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Analysis of Masonry Infill ConcreteStructure under Earthquake

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ABSTRACT

The infill masonry walls are seldom included in numerical analysis of reinforced concrete structural systems, since masonry panels are generally considered as non-structural components. However, these panels affect the structural response, although the complexity they introduce to analysis, generally keep them unaccounted for. The typical construction type in Turkey is reinforced concrete structures with masonry infill walls. Therefore, it is crucial to understand the contribution of infill walls to earthquake response of these structures. In this study, a 3-story R/C frame structure with different amount of masonry infill walls is considered to investigate the affect of infill walls on earthquake response of these type of structures. The diagonal strut approach is adopted for modeling masonry infill walls. Pushover curves are obtained for the structures using nonlinear analyses option of commercial software SAP2000. Nonlinear analyses are realized to sketch pushover curves and results are presented in comparison and the effects of irregular configuration of masonry infill wall on the performance of the structure are studied. From the pushover curves, story displacements, relative story displacements, maximum plastic rotations are determined.

INTRODUCTION

In developing countries, like India, brick masonry has been widely used as an infill in reinforced concrete (RC) frame building in the high risk seismic areas. Easy and low construction cost is the main reason for the use of brick masonry in the developing countries. In such countries, the damage pattern of RC frame buildings, after earthquakes, shows that the brick masonry as infill shows significant seismic resistant, in comparison to RC frame building without brick masonry infill. The brick masonry infill in RC frame building is considered to be non-structural member in seismic resistant design procedures. Therefore, this consideration may result in inaccurate predictions of lateral stiffness, strength and ductility of RC frame building. Reluctance of numerous engineers, to take into account the contribution of brick masonry infill is being due to inadequate knowledge regarding infill RC frame behavior, complications involved in structural analysis and uncertainty about the non- integral action between infill and RC frame.

Brick masonry infill remains in contact with RC frame structures under very low lateral loads and hence there is composite action between RC frame and brick masonry infill. Therefore, the stiffness of structural system becomes larger than bare RC frame structure. With increasing lateral loads, a gap in between the brick masonry and between RC frame starts and this gap keeps on increasing as the lateral load increases; hence the composite behavior is no more in nature. Further, separation between RC frame and brick masonry infill occurs in the tension zone when lateral loads are further increased. On the other hand, on the compression zone side, the brick masonry infill forms a diagonal strut action.

LITERATURE REVIEW

Sucuoglu & Mc Niven (1991) studied seismic response of reinforced masonry piers that reveal a shear mode of failure.

They performed experiments on reinforced masonry piers under cyclic lateral loads and studied the seismic behavior of the structure. They focused on the seismic shear response of reinforced masonry piers. They proposed a shear design concept for masonry piers based on experimental observations and analytical evaluation of masonry behavior at ultimateshear resistance level.

Sucuoglu & Erberik (1992) studied seismic performance of a three-story unreinforced masonry building which survived in 1992 Erzincan earthquake without damage. First, a set of experiments were performed to determine the mechanical properties of the masonry walls. Then an accurate model was developed for the non-linear dynamic analysis of masonry building with the help of a computer program.

Paulay & Priestley (1992) proposed a theory about the seismic behavior of masonry infill frame and a design method for infill frames. Authors said that although masonry infill may increase the overall lateral load capacity, it can result in altering structural response and attracting forces to different or undesired part of structure with asymmetric arrangement. This means that masonry infill may cause structural deficiencies.

Smith & Coull (1991) presented a design method for infil frame based on diagonally braced frame criteria. The developed method considered three possible modes of failure of infill: shear along the masonry, diagonal cracking through masonry and crushing of a corner of infill. They assumed effective width of diagonal compression strut as equal to one-tenth of the diagonal length of the infill panel. At the initial design stage, frame must be designed on the basis of the gravity loading.

Smith & Carter (1969) examined multi-story infill frames for the case of lateral loading. In the light of experimental results, authors proposed design graphs and design method based on an equivalent strut concept. First, they focused on the composite behavior of infill frame and failure modes.

Federal Emergency Management Agency (FEMA) prepared FEMA 273, the NEHRP Guidelines for the Seismic Rehabilitation of Buildings, to guide design professionals, for the seismic rehabilitation of buildings. Design professionals can use this document for design and analysis of seismic rehabilitation project. However, this document is not a code

Colombo, Negro & Verzeletti (1998) presented experimental results obtained from shake table tests, performed on a 2-storey frame considering at first the bare frame configuration and then an infill frame with irregular distribution of panels in plant, and from pseudo-dynamic test on a three storey frame with different infill distribution along building height. The specimens are full scale reinforced concrete frames infill with masonry hollow blocks. The study was finalized to the evaluation of the Euro code 8 prescriptions regarding the three-dimensional analysis of irregular structures.

