dead Load of Column = 0.4×0.4×25=4*KN/m,* Dead Load including the floor covering weight = 1.5KN/m^2, Live Load on the floor = 3KN/m^2, Weight of portioning wall = 2KN/m^2, Compressive Strength of concrete = 30MPa, Specific weight of RCC = 25KN/m^3, Soil Type –II, Seismic Zone 4, Z = 0.24, Importance Factor = 1.2 and Response Reduction Factor R = 3

3.2.4 METHODOLOGY AND ANALYSIS

Seismic analysis of the model was done by Etabs2016, and base shear and lateral forces was determined of the G+5 residential building

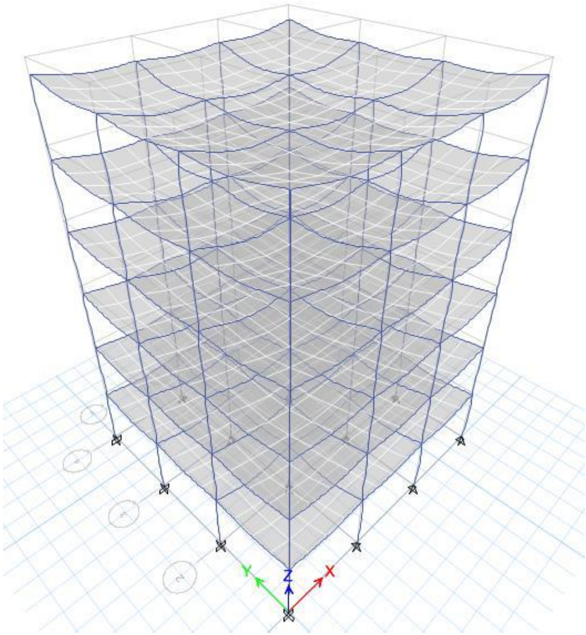


Fig 3. 4 Deformed shape of residential building

3.2.4.1 APPROACH USING IS 1893:2016 AND CALCULATION

Base shear and lateral forces were calculated using IS 1893:2016 [26].

Code provisions stipulate that a percentage of the design live load must be considered when calculating earthquake forces for the floors, while live loads for the roof are not to be considered.

- Calculate effective weight of each floor
  $1.5 + 2 + 0.25 \times 3 = 4.25\ KN/m^2$
- Calculate effective weight of roof
  $1.5\ KN/m^2$
- Calculate weight of all the beams and columns
  Weight of beam = $2.5 \times 16 \times 4 = 160\ KN$
  Weight of Column = $4\times 16 \times 3 = 192\ KN$
  Weight of Columns at roof = $0.5\times 192 = 96\ KN$
- Plan Area
  $16 \times 16 = 256m^2$

- Next, calculate the equivalent weight at roof level and of each floor

  Equivalent Weight at roof level = $1.5 \times 256 + 160 + 96 = 640KN$

  Equivalent Weight at each floor = $4.25 \times 256 + 160 + 132 = 1440KN$
- Calculate Seismic weight which is equal to the sum of equivalent weight of roof and equivalent weight of all the floors combined

  $640 + 1440 \times 5 = 7840KN$
- Calculate time period for both the direction

$$T_a = \frac{0.09h}{\sqrt{d}}$$

$$T_a = \frac{0.09 \times 18}{\sqrt{16}} = 0.405$$

- Determine the design acceleration coefficient (Sa/g)

  Because the value of $T_a = 0.405$ value of Sa/g will be 2.5

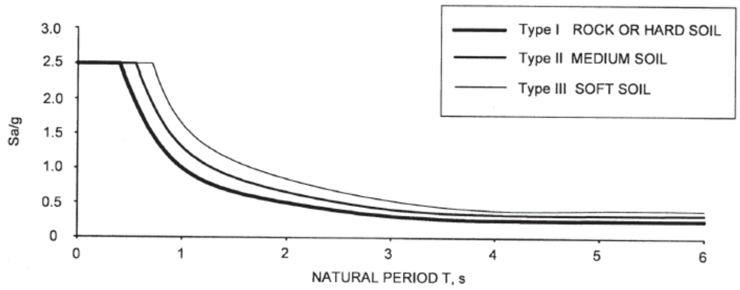


Fig 3. 5 Design Acceleration Coefficient

- Calculate the design horizontal seismic coefficient

$$A_h = \frac{\left(\frac{Z}{2}\right)\left(\frac{S_a}{g}\right)}{\left(\frac{R}{I}\right)}$$

$$A_h = \frac{\left(\frac{0.24}{2}\right)(2.5)}{\left(\frac{3}{1.2}\right)} = 0.12$$

- Calculate the design base shear

$$V_B = A_h W$$

$V_B = 0.12 \times 7840 = 940.8KN$

- At last, calculate lateral forces for all the floors

$$Q_i = \left(\frac{W_i h_i^2}{\sum_{i=1}^{n} W_i h_i^2}\right) V_B$$

Table 3. 1 Calculation of Lateral loads and shear

Floor	$\boldsymbol{W_I}$	$\boldsymbol{h_I}$	$\boldsymbol{W_I h_i^2}$	$\boldsymbol{\frac{W_i h_i^2}{\sum_{i=1}^{n} W_i h_i^2}}$	$\boldsymbol{Q_i}$	$\boldsymbol{V_i}$**(KN)**
Roof	640	18	207360	0.225352	212.0113	212.0113
5	1440	15	324000	0.352113	331.2676	543.2789
4	1440	12	207360	0.225352	212.0113	755.2901
3	1440	9	116640	0.126761	119.2563	874.5465
2	1440	6	51840	0.056338	53.00282	927.5493
1	1440	3	12960	0.014085	13.2507	940.8
			$\sum_{i=1}^{n} W_i h_i^2$ =920160			

3.2.5 RESULTS

Table 3. 2 Result for lateral forces

Lateral Forces			
Story	**Etabs**	**IS 1893**	**Error %**
	kN	kN	
Story6	180.546	212.0113	14.84133
Story5	300.266	331.2676	9.358476
Story4	192.546	212.0113	9.181256
Story3	107.76	119.25	9.63522
Story2	48.76	53.008	8.013885
Story1	11.94	13.25	9.886792

Table 3. 3 Results for design base shear

Design Base Shear		
Etabs kN	**IS 1893** kN	**Error %**
841.818	940.7982	10.52087

The results of the ETABS software are validated with the values of lateral force and base shear from IS code provisions 1893 (2016) and the percentage error on average is found to be 10.15%. for lateral forces and 10.52% for base shear

Hence, the results of ETABS are validated with IS code provisions.

