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COMPARISON OF REINFORCED CONCRETE FRAMES MODELLED WITH AND WITHOUT INFILL WALLS

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ABSTRACT

In the present scenario of the construction sector, reinforced concrete structures having infill walls are analysed and designed as bare frames i.e. without taking into consideration strength and stiffness of infills, though in reality they act as a single unit during earthquakes. The aim is to study the effect of masonry infill walls on the behavior and performance of the buildings through different parameters such as time period, storey drift, maximum displacement for column, details of concrete and reinforcement and distribution of base shear. For this purpose nine models of three, six and nine storeys have been selected and modeled with and without infill using STAAD.Pro V8i software. The results indicated that masonry infills eminently increase the stiffness and strength of a structure by reducing fundamental time period by 40%, storey drift by about (25-40)% and displacement by about (15-35)% ,also member forces were increased by (90-95)% showing that structure is attracting more forces due more stiffness.

Key words: Infill Walls, Reinforced Concrete, Frames Modelled.

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1. INTRODUCTION

Infill walls have been widely used in seismic regions for the construction of residential, industrial and commercial structures. But they are not considered in design and used as an architectural (non structural) part of the system.The presence of masonry infill walls has a significant impact on the seismic response of a reinforced concrete frame building, increasing structural strength and stiffness. Structures in many seismic areas of the world are built as per design codes but still suffer failure during earthquakes.This may mean that there are deficiencies in design. This event cannot be avoided but, by proper planning and design we can prevent it to a notable extent and hence structural engineers needs to design the structure taking into account all necessary factors including infill walls which plays a important role during earthquakes.

The aim is to study the response of the structural system when subjected to seismic forces having masonry infills walls included in the design. This is done by analysing nine models of three, six and nine storeys modeled with and without infill on STAAD.Pro V8i software. Objectives of this project are to study the effect of different parameters on the response of the structures, these parameters are time period, storey drift, maximum displacement for column, member forces, distribution of the base shear and base shear strength. In addition to this, details of concrete and steel in terms of percentage increase/decrease are also studied.

In this study model analysis were carried out from which it was concluded that by simple modeling of equivalent diagonal struts, which carry loads only in compression, is able to simulate the global seismic response of the infilled frames by changing the distribution of damage throughout the structure, and is suitable for practical applications.

2. LITERATURE REVIEW

It is very difficult to interpret the behavior of infill walls in a structure, this is due the various parameters occurring in the structural response i.e. mechanical properties of infills, depending upon brick and mortar properties and it may also be due to construction modalities which includes presence of openings, different opening conditions between frame and panel. Many researchers have studied the effects of masonry panels on reinforced concrete frames, in order to propose and validate some approaches able to evaluate the contribution of panels to the local and global behaviour of structures. In particular Mehmet Metin Kose [1] studied the effects of selected parameters i.e. building height, number of bays, ratio of area of shear walls to area of floor, ratio of infilled panels to total number of panels and type of frame on the fundamental period of RC buildings. In general, the fundamental period of RC frames are determined by a modal analysis, by discarding the effect of infill walls on the total mass and rigidity of the structure. He analysed 189 building models with selected parameters using finite element method. It was found that RC frames with infill walls had a shorter period, about 5% -10%, compared with RC frames without infill walls regardless of whether they had shear walls or not. The presence of shear walls also led to a reduction in the fundamental period, about 6% -10%, between models with and without infill walls. Paolo Ricci et al [2], studied the elastic period of infilled RC MRF buildings**.** Fundamental period of vibration, depends on mass and stiffness structure characteristics, is a key parameter in assessing seismic demand. Two models were used for the evaluation of infill stiffness. The analysis concluded that infills increased the overall lateral stiffness of the reinforced concrete MRF building. Parameters mostly influencing the fundamental period of infilled RC MRF buildings are plan dimensions and area of infill walls. The design procedure of the reinforced concrete structure does not influence significantly the experimental value of the elastic period of infilled RC building.