Fiorato (1970) conducted monotonic test as well as cyclic lateral loads on the 1/8- scale non ductile reinforced concrete frames infill with brick masonry. The test showed that the horizontal sliding failure of masonry infill introduces a short column effect, with plastic hinges and sometimes brittle shear failure developed at the mid height of the column. They have found that masonry infill can increase the stiffness and strength but reduces ductility of concrete frames.

Klinger and Bertero (1976, 1981) performed tests on 1/3- scale, three-storey-high, and reinforced concrete frames infill with fully grouted hollow concrete masonry under monolithic and cyclic lateral loading. The infill panels were reinforced with standard deformed bars in both vertical and horizontal directions. Additional shear steel that was beyond the minimum requirements of ACI code was used to enhance the shear strength of concrete columns.

Kahn and Hanson (1979) have observed in their tests of RC frames with reinforced concrete panels as infill that separating the infill from the bounding and columns and enhancing the shear transfer between the beams and the infill can prevent the brittle shear failure of the columns and, therefore, significantly enhance the ductility of the structure.

Bertero and Brokken (1983) tested RC frames infill with four types of masonry infill; two with hollow masonry unit, clay and concrete block, and one with light weight concrete panels, and one with solid clay brick infill reinforced with welded wire fabric at each face. The test model consisted of eighteen 1/3 – scale, three storey, one bay, reinforced concrete.

Mehrabi (1994, 1996) tested two types of frame, non-ductile frame and ductile frame designed for Seismic Zone 4 according to the 1991 Uniform Building Code. He tested single- storey; one-bay and single-storey; two-bay reinforced concrete frames with unreinforced masonry infill, made with either hollow or solid concrete blocks. He demonstrated that the beneficial influence of the infill in terms of lateral strength, stiffness and energy dissipation capability and that the shear failure of the reinforced concrete columns can be prevented in a well designed frame.

MATERIALS AND METHODS

General

The present study is concerned with the seismic behavior of RC frame buildings with masonry infill walls. In such buildings, generally variation in the stiffness and strength are usually observed as compared to bare RC frame buildings.

In the present study three methods namely Equivalent Static, Response Spectrum and non-linear Time History analysis methods are used to study the seismic response of buildings using STAAD Pro software.

Loads

The knowledge of various types of loads and their worst combinations to which a structure may be subjected during its life span is essential for safe design of structure. Forces acting on structures are called loads. Primary loads acting on the building have been considered as dead load, Live load and earthquake load. The dead load and live load has been applied in Gravity direction and earthquake load has been applied in lateral direction.

Dead load

Dead loads are permanent loads and acts vertically downward. Dead loads are basically due to self weight of structure as well as due the weight of floor slab, beams, columns, walls and floor finish. Dead load of buildings can be calculated by calculating the self weight of each structural element and adding them.

Self Weight (KN/m) = Unit Weight of Material (KN/m^3) × depth of element × width of element.

Live load

Live loads are those which may change in position and magnitude. The use of the term 'live load' has been modified to 'imposed load' to cover not only the physical contribution due to persons but also due to nature of occupancy, the furniture and other equipments which are a part of the character of the occupancy.

Earthquake load

North and northeastern parts of India have large scales of hilly terrain, which are categorized under seismic zone IV and V. Buildings in such regions are highly prone to earthquake. Earthquake generates due to collision of tectonic plates and hence epicenter of earthquakes is generally located at fault lines. During past earthquakes, reinforced concrete (RC) frame buildings that have columns of different heights within one storey, suffered more damage in the shorter columns as compared to taller columns in the same storey and hence demands careful design of buildings on hill slopes.

Load Combinations

In the limit state design of reinforced concrete structures, the following load combinations shall be accounted for:

1) 1.5 (Dead load + Impose load)
2) 1.2 (Dead load + Imposed load ± Earthquake load)
3) 1.5 (Dead load ± Earthquake load)
4) 0.9 (Dead load ± 1.5 Earthquake load)

MODEL DESCRIPTIONS

Model used for Seismic Design

A 4-storey U-shaped building (shopping complex) is modeled and analysis using STAAD Pro software. This shopping complex may be constructed in future at University campus Pantanagar. Fig. 4.1 shows the plan of the building, while Fig. 4.2 & 4.3 is the 3-D model of the building as generated by STAAD Pro.