3.3 DETAILS OF MODEL

The building is with plan dimensions of the length of the building is 16.0 m longitudinally and 16.0 m laterally. Bay dimension is assumed to be 4m in both the X and Y axes. Clear height of floor is regarded as 3 m and all columns are assumed to be in fixed condition.

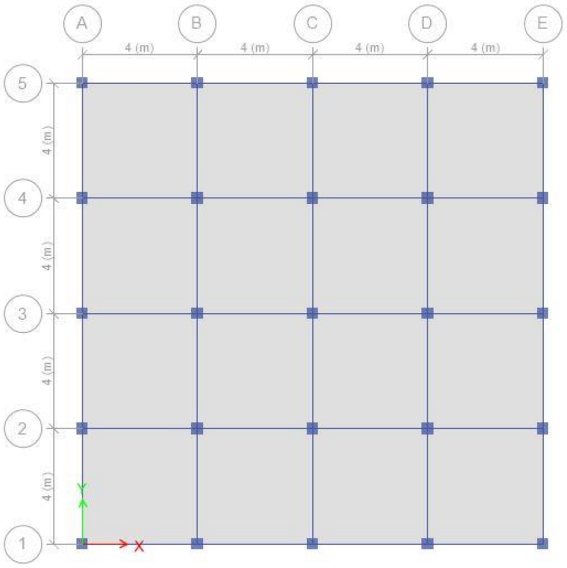


Fig 3. 6 Plan

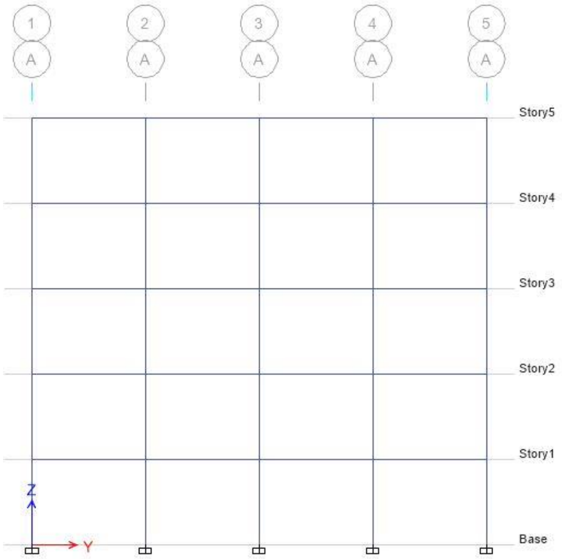


Fig 3. 7 Elevation

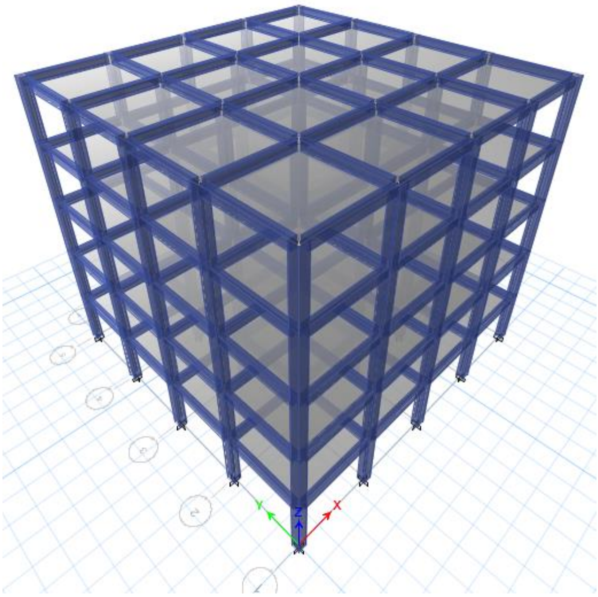


Fig 3. 8 Isometric View

Building is in zone 4 and soil type is medium. The model is assumed to be of ordinary moment resisting frame and damping is of 5%.

Cross section of beams – 250mm X 400mm

Cross section of columns – 400mm X 400mm

Thickness of slab – 150mm

Compressive Strength of concrete = 30MPa

Specific weight of RCC = 25KN/m^3

3.4 MODELLING OF MASONRY INFILL FRAME

The MI walls considered here in are modelled using equivalent diagonal strut method. And equivalent diagonal strut method can be approached using many methods and we have modelled struts as compression members using 2 approaches with the provisions given by IS 1893 code and FEMA 356.

3.4.1 Equivalent diagonal strut method as per IS 1893: 2016

Width of Equivalent Strut [26]

For URM infill walls in the absence of opening width w_{ds} of equivalent diagonal strut will be regarded as

$$w_{ds} = 0.175 \propto_h^{-0.4} L_{ds}$$

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

E_m is the modulus of infill material

The modulus of elasticity E_m (in MPa) of masonry infill wall will be regarded as:

$$E_m = 550 f_m$$

Where f_m is the brickwork prism's compressive strength (in MPa) achieved in accordance with IS 1905 or as determined by expression:

$$f_m = 0.433 f_b^{0.64} f_{mo}^{0.36}$$

- f_m is compressive strength in masonry
- f_b is Brick compressive strength

- f_{mo} is mortar's compressive strength
- E_f is modulus of elasticity of frame material
- t is the thickness of the infill frame
- I_c is the neighbouring column's moment of inertia
- h is height of infill frame
- θ is the horizontal angle of a diagonal strut
- L_{ds} is the infill frame diagonal length

Calculating the width of the equivalent strut was done by assuming the value of $f_{mo} = 10MPa$ and $f_b = 20MPa$ and t = 0.23m

So, the value of w_{ds} was coming out to be 477.2mm

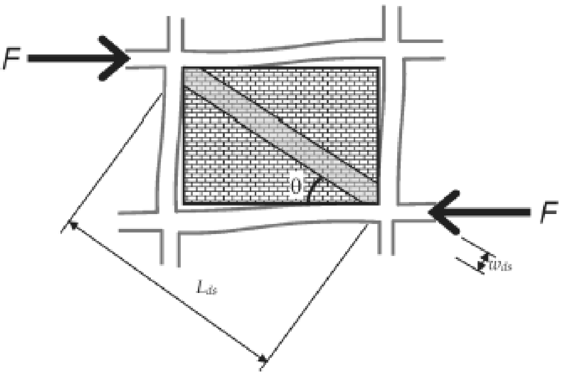


Fig 3. 9 Strut of masonry infill wall

3.4.2 Equivalent diagonal strut method as per FEMA 356

Width of Equivalent Strut [27]

$$a = 0.175(\lambda_l \lambda_{col})^{-0.4} r_{inf}$$

Where $\lambda_l = \left(\sqrt[4]{\frac{E_{me}t_{inf}\sin 2\theta}{4E_{fe}I_{col}h_{inf}}}\right)$

