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Performance of Masonry Infill Framed Structures During Earthquake: A State-Of-The-Art Review

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Abstract: - Masonry infill walls are widely known to increase lateral stiffness of the structure and for this reason it is accepted all over the world. This paper presents a review work on performance of infill framed structures that were damaged during several earthquakes. Study of behavior of damaged building during different earthquakes in world has been carried out. The mentioned earthquakes substantially caused damaged to the RC buildings. The RC buildings were damaged primarily because of improper design and reinforcement detailing at the design phase and improper workmanship and quality control at the construction phase. The main objective of this paper is to describe and analyze the failure patterns observed in reinforced concrete frame buildings with masonry infill walls and without masonry infill walls all over the world.

Key Words: — ***Infill Walls, Earthquake, Non Structural Elements, Failure Mechanism.***

I. INTRODUCTION

The present paper is concerned with the performance of buildings all over the world primarily due to ground shaking. From the past researches and field investigations by various researches it can be noted that building with masonry infill walls (or unreinforced masonry infill walls) perform better in earthquake. As compared to bare RC frame masonry infill frames can carry more seismic effect. From study it can be concluded that masonry infill walls or panels play very crucial role with respect to severe ground motions. Many structural deficiencies are highlighted here which were caused by earthquake, which consists of soft and weak stories, strong-beam and weak column, etc.

This paper mentions five great earthquakes that struck the world. Among these, two are Bhuj (2001) and Sumatra (2006) earthquake which happened in India. Bhuj earthquake is the largest earthquake that struck India. The remaining earthquakes are being mentioned here, Wenchuan Earthquake (2008), L'Aquila (2009) and Lorca (2011) earthquake.

II. LITERATURE REVIEW

Humar J. M. et al. (2001) and Sudhir K. Jain et al. (2001) reported on the performance of building during Bhuj earthquake that were damage during the earthquake. They both individually investigated that the open storey were severely damage as compare to that of infill storey. Hemant B. Kaushik and Sudhir K. Jain et al. (2004) reported that the great Sumatra earthquake of 26 December 2004 caused damages to RC buildings at Port Blair in the Andaman Islands in India. Li, B., Wang, Z., Mosalam, K. M., & Xie, H. et al. (2008, October) carried out field reconnaissance after Wenchuan earthquake in Dujiangyan, Hanwang, and Yingxiu, to investigate the types of damage occurred in the infill walls and/or the bounding frames. Manfredi and masi reported (Manfredi, V., & Masi, A. et al., (2011, 2014)) on the key role of the non-structural element in building during L' Aquila 2009 earthquake. They put forward an infill model capable of accounting for the effects arising from in-plane (IP) damage on the out-of –plane (OOP) capacity of infill panels. Hermanns, L., Fraile, A., Alarcón, E., & Álvarez, R. et al., (2014) analyzed the failure patterns observed in reinforced concrete frame buildings with masonry infill walls.

III. AN OVERVIEW

A. Bhuj Earthquake:

It is seen that most of the modern RC buildings that were collapsed in the damaged area were open at ground storey for the purpose of parking. The buildings which had few or no infill walls that were damaged are shown in figure 1(a). Open storey led to insufficient strength and stiffness of the structure resulting in failure of structure as shown in figure 1(b). Whereas it was observed from the study that the buildings with full scale infill walls at ground storey withstand earthquake without collapse.

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Earthquake Name	Time And Date	Location	Magnitude
Bhuj Earthquake	8:46 Am, January 26, 2001	Bhuj, Gujarat	M7.9
Sumatra Earthquake	6:28:53 Am, December 26, 2004	Port Blair, Andaman Islands	M9
Wenchuan Earthquake	2:28 Pm, May 12, 2008	Northwestern Sichuan, China	M8
L' Aquila Earthquake	3:32:52 (Local Time) , April 6, 2009	Abruzzo, Italy	M6.3
Lorca Earthquake	6:47pm(Local Time), May 11, 2011	Lorca, South-East Spain	M5.1

Fig.1(a). Precariously balance severely damaged RC frame buildings with open ground storey in Ahmadabad

Fig.1(b). Ground storey collapse of a four storey building with open ground storey at Bhuj

B. Sumatra Earthquake:

In the great Sumatra earthquake many damaged pattern were observed due to infill panel among these the common damages were open storey damage, OOP failure of masonry infill walls.

