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Experimental Investigation On Development And Structural Behaviour Of Rc Frames With Reinforced Infills

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INTRODUCTION

Tall towers and buildings have fascinated mankind from the beginning of civilization, their construction being initially for defence and subsequently for religious purposes. The growth in modern tall building construction, however, which began in the 1880s, has been largely for commercial and residential purposes. Tall commercial buildings are primarily a response to the demand by business activities to be as close to each other, and to the city center, as possible, thereby putting intense pressure on the available land space. Also, because they form distinctive landmarks, tall commercial buildings are frequently developed in city centers as prestige symbols for corporate organizations. Further, the business and tourist community, with its increasing mobility, has fuelled a need for more, frequently high-rise, city center hotel accommodations. The rapid growth of the urban population and the consequent pressure on limited space has considerably influenced city residential development. The high cost of land, the desire to avoid a continuous urban sprawl and the need to preserve important agricultural production have all contributed to drive residential buildings upward.

Masonry infill panels can be frequently found as interior and exterior partitions in reinforced concrete and steel structures. Since they are normally considered as architectural elements, their presence is often ignored by engineers. However even though they are considered non-structural, they tend to interact with the bounding frame when the structure is subjected to strong wind or earthquake loads. Such interaction may or may not be beneficial to the performance of the structure, and has been a subject of many debates. In some countries, masonry infill panels have been used as a means to strengthen existing moment resisting frames, and there is evidence that they improved the performance of structures under severe earthquake loads. The taller the building, the greater will be the effect of wind loads or similar lateral loads. Such loads produce critical stresses and undesirable

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vibrations in addition to lateral sway of the structure. In tall structures, the vertical loads do not pose many problems in the analysis and design as they are mostly deterministic. But the lateral loads due to wind or earthquake are a matter of great concern. These require special considerations in the design. Developments in the design of multi-story frames have emphasized the importance of limiting the side sway under the action of lateral loads.

Brick has been used in building construction since the start of civilization and it is one of the least expensive materials that can withstand aggressive environment much better than many other building materials. But it has poor shear and tensile strengths, brittle characteristics and is vulnerable to out-of-plane loads. Hence, in this study, to overcome the above limitations, traditional brick masonry infill has been modified by introducing horizontal reinforcement and the failure characteristics were analysed. Also the behaviour of new materials such as reinforced hollow blocks and reinforced aerocon blocks masonry infill was studied as a replacement for conventional brick masonry to enhance more stiffness, ductility and crack control property.

The composite behaviour of an infilled frame imparts lateral stiffness and strength to the building. The typical behaviour of an infilled frame subjected to lateral load with an initial bond between the frame and infill at their interface. The composite structure behaves like a solid cantilever till the bond is broken. After the bond is broken, separation occurs at the non-loaded corners. Upon separation the infill rests over certain length of the frame called length of contact and acts similar to a diagonal strut of a braced frame. When the frame is strong enough to cause an infill failure first, the observed failure is either by local crushing at the loaded corners or by shear cracking along the bedding joints of the infill or by diagonal compression failure in a slender infill.

1.1 PROBLEM STATEMENT

A construction system where steel reinforcement is embedded in the mortar joints of masonry or placed in holes after filled with concrete or grout is called reinforced masonry. There are various practices and techniques to achieve reinforced masonry. According to the ways in which reinforcement is arranged, reinforced masonry can be classified into reinforced hollow unit masonry, reinforced grouted cavity masonry and reinforced pocket type walls. The reinforced hollow block masonry type is the most common type but the construction of such walls are complex since before laying the units the vertical rebars should be straightened up in position first. Then the first course of masonry is laid in the mortar. Horizontal reinforcement may be provided at every two or every three bed joints depending on the arrangements. The vertical spacing between horizontal reinforcement can be a maximum of 600 mm. The holes with the vertical rebars are filled with concrete or type of mortar called grout. To increase strength where practicable all holes in the hollow masonry units can be filled up with grout.