Alessandra Fiore et al [3] studied a simple tool which is able to simulate the effect of infills in the global (stiffness) and local response (effects on the frame) of a building under earthquake loads. Finite Element analyses were performed. For a concrete frame with masonry infills that will crack when subjected to design lateral forces, the response can be represented by using a diagonally braced frame model, in which the infill acts as an equivalent compression strut.

The results indicated that the proposed two-strut model correctly reproduces both the global behaviour of infilled frames in terms of displacements and the local effects on frames in terms of stresses, bending moments and shear forces. Haroon Rasheed Tamboli et al [4] studied the seismic analysis using equivalent lateral force method for different reinforced concrete frame building models that include bare frame, infilled frame and open first storey frame. Diagonal Strut Method is used for modelling the infill wall. In this method the infill wall is idealized as diagonal strut and the frame is modelled as beam or truss element. Frame analysis techniques are used for the elastic analysis. The presence of infill wall can affect the seismic behaviour of frame structure to large extent, and the infill wall increases the strength and stiffness of the structure. Therefore it is important to consider the infill walls in the seismic analysis of structure. Nikhil Agrawal et al [5] studied the performance of masonry infilled reinforced concrete (RC) frames including open first storey of with and without opening. The calculation of stiffness of infilled frames is done by using “Equivalent Diagonal Strut Method”. This analysis is to be carried out on the models such as bare frame, strut frame, with 15% centre and corner opening, which is performed by using computer software STAAD-Pro from which different parameters are computed. In which it shows that infill panels increase the stiffness of the structure.

3. METHODOLOGY

The methodology involves modeling of infill walls as equivalent diagonal compression strut for six models of three, six and nine storeys for analyzing the infilled frame systems. Infill walls behave like equivalent diagonal compression struts in resisting the lateral loads. The width of equivalent compression strut is given by [6]:

$$a = 0.175(\lambda_1 . h_{col})^{-0.4} . r_{inf}$$

with:

$$\lambda_1 = \left[\frac{E_{me} t_{inf} \sin 2\theta}{4 E_{fe} I_{col} h_{inf}}\right]^{\frac{1}{4}}$$

where,

h_{col} is the height of column between centerlines of beams.

h_{inf} is the height of infill panel.

E_{fe} is the expected modulus of elasticity of frame material.

E_{me} is the expected modulus of elasticity of infill material.

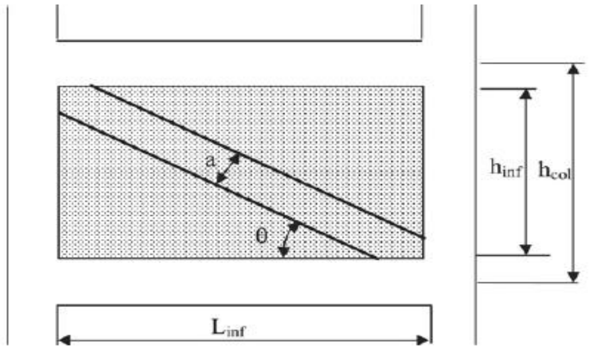
I_{col} is the moment of inertia of column.

r_{inf} is the diagonal length of infill panel.

t_{inf} is the thickness of infill panel and equivalent strut.

h is the angle whose tangent is the infill height-to-length aspect ratio;

k_1 is the coefficient used to determine the equivalent width of the infill strut.



1. Equivalent diagonal compression strut model for infill walls.

Figure 1 Compression strut [7]

Following data is used in the analysis of the RC frame building models:

- Type of frame: Ordinary RC moment resisting frame fixed at the base
- Seismic zone: II
- Number of storey: Three, six and nine.
- Floor height: 3 m
- Depth of Slab: 150 mm
- Size of beam: (300 × 450) mm
- Size of column: (300 × 500) mm
- Spacing between frames: 5 m along both directions
- Live load on floor: 4kN/m^2
- Floor finish: 0.36 kN/m^2
- Terrace water proofing: 0.75kN/m^2
- Materials: M 25 concrete, Fe 415 steel and Brick infill
- Expected Modulus of elasticity of infill wall: 1393 N/mm2
- Expected Modulus of elasticity of frame elements: 25000 N/mm2
- Thickness of infill wall: 230 mm
- Width of strut: 730mm (Calculated as per the formula above)
- Density of concrete: 25 kN/m^3
- Type of soil: Medium

3.1. Models

Figures 2, 3, 4 and 5 showing plan, elevation, bare frame and modeling of infills respectively for a three storey building.