Parameters considered in the Analysis

Natural Frequency

Natural frequency is defined as the frequency of the building at which it tends to oscillate in the absence of any diving or damping force. Free vibration of any elastic body is called natural vibration and happens at a frequency called natural frequency. Natural vibrations are different from forced vibrations which happen at frequency of applied force. For a building if the natural period of the building is equal to frequency of the ground motion then they are in resonance with each other. Because of this, buildings suffer the greatest damage from ground motion at resonance i.e when the ground motion frequency is close or equal to their own frequency. It is related to time period and mode shape of the building by formula:

Base Shear

Base shear is defined as the total horizontal force on the structure that is calculated on the basis of structural mass and fundamental period of vibration and corresponding mode shape. The base shear is distributed along the height of the structures in terms of lateral forces according to code formula. This method is usually conservative for low to medium height buildings with a regular conformation.

Inter-storey Drift

Storey-drift is defined as the lateral displacement. Storey-drift is the drift of one level of a multistory building relative to base level. It is difference between the roof and floor displacements of any given storey as building sways during the earthquake, normalized by storey height. Greater the storey-drift, the greater is the likelihood of damage. Peak inter storey drift values larger than 0.06, then damage to building is severe, if it is 0.025 then damage is serious and when it is greater than 0.10 then there is probable collapse of building.

Storey Displacement

Displacement is the total drift value of the building relative to ground level. It is different from inter-storey drift in terms that its absolute value of displacement measured from ground while inter-storey drift gives the relative displacement of the floor with respect to its base level. Its value increases as the height of the building.

RESULTS AND DISCUSSIONS

General

Analysis of RC building with brick masonry infill walls under the action of earthquake forces is carried out. Results obtained are discussed in this chapter. A 4 storey U-shaped building isadopted for analysis. The performance of the RC structure with brick masonry infill has been studied and then compared with the performance of bare RC frame building. The parameters considered here are fundamental natural time period, base shear of the building, inter-storey drift, and lateral forces at each storey. Equivalent static, response spectrum method and time history method are used for linear analysis of the building (IS 1893-2002)

RESULTS AND DISCUSSIONS

Fundamental time period is the period of the building at which it vibrates. It is inverselyrelated with frequency of the building. Table 5.1 shows natural time period for the structure.

Table 5.1 Natural Time Period by Equivalent Static method

	Bare RC frame building	RC frame building with masonry walls
Time Period	0.54281	0.207

In this study it is found that the bare frame model shows longer time period as predicted byIS: 1893-2002 whereas the infill frame model predicts natural time period closer to the value as predicted by the code.

CONCLUSIONS

Masonry infill walls in RC frame structures have been long known to affect the behavior of the whole structure particularly increasing the lateral stiffness and strength of infill frame structures. Lot of extensive analytical and experimental studies has been conducted by a number of researchers to investigate the effect and the behavior of masonry infill in RC frame structures.

However, there has been neither well-developed design recommendation nor well accepted analytical procedures for masonry infill frames. Therefore, in the seismic area such as India, the masonry infill is still considered as a non-structural element and ignored in seismic design calculations of the buildings. This study focuses on evaluating the brick infill contribution to seismic performance of RC frames by Equivalent static, Response spectrum and Time History method by STAAD Pro software. The infill masonry has been modeled as compression only diagonal strut. The compression strut width is determined as a function of infill/column contact length. The compression diagonal strut is provided with the property of masonry material. From the data revealed by the seismic analysis for the structures with various loading combinations the following conclusions are drawn:

1. Fundamental natural period of vibration decreases for infill frame compared to bare frame in Equivalent Static method. There is no change in period of infill frame compared to bare frame when Response Spectrum analysis was used.
2. Base shear for infill frame and bare frame structure comes out to be almost equal for both Equivalent Static and Response Spectrum method.
3. Storey Drift value decreases for infill frame structure when compared to the bare frame and thisdecrease is almost 90 percent of the value that is obtained for the bare frame structure. This is because the masonry infill imparts lateral strength and stiffness to the structure which helps in the better performance during earthquake phenomenon.
4. Average storey displacement also decreases for infill frame when compared to that of bare frame structure. Here also it was observed that this decrease in the storey displacement value can be as high as 90 percent of that of bare frame structure.

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