The reinforced grouted cavity masonry consists of a cavity masonry wall and steel mesh providing the vertical and horizontal rebars are placed in to the cavity. In order to achieve integrity of the wall two leaves are connected by means of standard wall ties or rebars. In reinforced pocket type walls, vertical reinforcement can be placed in vertical ducts or pockets formed between solid or hollow masonry units. The vertical reinforced ducts are filled with concrete or grout as the construction of the wall progresses. The horizontal reinforcement can also be placed in the bed joints at vertical spacing maximum of 600 mm. The effectiveness of the reinforcement strongly depends on the type and quality of the masonry. During earthquake, apart from the existing gravity loads, horizontal racking loads are imposed on walls. However, the unreinforced masonry behaves as a brittle material which leads to brittle failure. Therefore un-reinforced masonry walls are vulnerable to earthquake and should be confined or reinforced whenever possible.

1.2 RATIONALE OF THE STUDY

Masonry infill walls in frame structures have been long known to affect the strength and stiffness of the infilled frame structures. In seismic areas, ignoring the composite action is not always on the safe side, since the interaction between the wall and the frame under lateral loads dramatically changes the characteristics of the composite structure. It has been generally observed that infill walls enhance the response of frame buildings in low to moderate seismic regions, yet they exhibit poor seismic performance under high seismic demand. This behaviour is due to the degradation of stiffness, strength and energy dissipation of the masonry wall and the deterioration of wall frame interfaces. Due to the difficulty associated with modelling, an attempt of isolating the infill wall from the surrounding frame has been followed. These attempts faced failure, primarily because of the out-of plane instability.

1.3 SCOPE OF THE STUDY

This study is made for finding the effectiveness of reinforced masonry infill in multistorey, multibay reinforced concrete frame to resist the cyclic lateral loads in the building. The load carrying capacity, stiffness, ductility characteristics and energy dissipation characteristics of the structure is studied to check the stability. The study is made on six numbers of one fourth size two bay five storey reinforced concrete frames. The test results of reinforced brick masonry, hollow block masonry, reinforced hollow block masonry, reinforced aerocon block masonry are compared with the frame without infill and with traditional brick masonry infill.

1.4 LIMITATION/DELIMITATION

- This investigation was done for plane frames. But the actual frame structures are having three dimensional structural elements
- In this investigation, the reinforced concrete infill frames have been considered. But in high rise buildings steel frames are normally used
- In this work, the infill panels were considered without door and windows openings.
- In reinforced masonry infill, the reinforcements were provided without any connection with beams or columns.
- The infilled frames were tested with equivalent static cyclic loads. The frames can be tested under dynamic loading to study the actual wind or earthquake loads.
- In all infilled frames, the severe damage occurred at the bottom storey leeward side columns.

2. LITERATURE REVIEW

Hemant B. Kaushik (2006) Masonry infill MI walls are remarkable in increasing the initial stiffness of reinforced concrete RC frames, and being the stiffer component, attract most of the lateral seismic shear forces on buildings, thereby reducing the demand on the RC frame members. However,

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behaviour of MI is difficult to predict because of significant variations in material properties and because of failure modes that are brittle in nature. As a result, MI walls have often been treated as non-structural elements in buildings, and their effects are not included in the analysis and design procedure. However, experience shows that MI may have significant positive or negative effects on the global behaviour of buildings and, therefore, should be addressed appropriately. Various national codes differ greatly in the manner effects of MI are to be considered in the design process from aseismic performance point of view. This paper reviews and compares analysis and design provisions related to MI-RC frames in seismic design codes of 16 countries and identifies important issues that should be addressed by a typical model code.

L.D. Decanini (2010) Framed structures are usually infilled with masonry walls. Since the infills included in the frame produce significant increase in both horizontal stiffness and strength their structural contribution should not be ignored, especially in regions of moderate and high seismicity. Simple models to take into account infill walls are available for solid walls, such as the diagonal no tension strut models, while infilled frames with openings have not been sufficiently investigated. In the present study the effect of openings on the lateral stiffness and strength of infilled frames is studied by means of numerical and experimental analyses available in the literature and a simple model to take into account the presence of openings is presented. The proposed model, which takes into account the presence and type of reinforcing elements around the openings, allows the evaluation of the reduction of stiffness and strength of the panel due to openings.