- E_{me} is Young's modulus of infill material

- E_{fe} is Young's modulus of frame material
- t_{inf} is the thickness of the infill frame
- I_{col} is the neighbouring column's moment of inertia
- h_{inf} is height of infill frame
- θ is the horizontal angle of a diagonal strut
- r_{inf} is the diagonal length of infill frame
- h_{col} is column height between centrelines of beams

Calculating the width of the equivalent strut was done by taking the value E_{me} as same as E_m in IS 1893 method and t_{inf} = 0.23m

So, the value of a was coming out to be 450.4mm

Strut was modelled by the section designer in E Tabs

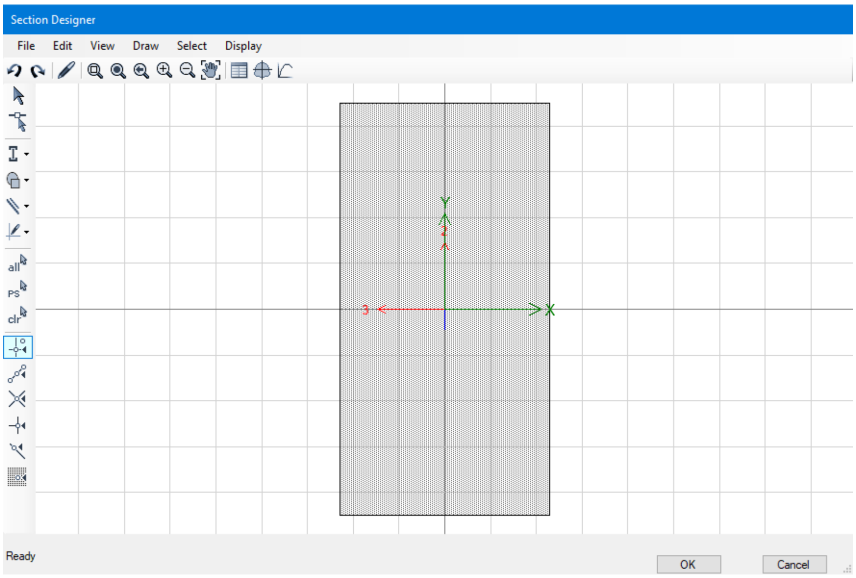


Fig 3. 10 Section Designer

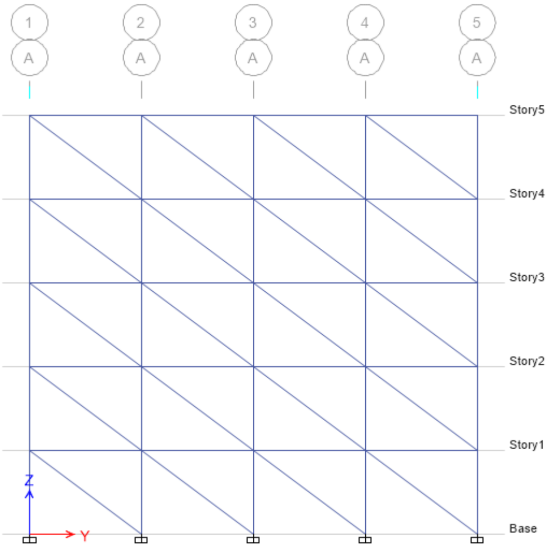


Fig 3. 11 Elevation of infill panel

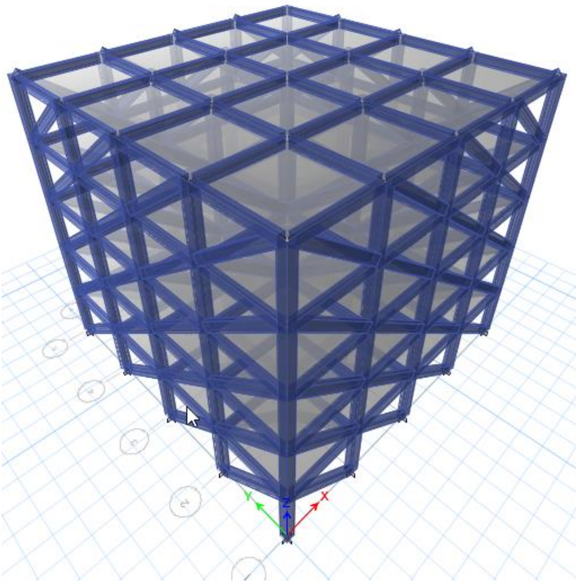


Fig 3. 12 Infill Panel Isometric View

CHAPTER 4

RESULT AND DISCUSSION

4.1 GENERAL

In evaluating dynamic analysis results of residential buildings, ETABS software is used to create building models and to examine the effect of RC frame structure by considering and ignoring masonry infill walls in residential buildings.

4.2 ASSUMPTION OF VALUES

RS analysis is carried out in x-direction. In the vertical force calculation on a building, dead loads and live loads are considered. The slab is assumed to have a dead load of 1.5 kN/m^2. Live load on the floor is assumed to be 3 kN/m^2. Weight of floor finishing is assumed to be 2 kN/m^2. Bricks are assumed to have a compressive strength of 20MPa, and mortar is assumed to have a compressive strength of 10MPa. The analysis and design of buildings are done by using concrete having a compressive strength of 30 kN/m^2. It is a considered that reinforcement concrete has a specific weight of 25 kN/m^3, while the modulus of elasticity of concrete is calculated according to IS 456. In IS 1893 and FEMA 356, provisions are given for calculating the compressive strength of infill. Moment of inertia is calculated for adjacent columns and then used for width calculation. Width of the compression using IS 1893 is taken as 0.477 m and while using FEMA 356 IS taken as 0.45m, with thickness of 0.23 m and length of strut comes out to be 5 m.

