Effect of Infill Walls on Structural Frames

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Abstract—In the building construction, framed structures are frequently used due to ease of construction and rapid progress of work, and generally these frames are in-filled by masonry infill panels or concrete blocks. Usually in analysis only the bare frame is modeled ignoring the effect of infills with the assumption that such modeling is conservative for structures. The present study compared the results of Equivalent Static Analysis and the Response Spectrum Analysis of frames modeled with and without infills. In this investigation the performance of masonry infill components on frames under different conditions have been studied. The drift and flexural behavior of the frame with different combinations of infill walls have been studied and compared using both the Equivalent Static Analysis and Response Spectrum Analysis techniques. The present study is aimed at finding out the effect of infills on structures due to horizontal loading, which would lead to safe, economic and durable framed structures against earthquakes. It is found that the Equivalent Static Analysis shows higher values for deflection and moment than the Response Spectrum Analysis only for the bare frame, but presence of infill in the frame shows reverse results. It is observed that moment increased depending on the increase of the infill percentage on the frame. When all bays have infill it shows the highest variation of maximum moment and conservative results are shown by the Response Spectrum analysis than the Equivalent Static one.

Keywords—Infill wall, softstory, drift, masonry wall.

I. INTRODUCTION

FRAMES structures are frequently used in multistoried buildings, mainly due to ease of construction and rapid progress of work. Column and girder framing of reinforced concrete, or sometimes steel, is in-filled by panel of brickwork, block work, cast in place or pre-cast concrete. When an in-filled frame is subjected to lateral loading, the infills behave effectively as struts along its compression diagonals to brace the frames [1]. A large number of papers have focused on plan irregularity resulting in torsion in structural systems. Vertical irregularities are characterized by vertical discontinuities in the distribution of mass, stiffness and strength. Very few research studies have been carried out to evaluate the effects of masonry infill walls effect on the response of the building frame in presence of horizontal loading. There have also been detailed studies on real irregular buildings that failed during earthquakes [2,3] but such studies are small in number. Many researchers studied the response of set-back structures [4] – [8]. A set-back structure is thought of being made up of two parts: a base (the lower part having many bays), and a tower (the upper part with fewer bays).

When a sudden change in stiffness takes place along the building height, the story at which this drastic change of stiffness occurs is called a soft story. According to BNBC [9] a soft story is the one in which the lateral stiffness is less than 70% of that in the story above or less than 80% of the average stiffness of the three storeys above. The most common form of vertical discontinuity arises due to the unintended effect of infill component. The problem is most severe in structures having relatively flexible lateral load resisting system because the infill can compose a significant portion of the total stiffness. The provision of adequate stiffness, particularly lateral stiffness, is a major consideration in the design of building for several important reasons. In terms of serviceability limit state, deflections must first be maintained at a sufficient low level to allow proper functioning of non structural components, to prevent excessive cracking and consequent loss of stiffness. In seismic design at least a minimum stiffness is ensured through the limitation on the drift, i.e., horizontal relative floor displacement per unit story height. According to UBC [10] the allowable story drift is 0.005 of the story height. If this limitation exceed for any floor then that particular floor forms a soft story.

The ground floor is the most common location, which is usually devoid of infill component due to parking or large commercial spaces. Normally these open spaces have only columns as vertical members and there is no infill component. The adjacent floors, however, possess some infill components in between two columns to create utility spaces. The infill components increase the lateral stiffness and serve as a transfer medium of horizontal inertia forces. From this conception the floors that have no infill component has less stiffness regarding other floors. Normally in structural analysis it is considered that the Equivalent Static Analysis is more conservative against ground shaking for regular structures. Usually in analysis only the bare frame effect is considered ignoring the effect of masonry infill. According to Tentry et al. [11] such an assumption may lead to substantial inaccuracy in predicting the lateral stiffness, strength and ductility of the structures. The aim of this study is to find out the infill effect on structures due to horizontal loading. This may lead to safe, economic and durable framed structures against earthquakes.