M. F. PAULO PEREIRA (2011) the building envelope in Europe is usually made of masonry walls, with enclosure and infill functions. Masonry walls have a major economic importance and contribute significantly to the building performance. Even if infill walls have no load-bearing function, they contribute significantly to the seismic behavior of buildings. Therefore, their adequate structural performance is needed, avoiding the occurrence of severe in-plane damage, with very large economic losses, and the out-of-plane expulsion, which additionally represents a large risk for human life. This paper presents the experimental work and results achieved by applying cyclic out-of plane loads to damaged masonry infilled RC frames. The masonry panels were previously damaged by applying an in-plane cyclic load after which the cyclic out-of- plane loads were applied. The frames and panels tested follow the traditional Portuguese RC structure construction system to which different types of reinforcement have been introduced in the panels.

Mehmet Baran (2010) Although hollow brick infills, widely used as partition walls, are considered as non-structural members, experimental studies revealed that hollow brick infills have favourable effects on strength and stiffness of structures. In this work, analytical studies were conducted to investigate the hollow brick infill behaviour, in which infills were modeled by diagonal compression struts. Results were compared with experimental ones obtained from tests of one-bay, one or two story reinforced concrete (RC) frames, tested under both vertical and reversed-cyclic lateral loads simulating earthquake. Test frames have intentionally been constructed poorly to reflect the most common deficiencies encountered in Turkey such as strong beam-weak column connections, insufficient confinement, low-grade concrete, poor workmanship and insufficient lap-splice length. Experimental studies shows that hollow brick infills increased both strength and stiffness of RC frames. Analytical studies conducted, shows that hollow brick infills could adequately be modeled by diagonal compression struts.

Sachin Surendran (2012) Un-reinforced masonry walls are commonly used as infills in reinforced concrete (RC) buildings. These buildings have high in-plane stiffness and strength, and therefore, the lateral load behaviour of such RC frames is different than that of the frames without infill walls. Openings in walls significantly reduce the lateral strength and stiffness of RC frames, and alter their failure modes. Past researchers have tried to find out experimentally and analytically the influence of several parameters, like opening size and location, aspect ratio of openings, connection between frame and infill wall, ductile detailing in frame members, material properties, failure modes, etc. on behavior of masonry infill RC frames. Accordingly, several analytical models have been proposed in the literature and seismic codes of some countries to model the stiffness and strength properties of infill walls. Most of the past studies and seismic codes recommend modeling the infills as equivalent diagonal struts, and cross-sectional area of the struts are reduced appropriately to account for openings in the walls. Analytical methods have also been proposed to estimate the possible mode of failure and lateral load carrying capacity of infill frames with and without openings. The current article is intended to review and compare past relevant studies and seismic codes of different countries on in-plane lateral load behaviour and modeling approaches for masonry infill RC frames with openings. The comparative study may help designers and code developers in selecting and recommending suitable analytical models for estimating strength, stiffness, failure modes, and other properties of infill RC frames with openings.

P Benson Shing (2002) Masonry infills are frequently used as interior partitions and exterior walls in buildings. They are usually treated as non-structural elements, and their interaction with the bounding frame is often ignored in design. The performance of such structures during an earthquake has attracted major attention. Even though frame–infill interaction has sometimes led to undesired structural performance, recent studies have shown that a properly designed infilled frame can be superior to a bare frame in terms of stiffness, strength, and energy dissipation. A number of different analytical models have been developed to evaluate infilled structures. Nevertheless, most of the models proposed today have been validated with limited experimental data, and they have often yielded different performances when compared with recent test data. Limit analysis methods that can account for a variety of possible failure modes seem to be the most promising approach. However, these methods need to be further refined and validated in a systematic manner before they could be used in engineering practice. Sophisticated finite element models have also been developed to analyse infilled structures. While these models are general and widely applicable to different types of infilled frames, they should be used with caution because they could be easily misused and lead to unconservative results. This paper summarizes some of the recent findings and developments on the behaviour and modelling of infilled structures, and provides thoughts for future research.