4.3 COMPARISION OF SEISCMIC PARAMETERS OF BARE FRAME AND RC FRAME WITH INFILL WALLS

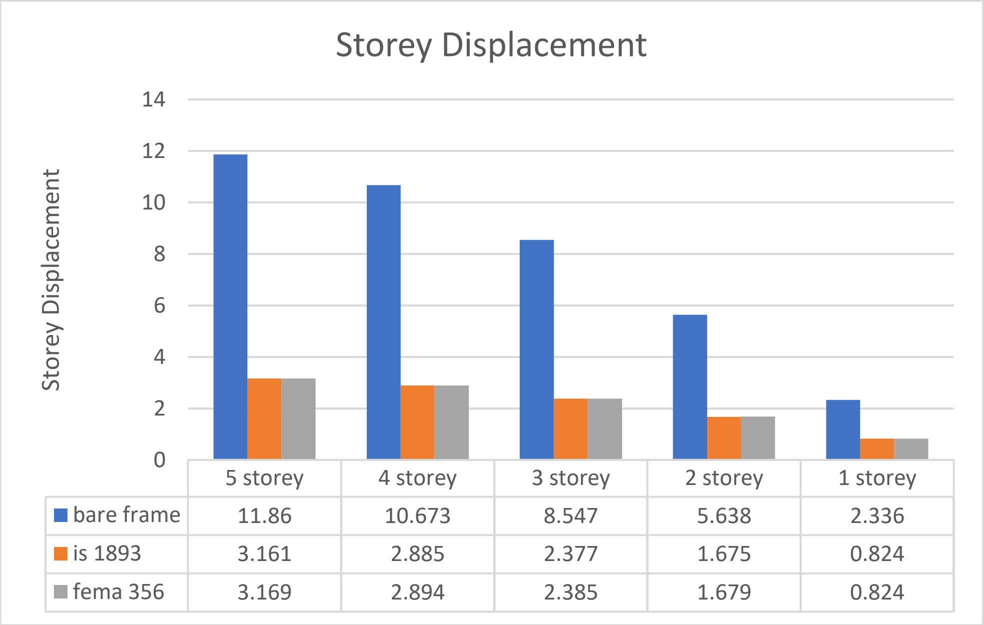
Storey Displacement

A response spectrum method is used to analyse the results of dynamic analysis, and comparative studies are made. The changing properties of the building under dynamic lateral loads are examined and represented in graphical format to study the damage to the structure. Resultant displacement of X-direction is considered. With respect to bare frame, it was observed that with increasing stiffness of the structure by including infill panels storey displacement reduces.

Table 4. 1 Percentage representation of storey displacement compared to bare frame and infill walls

Storey	**RC Frame modelled by IS 1893**	**RC Frame modelled by FEMA 356**	**Comparison between RC Frame modelled by IS 1893 and FEMA 356**
Storey 5	73.3 %	73.2%	-
Storey 4	72.9%	72.8%	-
Storey 3	72.1%	72.09%	-
Storey 2	70.3%	70.3%	-
Storey 1	64.72%	64.72%	-

Also, as seen from Table 4.1 there is no difference between the maximum storey displacement of RC frame with infill panel modelled by IS1893 and RC frame with infill panel modelled by FEMA 356.



	5 storey	4 storey	3 storey	2 storey	1 storey
🟦 bare frame	11.86	10.673	8.547	5.638	2.336
🟧 is 1893	3.161	2.885	2.377	1.675	0.824
⬜ fema 356	3.169	2.894	2.385	1.679	0.824

Fig 4. 1 Variation of Storey Displacement

Base Shear

It is evident that presence of infill wall by IS1893 has pronounced the base shear results

Table 4. 2 Percentage representation of base shear compared to bare frame and infill walls

Storey	RC Frame modelled by IS 1893	RC Frame modelled by FEMA 356	Comparison between RC Frame modelled by IS 1893 and FEMA 356
Base	27.69 %	22.71%	4.06%

When the results of infill panel are compared, from table 4.2 that presence of infill wall by IS1893 has pronounced the base shear results as compared to RC frame in the presence of FEMA 356.

