Weak-layer Deformation of Vertically Irregular Infilled Frames under horizontal earthquakes

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Abstract. Based on the SeismoStrcut model of full-scale, four-story, 2D infilled reinforced concrete frame, this paper set the infill walls at different locations in the structure to obtain vertical stiffness irregular frames with weak layer. The displacement response of different weak layer frames is studied by input the same seismic waves. The results show that the vertical stiffness of the infill wall frame structure will greatly affect the response and interlayer drift. The displacement of concrete frames contains weak-layers is larger than the common ones. When the bottom layer has no infill wall, the top displacement is larger than other cases. The presence of the infill wall can limit the interlayer deformation of the frame structure.

1. Introduction

The reinforced concrete frame structure is widely used in building structures such as commercial and residential buildings, office buildings, hospitals, teaching buildings and hotels. Frame structure has the characteristics of flexible layout, large indoor space. In the frame structure, the infill wall is usually set due to the room layout. Weak layers of the frame structure are strongly related to the placement of the infill walls. When there is room with space, the infill wall must be cut. Due to structural stiffness of the lateral force components and bearing capacity is not continuous, the damage of the weak-layer is caused by the failure of the structural bearing capacity. The Code clearly specifies measures to avoid weakness. The actual damage shows that the emergence of weak-layers will lead to serious damage to the structure, even collapse.

The structures [1] studied are two-dimensional building frames with multiple stories. Irregularities are introduced by changing the properties of one-story or floor. The effects of the irregularities on shear forces and maximum ductility demands are studied. The seismic performance of one-side setback structures is investigated [2]. From this paper, values of area setback ratio are influential to the confidence levels of the one-side setback buildings. That means irregularity has a great influence on the structure. The seismic response of irregular (both in plan and in elevation) buildings subjected to bidirectional ground motions are assessed by bidirectional pushover analysis method [3]. The seismic demands for vertically irregular and regular frames are studied [4]. Considering irregular of stiffness and strength, three types of irregularities similarly influence the height-wise variation of story drifts. These papers have studied irregular structures, however, we have made a four-story and three-span 2D frame model. Infilled walls are set up at different heights and floors to achieve the irregular frame. The vertical stiffness of these frames is not consistent. Displacement of weak layers without infilled walls is studied, the effect of vertical stiffness inconsistent on displacement response is also discussed.
2. Basic situation of the study

2.1 SeismoStruct Verification
The modelling of a full-scale, four-story, 2D infilled reinforced concrete frame, which is representative of the design and construction practice of the 50s-60s in Southern Mediterranean countries. The frame includes infill walls with openings of different dimensions [5-7]. This paper uses the model to conduct seismic response to vertically irregular infilled frames.

2.2 FE Models
The four-story and three-span 2D frame is used as the analysis object. Non-linear analysis is done on SeismoStruct [8]. The material used in the analysis was based on the Mander uniaxial nonlinear constant confinement model (con_ma in SeismoStruct) and the steel based on Menegotto-Pinto model (stl_mp in SeismoStruct). The fibre section was used to simulate the bipolar bending characteristics of the column. Columns and beams are modelled through 3D force-based inelastic frame elements (infrmFB) with 4 integration sections. The number of fibres used in section equilibrium computations is set to 200. The infill walls can be seen as equivalent diagonal oblique support bar model and being modelled through a four-node masonry panel element (inelastic infill panel element). Considered a variety of infill wall vertical arrangement form, the number and corresponding model is shown in Figure 1.

2.3 Earthquake Input
The input earthquake wave selected in this paper is The Imperial Valley (USA) earthquake. The Imperial Valley (USA) earthquake is October 15, 1979. It is from PEER Strong Motion Database. The recording stations is USGS STATION 5115. The frequency range is 0.1-40.0Hz. The first 20 seconds interception is used in the seismic analyses.
3. Results of seismic response

3.1 Top Displacement
Under the same input, the frame has the largest displacement when there is no infill wall (0-1234). When there is one layer of infill wall, the infill wall is located on the fourth floor (4-123) is the largest displacement. That means the infill wall of the upper layer leads to structural response. When there are two layers of infill wall, the infill wall is located on the adjacent floor (12-34, 34-12) is the larger displacement. Overall, when the bottom has no infill wall, the top displacement is larger than other cases. When the frame is full of infill walls, the top displacement is the minimal. That illustrates the effect of the infill wall on the structural response.

3.2 Story Drift
The story drift is shown in Figure 2. The layer set the infill wall is not deformed. The presence of the infill wall can limit the interlayer deformation of the frame structure. When set one layer of infill wall, the interlayer deformation suddenly becomes smaller. When set two layers of infill wall, the interlayer deformation becomes larger when the floor with no infill wall. In this case, if the infill wall set interval, the floor between the infill walls become the weak layer. From Figure 2, there is obviously sudden change when weak layer appears in 13-24. 14-23. This indicates that this layer is a weak layer, and the displacement of the weak layer is related to the stiffness irregularity.

![Figure 2. Story Drift of models](image)

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4. Conclusion
A four-story and three-span 2D frame model was built to study the influence of the vertical irregular arrangement of the infill walls on the seismic displacement of the reinforced concrete frame, and the deformation of the weak-layer is studied in this paper. The results show that the vertical stiffness of the infill wall frame structure will greatly affect the displacement response and interlayer drift. When
the bottom layer has no infill wall, the top displacement is larger than other cases. The presence of the infill wall can limit the interlayer deformation of the frame structure in this case.

Acknowledgments
This paper was financially supported by Youthful Top Talents Cultivation Plan of North China University of Technology (XN012/072). The authors’ deeply express sincere appreciation to them.

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