Mohamed et al (2003) have evaluated the seismic performance of concrete-backed stone masonry walls subjected to cyclic load. Six 1/3-scale, single-story, single-bay wall samples were tested. The influence of the type of construction, applied vertical loads, and existence of dowels between the infill concrete panel and the base on the lateral resistance, ductility, energydissipation, stiffness degradation, and failure mechanisms were investigated. The experimental results indicated that an increase in the applied vertical load resulted in a substantial increase in both the lateral strength and stiffness of the tested samples.

Diptesh Das and Murty (2004) have designed five reinforced concrete framed buildings with brick masonry infill for the same seismic hazard in accordance with the applicable different design methods. The buildings designed by the Nepal building code 201 and the equivalent braced frame

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method were found to be more economical.

Diptesh Das and Murty (2004) have performed non-linear pushover analysis on five R.C.frame buildings with brick masonry infill. It has been reported that brick infill walls present in R.C.frame buildings reduce the structural drift but increase the strength and stiffness. Also building designed by the equivalent braced frame method showed better overall performance.

Henderson et al (2003) have demonstrated that unreinforced masonry infills are more ductile and resist lateral loads more effectively than anticipated by conventional code procedures. For this, a five-year, large- and small-scale, static and dynamic experimental research program was conducted in which more than 700 tests were tested. The results from approximately 25 moderate and full-scale tests on infills showed that with simulated seismic loads the frames confined the masonry and the load-carrying capacity of the infill was considerably above the load that caused initial cracking.

GAPS IN EXISTING LITERATURE

From the literature review, it was found that most of the efforts have been focused on single bay single storey R.C. frames with brick masonry infill under monotonic or cyclic loading. For seismic evaluation purposes, it is not clear how to extrapolate the results of these experiments to multibay 32 multistorey infilled frames. Moreover, few works have been done on reinforced concrete frames infilled with materials other than bricks such as plain or reinforced concrete, clinker blocks, hollow blocks etc., and there is limited work on reinforced masonry infill. Hence, this programme consisted of studying six quarter scale two bay five storey reinforced concrete frames with different infills including reinforced masonry infill. In this chapter, contemporary literature within the purview of the present study is reviewed and presented under the major topics experimental study on the R.C. frames and analytical study using equivalent strut model and finite element model. The additional relevant literature is further cited in the oncoming chapters at appropriate places. It is further described that how the present study differs from the literature cited.

3. OBJECTIVES

1. To study the effect of reinforced masonry infill on the performance of the reinforced concrete frame
2. To assess the behaviour of reinforced masonry infill when subjected to static cyclic loading.
3. To lateral cyclic loading to simulate the lateral load caused by wind and earthquake forces
4. To create analytical model using equivalent strut concept and finite element concept using ANSYS software.
5. To find the effectiveness of reinforced masonry in resisting lateral loads.

4. RESEARCH METHODOLOGY

DESIGN OF FIVE STOREY R.C FRAME

In the design, it is assumed that the plastic hinges form in all floor beams before the formation of plastic hinges in the columns. It is desirable that energy be dissipated by the floor beams before hinging of column commences. This will ensure that the columns remain in the elastic range of behavior till a very late stage of disturbances and thus, have a higher degree of protection against permanent damage. Loads will be calculated as per 2008-2012 (Part 2 and 3) and various load combinations were considered for the design of five storey R.C. frame. The model RC frames will be designed for lateral load assuming that the frames in the real structure are spaced at 4m interval.

MATERIALS USED

Hard blue granite metal available around Virudhunagar will be used as coarse aggregate. Well graded river sand will be used as fine aggregate. Ordinary Portland cement conforming to IS 269-1989 will be used for concreting and for masonry works. Potable water available in the college campus will be used for concreting, curing and for construction of infill. High Yield Strength Deformed bars (HYSD) of various sizes will be used as reinforcement of R.C. frames. M20 Grade concrete will be used and the mix design will be done according to B.I.S. method to achieve the

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required target strength. Good quality bricks, hollow blocks and aerocon blocks will be used as infill materials.

CONCRETING AND CURING

Steel mould which will be made up of rolled steel channel sections and plates will be used for casting frames. The steel mould will be fabricated to facilitate easy assembling and dismantling for repetitive works. The frames will be cast in the college Structural Engineering Lab and sufficient precautions will be taken for removing the specimen from the mould and for erection. The side plates of the mould will be removed after 24 hrs and the specimen will be covered with wet gunny bags for continuous curing. It will be kept moist by periodical springing of water for a period 28 days after casting. The control specimens will be also cured under identical conditions as that of the frames.