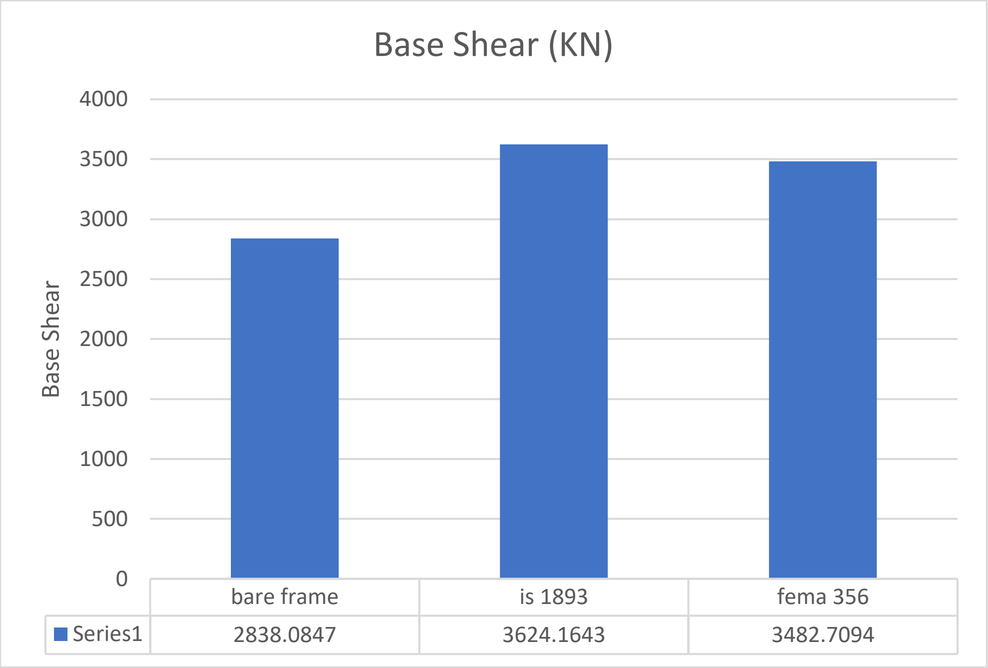


Fig 4. 2 Variation of Base Shear

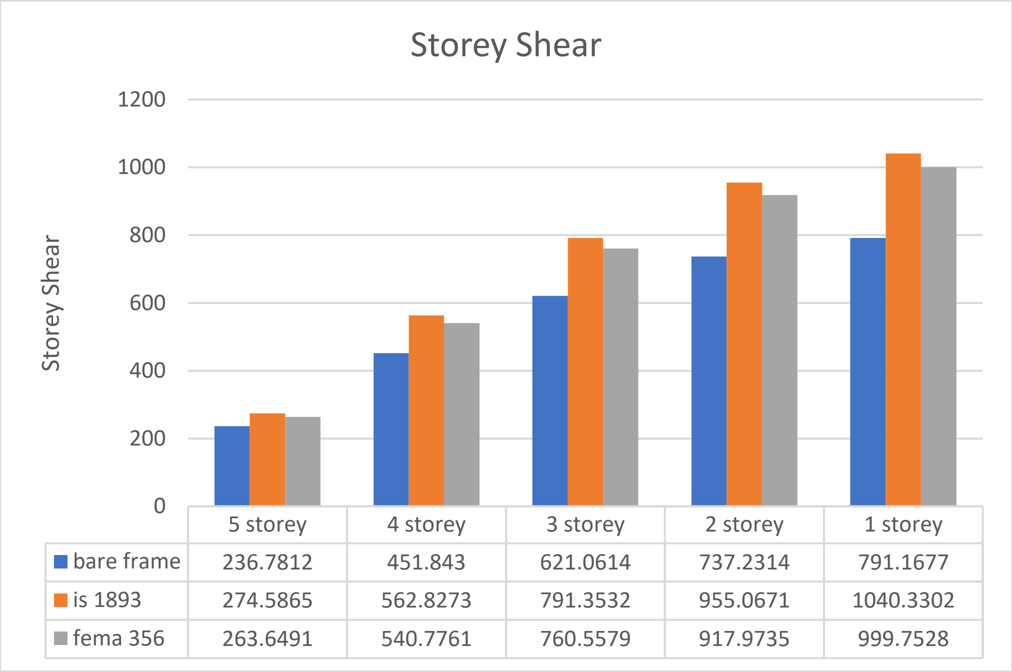
Storey Shear

An important parameter for structural engineers is storey shear. The results show that ignoring the effect of masonry infill walls and treating it as RC bare frame resulted in increased by substantial differences in values of storey shear.

Table 4. 3 Percentage representation of storey shear compared to bare frame and infill walls

Storey	RC Frame modelled by IS 1893	RC Frame modelled by FEMA 356	Comparison between RC Frame modelled by IS 1893 and FEMA 356
Storey 5	15.96 %	11.34%	4.14%
Storey 4	24.56%	19.68%	4.07%
Storey 3	27.41%	22.46%	4.09%
Storey 2	29.54%	24.51%	4.04%
Storey 1	31.49%	26.36%	4.058%

By observing table 4.3 and comparing infill RC frame structure modelled by IS1893 and FEMA 356, the storey shear of infill RC frame structure modelled by IS1893 is increased as compared to RC frame structure modelled by FEMA 356.



	5 storey	4 storey	3 storey	2 storey	1 storey
■ bare frame	236.7812	451.843	621.0614	737.2314	791.1677
■ is 1893	274.5865	562.8273	791.3532	955.0671	1040.3302
■ fema 356	263.6491	540.7761	760.5579	917.9735	999.7528

Fig 4. 3 Variation of Storey Shear

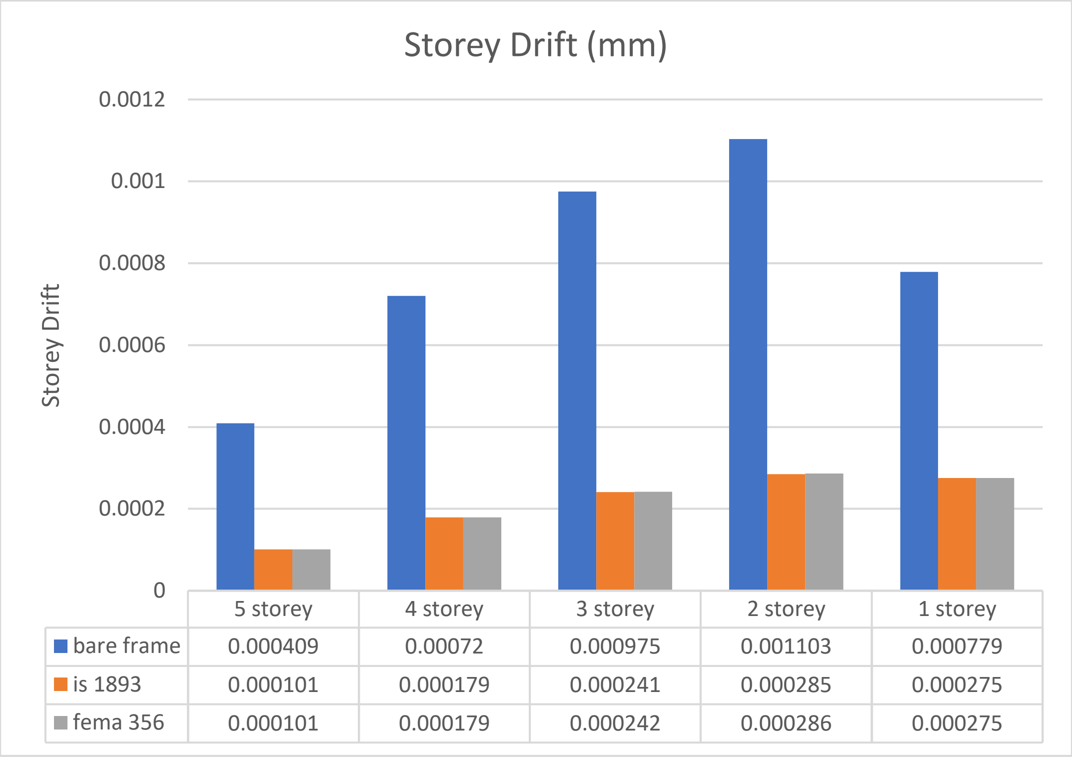
Storey Drift

The difference in displacements between two successive storeys divided by the height of that level is called storey drift. Installing infill panel influences the values of storey drift as compared to bare frame.

Table 4. 4 Percentage representation of storey drift compared to bare frame and infill walls

Storey	**RC Frame modelled by IS 1893**	**RC Frame modelled by FEMA 356**	**Comparison between RC Frame modelled by IS 1893 and FEMA 356**
Storey 5	75.3%	75.3%	-
Storey 4	75.13%	75.13%	-
Storey 3	75.28%	75.28%	-
Storey 2	74.16%	74.16%	-
Storey 1	64.69%	64.69%	-

But RC frame structure in which infill is modelled by IS1893 has little to no difference as compared to RC frame structure in which infill is modelled by FEMA 356 as seen in table 5.4



	5 storey	4 storey	3 storey	2 storey	1 storey
🟦 bare frame	0.000409	0.00072	0.000975	0.001103	0.000779
🟧 is 1893	0.000101	0.000179	0.000241	0.000285	0.000275
◼ fema 356	0.000101	0.000179	0.000242	0.000286	0.000275

Fig 4. 4 Variation of Storey Drift

4.4 THE VARIATIONS OF SEISMIC PARAMETERS BY REDUCING THE DENSITIES AND YOUNG'S MODULUS E IN THE SAME PROPORTION (UNTIL 60%)

For this analysis of the objective results of RC frame modelled by IS 1893 has been used. Densities of the material of infill panel was reduced till 60%. And Young's modulus E was also reduced in the same proportion. And with the change of E width of diagonal strut is also changed. Initially the density of the infill panel was $\rho = 21.2068\ KN/m^3$ and E was coming out to be $E = 3711\ MPa$. And using the equivalent strut method width of the strut was coming out to be 477.2mm.