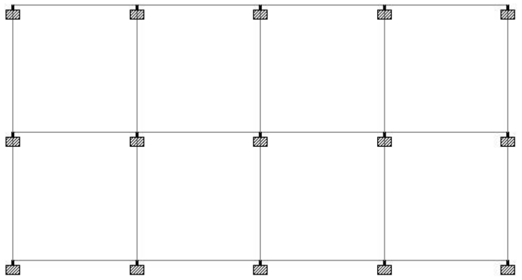


Figure 2 Building Plan

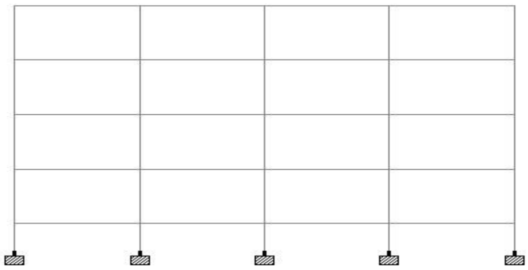


Figure 3 Building Elevation

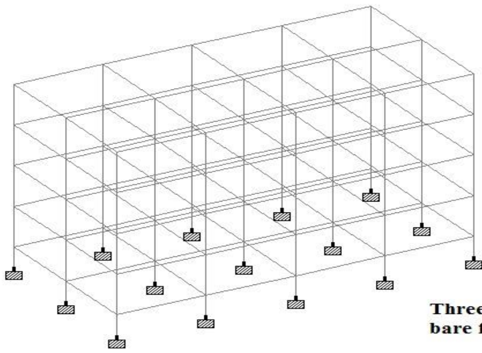


Figure 4 Three storey bare frame

Figure 5 Modelling of compression strut

4. RESULTS AND DISCUSSIONS

The main is to study the effect of masonry infill walls on the behavior and performance of the structures when it is subjected to earthquake forces. The effect of different parameters on seismic response of structure is discussed. From the different parameters studied it was concluded that each parameter has a significant effect on the seismic response of the structure.

4.1. Effect due to Change in Time Period

In this analysis, time period of buildings modeled with and without infill walls were studied, which showed that on providing infill walls or considering infills in the design the time period gets reduced substantially because of reduced amplitude of oscillation of the structure due to increased stiffness. This reduction comes out to be about 40%.

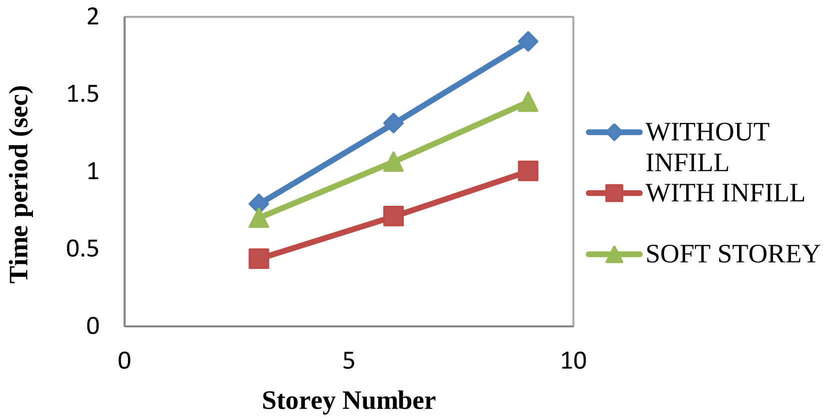


Figure 6 Time period for with, without and soft storey models for all floors

4.2. Effect due to Change in Storey Drift

Storey drift is nothing but the displacement of one level relative to the other level above or below. The analysis done on this parameter clearly shows that building structures without infills causes notable drifts. Analysis on bare frame showed considerable drifts but by providing infill walls these inter storey drifts were reduced significantly by about 25 to 40 % approximately.