LIFTING AND ERECTION OF THE FRAME

The specimen will be cured for 14 days using gunny bags. Then the specimen will be cleaned and allows resting on 75mm diameter mild steel pipes places across the specimen at regular intervals. A steel wire rope tied at third storey level will be used to lift the specimen. The frame will be lifted using 5T capacity electrically operated overhead crane and then moved towards the foundation block. The foundation portion of the test specimen will be inserted in the gap between the two webs of the foundation block

CONSTRUCTION OF INFILL

The significance of infill in determining the actual strength and stiffness of the framed buildings subjected to lateral force has long been recognized. Despite rather intensive investigations inclusion of infilling walls as structural elements in the design is not yet common because of the design complexity and lack of suitable theory for analysis. Hence, in this study the RC frame with various infill materials such as brick masonry, reinforced brick masonry, hollow block masonry, reinforced hollow block masonry and reinforced aerocon block masonry were considered. In the frame, construction of infill will be carried out on the same day of erection. Suitable scaffolding arrangement will be made for the construction of infill. The cement mortar 1:4 with water cement

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ratio of 0.45 will be used. The panel sizes for all infilled specimens will be 1000 x 600 mm with a thickness of 100mm.

TEST SETUP

The static cyclic load involves loading a structure to failure by applying a load at a constant rate in a series of load-unload cycles. The schematic diagram of test setup is presented with the following arrangements to measure load, deflection, strain and crack pattern. The static cyclic load will be applied at first, third and fifth storey levels by means of hydraulic jacks of 500 kN capacity. All the three jacks will be actuated by two hydraulic pumps for loading and unloading. The load applied will be measured by means of load cell placed between loading frame and the jack. The reading will be taken through load indicator having 10 channels. The linear variable displacement transducers (LVDT) will be used to measure deflection. The LVDT will be fixed to square mild steel tubes that will be in turn fixed to H type reaction frame. The LVDT will be connected to a common digital displacement meter having 10 channels. Proper provisions will be made to anchor the specimen to the testing floor to avoid the rigid body rotation. However, the deflection due to rigid body rotation any will be measured by dial gauges which will be provided on the base slab of the foundation block. Demountable mechanical strain gauge (DEMEC) will be used to measure strain at different locations while testing the frame.

TESTING PROCEDURE

The models will be tested as a vertical cantilever by varying shears under a cyclic loading program. To start with, the frame will be loaded with small loads and then released to check the effectiveness of the instrumentation setup and loading. This process will be repeated till readings will be constant. A load increment of 5 kN will be applied in each cycle. At ultimate load of each cycle, deflection, strains and crack pattern were measured. The load cycles will be continued till the final collapse occurred.

5. EXPECTED OUTOCME

The principal aim of introducing steel in the masonry infill in this study is to make it ductile and to enable it to resist tensile forces. The reinforced masonry ensured sufficient ductility by permitting redistribution of lateral load and by providing good energy dissipation characteristics for cyclic loading. The horizontal reinforcement provided in the reinforced brick masonry infill prevents the separation of joints due to diagonal shear cracking. This improves the resistance and energy dissipation capacity of the wall when subjected to cyclic lateral load. In un-reinforced masonry infill frames, a diagonal crack causes shear deterioration in strength and subsequence brittle collapse. However, in the reinforced brick masonry infill frame due to the provision of horizontal reinforcement the cracks distributed over the entire surface of the walls. At ultimate state, crushing of masonry due to a combination of bending and shear was observed indicating that the load bearing capacity of masonry units is fully utilized. Shear resistance of reinforced masonry infill depends on different mechanism such as tension of horizontal steel and dowel action of vertical steel. Moreover, the combinations of truss and arch-beam action of vertical and horizontal reinforcement with masonry improve the performance of infilled frames. Hence, horizontal bed joint reinforcement is efficient in the case of shear mode of failure and vertical reinforcement is needed for the bending mode of failure. Infills have a significant beneficial effect on the strength, ductility and energy dissipation capacity of frames.

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