Table 4. 5 Values of reducing densities and young's modulus

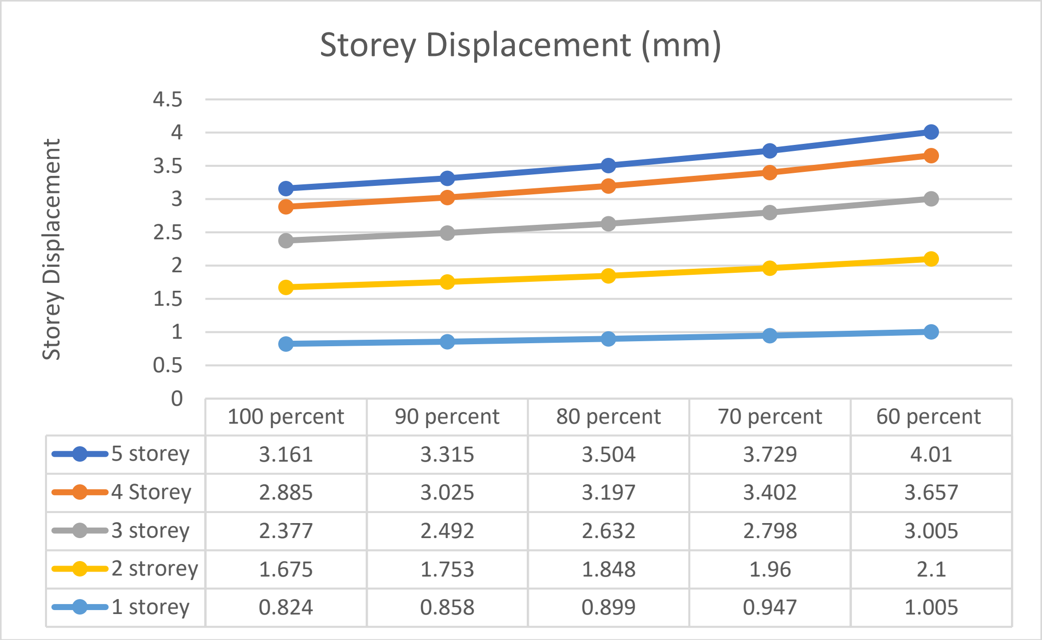
Density $(\frac{KN}{m^3})$	**Young's Modulus E (MPa)**	**Width W_{ds} (mm)**
21.2068	3711.16	477.2
19.086	3340.044	482.8
16.965	2968.93	487.68
14.844	2597.812	494.52
12.724	2226.696	501.9

Storey Displacement

When densities of the infill panel are reduced, it is evident that storey displacement increases.

Table 4. 6 Percentage representation of Storey Displacement with reducing densities

Density Reduced to	**Increase in upper storey**	**Increase in Lower storey**
90%	4.87%	4.12%
80%	10.85%	9.1%
70%	17.96%	14.92%
60%	26.85%	21.96%



	100 percent	90 percent	80 percent	70 percent	60 percent
5 storey	3.161	3.315	3.504	3.729	4.01
4 Storey	2.885	3.025	3.197	3.402	3.657
3 storey	2.377	2.492	2.632	2.798	3.005
2 strorey	1.675	1.753	1.848	1.96	2.1
1 storey	0.824	0.858	0.899	0.947	1.005

Fig 4. 5 Variation of Storey Displacement with reducing densities

When storey displacement in percentage of each storey was averaged and then compared with the percentage by which density has been reduced a trend can be seen.

Table 4. 7 Average Percentage Storey Displacement with reducing Density

Percentage Reduction %	Average Percentage of Storey Displacement of each storey %
90	4.669104688
80	10.36473254
70	17.10855704
60	25.47533971