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II. METHODOLOGY OF THE WORK

For this research work available literature are reviewed in order to know the behavior of masonry infill walls on framed structures. Two dimensional six storied frames have 300 x 300 mm column section and 250 x 400 mm beam sections are studied in this work. All storeys have 3 m floor to floor height and the base of the structure placed at 1.6 m below the G. beam level. These frames are analyzed by the Equivalent Static Method and the Dynamic Analysis Method using Response Spectrum. The frames are divided in a number of ways, a) Bare frame (Type A); b) One bay has infill wall out of three bays (Type B); c) Two bays have infill wall out of three bays (Type C); d) All bays having infill walls (Type D). The infill walls have 125 mm thickness and combined compressive strength ($f'_m$) of the brick masonry infills is 2757.9 N/cm². Property of the masonry struts are calculated from various published books and literatures [9], [12]. After find out the size, shape and property of the strut, it placed to the frame with a hinge connection to allow compression only in the strut member. After analyzing the frames, deflection pattern and variation of moments in columns and beams are observed. These quantities are compared for different infill patterns and analysis procedures. All the results are summarized and graphs are drawn with respect to the bare frame static analysis result.

III. RESULTS AND DISCUSSIONS

This works mainly divided into two different parts, mainly of deflection behavior of the frame and flexural behavior of the frame. The details are presented below.

A. Deflection Behavior of the Frame

Deflections of bare frame and bare frame with different patterns of infill walls have been summarized and some graphs have been plotted using those results. From Figure 1 it is found that the Equivalent Static analysis shows higher values only for bare frame, but when infill is present in the frame then Response Spectrum Analysis gives higher values of deflection for all other cases. This variation in results is also observed in the variation of number of story of the frame.

Story wise total deflections of all the frames under consideration have been summarized and graphs have been plotted using those results. From Figure 2 it is observed that the Equivalent Static analysis shows higher values only for bare frame (Type A) but when infill is present in the frame then Response Spectrum Analysis gives higher values of deflection for all other cases except the bare frame.

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**Fig. 1** Deflection of the frame

**Fig. 2** Storey wise deflection
The effects of analysis procedure on the deflection of frames of different types are shown in Fig. 3. It is found from the figure that the Equivalent Static Analysis (ESA) procedure gives higher deflection values compared to the Response Spectrum Analysis (RSA) procedure only for bare frame (Type A). But when the frames have masonry infill walls, the result are drastically changed, especially at the level below which there is no infill and above which the infill wall is present.

The inter story drift (ID) is one of the most important parameters for serviceability of any structure. In this research it is found that the Equivalent Static Analysis and the Response Spectrum Analysis give different nature of ID in different conditions of the frame. It is found from the Fig. 4 that the ID values depend mainly on the presence and the pattern of infill components of the frame. All these results are shown in Fig. 4. In this figure ID is shown only for that story which has no infill (Ground Floor) and the adjacent story has infill components (1st floor). The bare frame ID values are also given for the same location. After studying the moment nature, the influence of the infill wall and analysis techniques are finally understood.

**B. Flexural Behavior of the Frame**

In this investigation two different analysis techniques have been used to find out the flexural effects on different types of frames due to the presence of infill wall. The results of different infill conditions are summarized in Figures 5 and 6. From these figures it is found, that the amount of moment is increased in the frame due to the Response Spectrum Analysis (RSA) than Equivalent Static Analysis (ESA), specially when the frames have infill components while some story have no infill. Equivalent Static Analysis shows higher values only for bare frame. In the frame the moment increased depending on the increase of the infill percentage. When the frames have infill in all bays (Type D) it shows the highest amount of moment. From the result it can be concluded that the Response Spectrum Analysis (RSA) procedure is more conservative analysis.
IV. CONCLUSIONS

A study using different numerical analyses was performed on the effect of infill walls on the behavior of frames due to lateral loading. The infill walls were provided in different patterns and conditions. Strength of the frame components was kept unchanged in all the cases. With the limitation and scope of this study the following conclusion can be drawn.

The Equivalent Static Analysis gives conservative values for deflection and moments instead of the Response Spectrum Analysis technique for bare frame and for all other types of frames i.e., type B, C and D, the Response Spectrum Analysis gave higher values than the Equivalent Static Analysis.

It is believed that due to some limitations of this present study, a complete guideline for the designers could not be developed here. The present study may be regarded as a preliminary work for an extensive research work on the effect of infill walls on frames due to horizontal loading.

REFERENCES