The buildings that were constructed without engineering supervision and were located in silts were collapsed partially or completely. In a collapsed 3-storey building at Naya Gaon, the upper stories suffered only nominal damages in the RC frame and masonry infill (Fig. 2a). Some recently constructed buildings on stilts at Bamboo Flat collapsed completely (Fig. 2b). It was also noticed that a 2-storey Police-Barrack Government owned building, which had the open first storey for storage purpose collapsed at Haddo wharf (Fig. 2c), whereas the adjacent infill buildings in the first storey survived the ground motions. The passenger terminal building at Haddo Wharf (Fig. 2d), was constructed under the supervision of a construction firm gets partially collapsed as it has open masonry infill panels for the purpose of ventilation and in the inner periphery infill walls were not present for the purpose of open space. Due to poor masonry quality and loose frame joints OOP failure was observed.

Figure 3 shows OOP failure of masonry infills in buildings at (a) Mohanpura (school building), (b) Bamboo flat, and (c) Passenger Terminal Building at Haddo wharf.

Fig.2. Collapse of RC buildings at (a) Naya Gaon, (b) Bamboo Flat, and (c) Haddo wharf, and (d) partially collapsed Passenger Terminal Building at Haddo wharf.

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Fig.3. shows OOP failure of masonry infills in buildings at (a) Mohanpura (school building), (b) Bamboo flat, and (c) Passenger Terminal Building at Haddo wharf.

C. *Wenchuan Earthquake:*

It was observed that many residential and commercial buildings in the epicenter suffered severe damage due to soft storey effect of infill walls. Many buildings had open storey which serve as the purpose of parking. Many buildings had less or no infill walls. Many buildings were made using hollow clay tiles and gas concrete masonry infill walls. It was observed that damage to masonry infill walls was concentrated in the lower stories of buildings where less or no infill walls were provided. It can be noticed from the results that hollow infill walls contribute to stiffness but less strength. Arrangement of infill panels in orthogonal direction to create residential space resulted in creating stiffness discontinuities. Figure 4 shows a six-storey building where the first storey was available for the purpose of parking and had less infill walls while the upper stories are residential and has many infill walls.

Fig.4. Formation of weak storey: leaned 6-story building in Dujiangyan

D. *L' Aquila Earthquake:*

During past earthquakes in Italy these non-structural elements have contributed significantly in resisting lateral loads. Figure 5 shows example of masonry panel expulsions from the structural frame, resulting from a poor connection.

Fig.5. Examples of out-of-plane collapse of infills poorly connected to the RC frame

E. *Lorca Earthquake:*

Figure 6 shows one of the parapet walls that collapsed during lorca earthquake which shows the importance of studying the behaviour of non-structural components. It can be noted that acceleration at roof level is significantly higher than that at ground level. Figure 7 shows soft storey mechanisms due to infill panels with lower stiffness at ground storey.

Figure.6. Building with a partially collapsed parapet wall

Fig.7(a). Building with soft storey

Fig.7(b). Severely damaged column

IV. CONCLUSION

From the above study it can be contributed that masonry infill walls contributes significantly in increasing the lateral stiffness of the structure and increasing the strength of the structure. Also it can be noticed that connection between frames and infill walls play important role in failure pattern. No infill panel or less infill panel leads to soft storey mechanism in which flexibility of the structure is reduced. Hence from the observation it can be mentioned that it is important to provide good quality masonry infill panels under engineer's supervision.

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