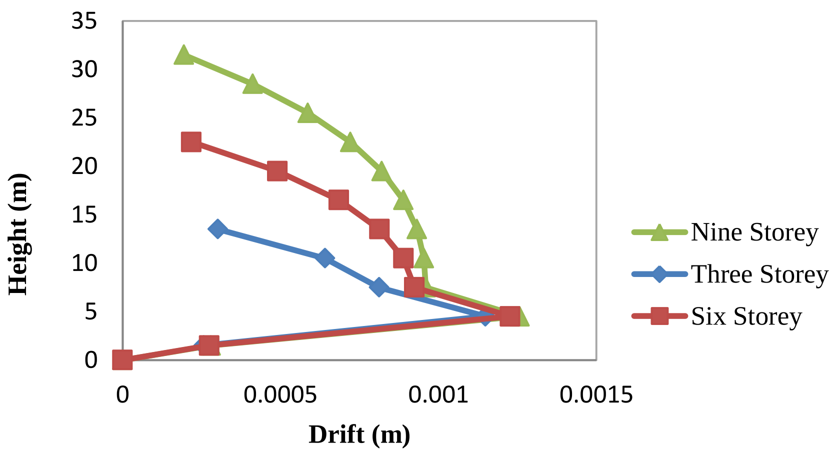


Figure 7 Summary of storey drift for all models

4.3. Effect due to Change in Displacements

This analysis is done for an exterior column for both the frames. Study showed that displacements were high for the bare frame and on increasing the stiffness of the structure by providing infills. These displacements were significantly reduced making the system more safe. This change is about 15 to 35 %.