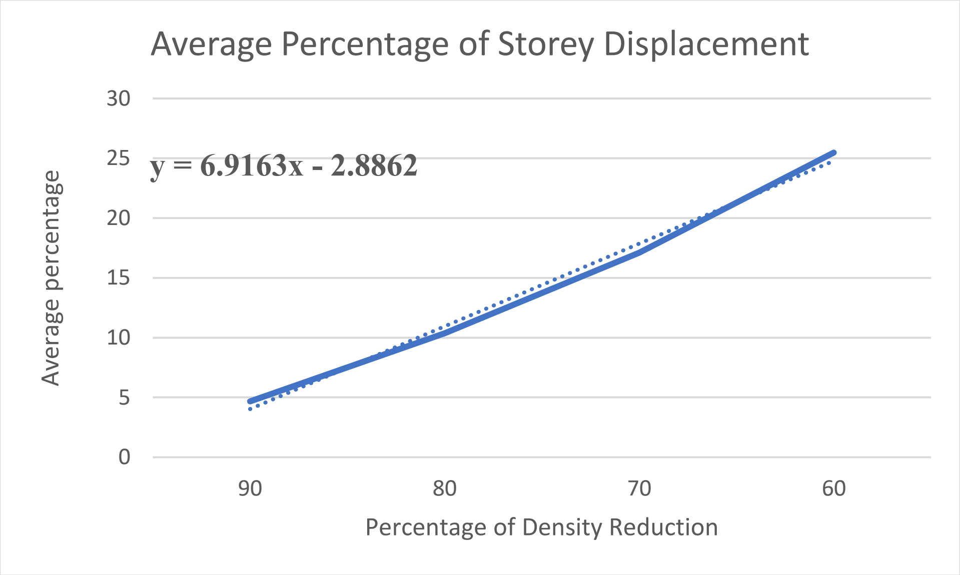


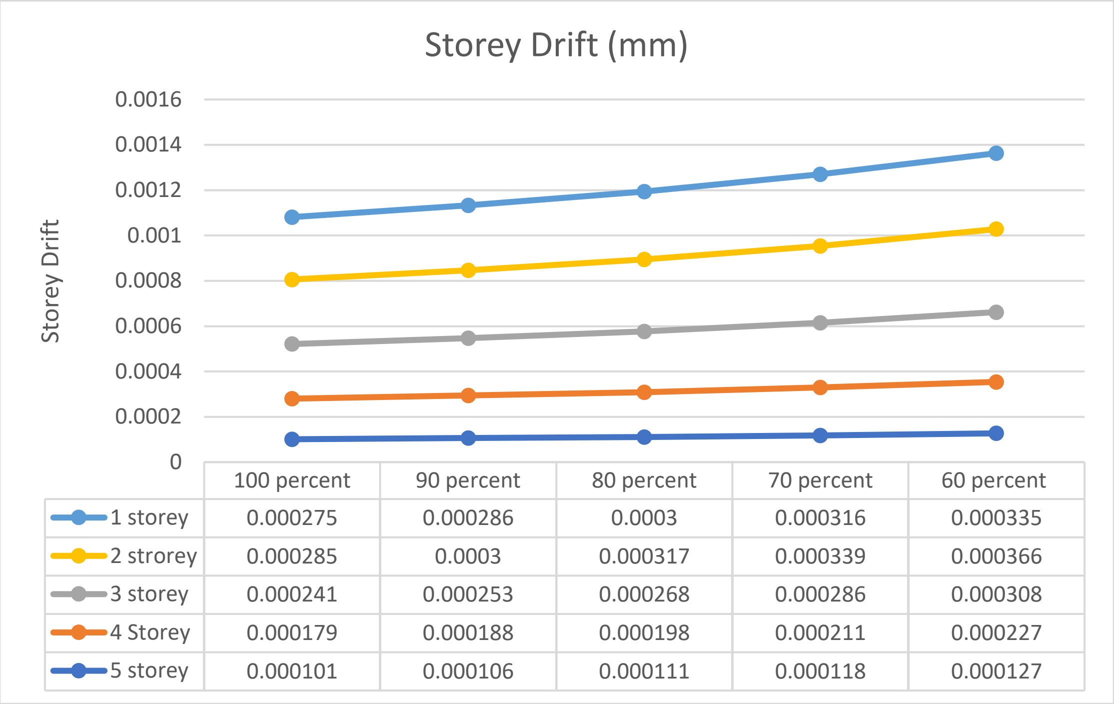
Fig 4. 6 Trendline for Storey Displacement

Storey Drift

When densities of the infill panel are reduced, storey drift increases.

Table 4. 8 Percentage representation of Storey Drift with reducing densities

Density Reduced to	**Increase in Upper storey**	**Increase in Lower storey**
90%	4.95%	4 %
80%	9.9%	9.09%
70%	16.8%	14.9%
60%	25.74%	21.81%



	100 percent	90 percent	80 percent	70 percent	60 percent
1 storey	0.000275	0.000286	0.0003	0.000316	0.000335
2 strorey	0.000285	0.0003	0.000317	0.000339	0.000366
3 storey	0.000241	0.000253	0.000268	0.000286	0.000308
4 Storey	0.000179	0.000188	0.000198	0.000211	0.000227
5 storey	0.000101	0.000106	0.000111	0.000118	0.000127

Fig 4. 7 Variation of Storey Drift with reducing densities

Similarly, when storey drift in percentage of each storey was averaged and then compared with the percentage by which density has been reduced a trend can be seen.

Table 4. 9 Average Percentage Storey Drift with reducing Density

Percentage Reduction %	**Average Percentage of Storey Drift of each storey %**
90	4.844168
80	10.40756
70	17.44749
60	26.11966

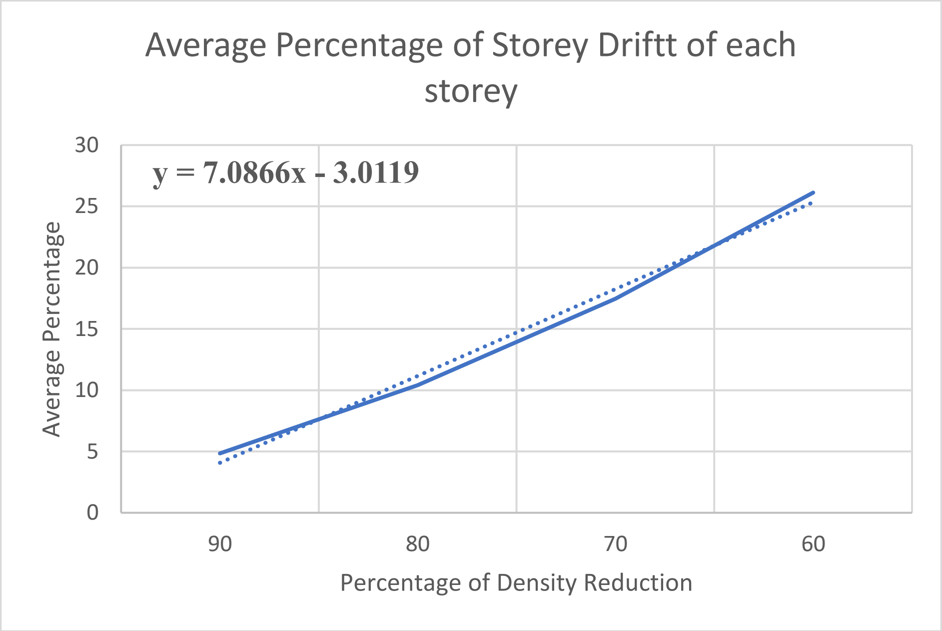


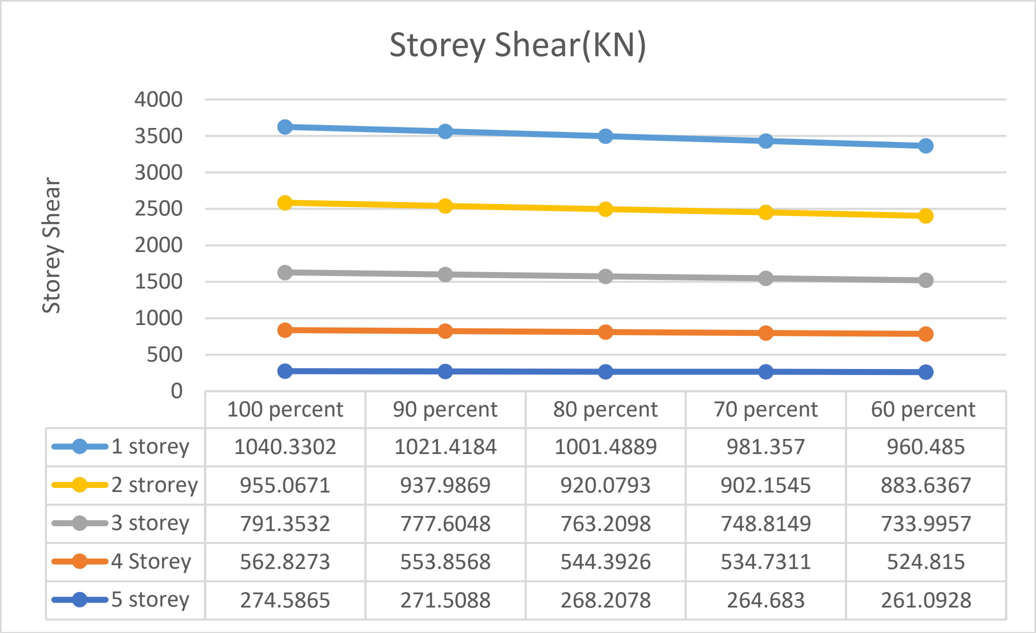
Fig 4. 8 Trendline for Storey Drift

Storey Shear

When densities of the infill panel are reduced, storey shear decreases.