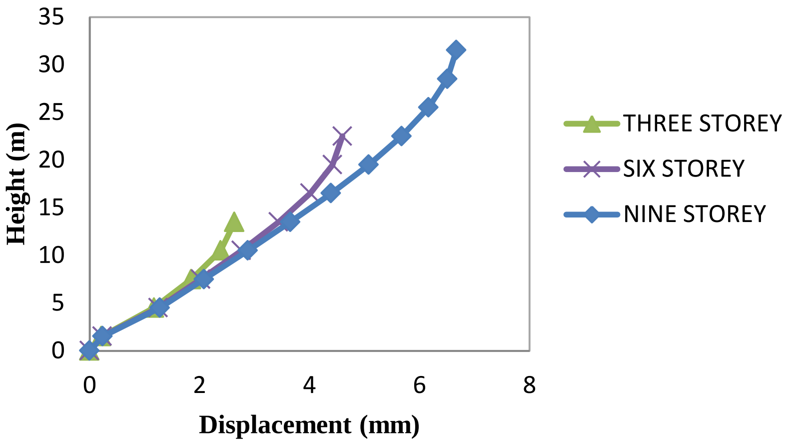


Figure 8 Displacement for without infill models

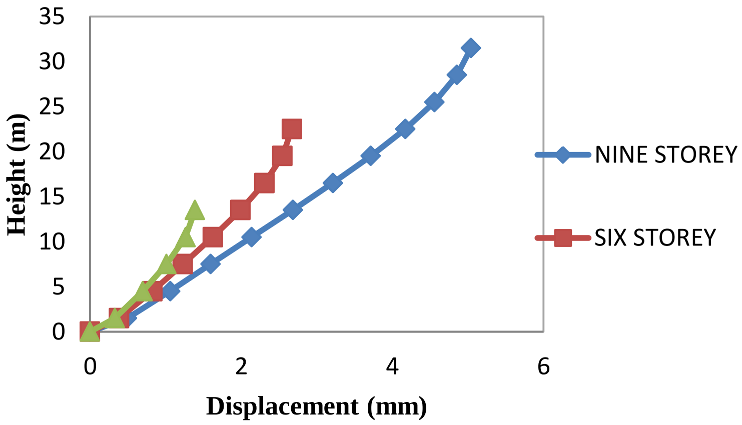


Figure 9 Displacement for with infill models

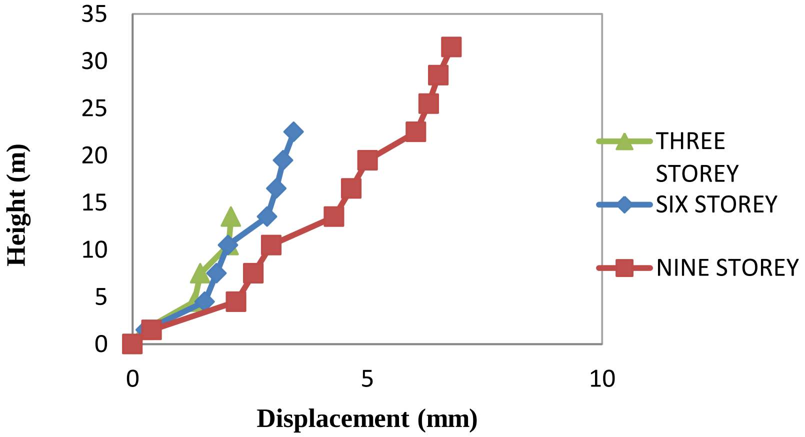


Figure 10 Displacement for Partial infill models

4.4. Effect due to Changed Member Forces

Members are one of the most important components of the structural system as the majority of the load coming on to the structure is taken by them. Both the frames were analyzed and it is concluded that bare frame is taking less load than the infilled frame, reason being the increased stiffness due to the infill walls. Due to high stiffness the infilled frame is attracting more forces and thus providing more time for the occupants to escape from the building during the earthquake. These member forces are increased by about 90 to 95 % approximately.

4.5. Effect of Infills on Base Shear

Attraction of forces depends upon the stiffness of the structure, therefore by providing infill wall the stiffness of the structure increased and it was observed that the base shear strength is enhanced by 80 to 100 percent when compared with bare frames.

5. DETAILS OF CONCRETE AND REINFORCEMENT IN VARIOUS MODELS

The comparison is done with respect to the bare frame. The quantity of concrete for one set of models i.e. bare frame, infilled frame and frame with soft stories remains same showing that there is no failure of any member in the structure. Reinforcement part is explained with a example that the quantity of steel for three storey bare frame is 54.21kN and the same for infill model is reduced to 53.69kN which means that infill walls doesn't have any significant effect on structures upto four storey when it comes to earthquake. But it has a significant effect due to increased stiffness on six storey structure as the percentage of reinforcement is increased by 1.82% in this case. For the nine storey case this percentage is reduced by a considerable amount of 3.6% and this reduction is justified too, reason being the section of the members i.e. the section which was adequate for three and six storey structures are not found to be adequate by the software for nine storey resulting in failure of the members particularly columns because of attraction of higher forces due to increased stiffness.

6. CONCLUSIONS

The results indicated that by simple modeling of the structure with equivalent diagonal struts, which carry loads only in compression, is able to simulate the global seismic response of the infilled frames. Considering infill walls in design resulted in reduced fundamental period due to high stiffness by 40%. On providing infill walls the maximum displacement occurring in an outer column reduced significant factor of 15 to 35 %. The base shear is increased by 80 to 100 % when compared with bare frames.Out of the frames of three, six and nine storey the analysis indicated that the intra change in the storey drift for all models is about 70 to 80 %.

The study of quantity of steel and concrete showed that infills doesn't have any significant effect on structures upto three storey but it has a considerable effect as the height of the structure increases. Although failure of infills occur in the early stages of an earthquake, their presence is useful in increasing the resistance of the frame. The influence of infills on the seismic response of the investigated structures is beneficial.

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