Table 4. 10 Percentage representation of Storey Shear with reducing densities

Density Reduced to	Decrease in Upper storey	Decrease in Lower storey
90%	1.13%	1.85 %
80%	2.37%	3.87%
70%	3.74%	6.01%
60%	5.16%	8.31%



	100 percent	90 percent	80 percent	70 percent	60 percent
1 storey	1040.3302	1021.4184	1001.4889	981.357	960.485
2 strorey	955.0671	937.9869	920.0793	902.1545	883.6367
3 storey	791.3532	777.6048	763.2098	748.8149	733.9957
4 Storey	562.8273	553.8568	544.3926	534.7311	524.815
5 storey	274.5865	271.5088	268.2078	264.683	261.0928

Fig 4. 9 Variation of Storey Shear with reducing densities

Similarly, when storey shear in percentage of each storey was averaged and then compared with the percentage by which density has been reduced a trend can be seen.

Table 4. 11 Average Percentage Storey Drift with reducing Density

Percentage Reduction %	**Average Percentage of Storey Drift of each storey %**
90	1.638741
80	3.426622
70	5.31023
60	7.324453

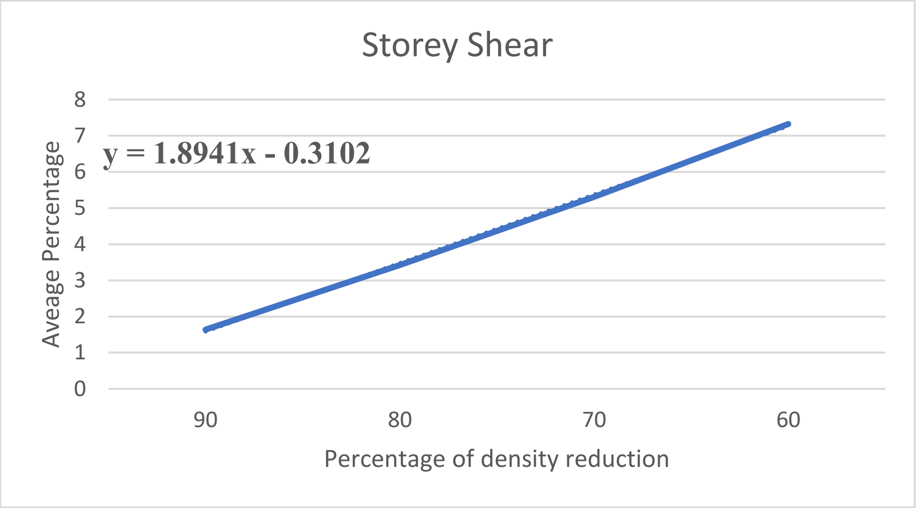


Fig 4. 10 Trendline for Storey Shear

CHAPTER 5

CONCLUSION

RC framed residential buildings are investigated for their response to MI walls using response spectrum analysis.

For the first and second objective of the study of seismic response of MI walls, a RC frame structure with and without MI walls is considered.

- According to the report the purpose of the report was to study the variation of the seismic parameters of RC frame structures with and without the infill walls by using 2 different approaches of equivalent diagonal strut method (By IS 1893 and FEMA 356).
- For the variation of storey displacement, the parameter was found to be
    - Decreased by average percentage of 70.62%, when the parameter of bare frame is compared to IS 1893 as well as FEMA 356
    - Of the same value when IS 1893 values were compared to FEMA 356 values
- For the variation of base shear, the parameter was found to be
    - Increased by of 27.69%, when the parameter of bare frame is compared to IS 1893 and increased by 22.71% when the parameter of bare frame is compared to FEMA 356.
    - Decreased by 4.06% when IS 1893 values were compared to FEMA 356 values.
- For the variation of storey shear, the parameter was found to be
    - Increased by average percentage of 25.79%, when the parameter of bare frame is compared to IS 1893 and increased by 20.87% when the parameter of bare frame is compared to FEMA 356.

    - Decreased by average percentage of 4.07% when IS 1893 values were compared to FEMA 356 values.
- For the variation of storey drift, the parameter was found to be
    - Decreased by average percentage of 72.19%, when the parameter of bare frame is compared to IS 1893 as well as FEMA 356
    - Of the same value when IS 1893 values were compared to FEMA 356 values
- From the above results, we can conclude that storey drift is the most susceptible parameter when infill wall is installed in a bare RC frame, while storey shear is the least. Whereas, when approach of modelling is change from IS 1893 to FEMA 356, there is no change in storey displacement and storey drift but there is a small change in base shear and storey shear.

For the study of seismic response of MI walls, a RC frame structure with infill wall modelled by IS 1893 is considered. The results were shown using graphs

- According to the report the purpose of the report was to study the variation of the seismic parameters of RC frame structures with infill wall by reducing the densities of the infill wall material
- For the variation of storey displacement, the parameter was found to be
    - Increased when density was being reduced with young's modulus proportionately
    - From the Fig 4.6 we can see the trendline of the increasing percentage of storey displacement with reducing densities. The linear equation was coming out to be $y = 0.0692x - 0.0289$. This means the slope of this equation becomes 0.0629.
- For the variation of storey drift, the parameter was found to be
    - Increased when density was being reduced with young's modulus proportionately
    - From the Fig 4.8 we can see the trendline of the increasing percentage of storey drift with reducing densities. The linear equation was coming out

    to be y = 0.0709x - 0.0301. This means the slope of this equation becomes 0.0709.

- For the variation of storey shear, the parameter was found to be
    - Increased when density was being reduced with young's modulus proportionately
    - From the Fig 4.8 we can see the trendline of the increasing percentage of storey drift with reducing densities. The linear equation was coming out to be y = 0.0189x - 0.0031. This means the slope of this equation becomes 0.0189.

  Similarly, if we plot the graph of the average percentages, draw the line of best fit then the linear equation comes out to be y = 0.0189x - 0.0031. This means the slope of this equation becomes 0.0189.

- From the above results, and by observing the slopes of all the trendlines of all the parameters we can conclude that storey drift is the most susceptible when the density of the material reduces, and storey shear is the least susceptible.

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