Research Article

Study on Performance of Infilled Wall in an RC-Framed Structure Using a Reinforcing Band

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Infilled wall is a primary structure which is used in a multistorey RC-framed structure. It is not designed like structural elements, but it is subjected to structural load and response as a heavily damaged element into the building. The main problem of an infilled wall is not actively utilizing in the framed structure and it is not interacted with frame elements. The objective of research is to utilize the infilled wall in the RC-framed structure by improving its performance of behavior. Here, two different types of brick masonry like Autoclaved concrete and clay brick masonry were used as the infilled wall in an RC-framed structure. A singly bay and single storey RC framed structure was cast and tested under a 1/10th scale model by diagonal compressive loading. The specimen was subjected to static loading by a universal testing machine. Infilled wall is weak in tension, so a reinforcing band was used to improve the performance like load carrying capacity, stiffness, ductility, and energy dissipation capacity. Based on the results of the experimental study, it is found that reinforcing band with the infilled wall gives better behavior of the RC-framed structure.

1. Introduction

At present, the development of tall construction is necessary to avoid more utilization of land area for building up the structure in the urban community [1, 2]. At the same time, the effects of earthquake in tall structures have been severely damaged due to out of uncontrolled lateral displacements and it makes serious damages to the structural elements [3, 4]. Structural construction with infilled frames has induces more trouble with the recommended resources of lateral load [5, 6]. Normally, all type of framed structures consisted of structural and nonstructural elements [7, 8]. In that, masonry infilled walls are recommended as a non-structural member for separating the rooms and living can be proficiently used in combination with a framing system [9, 10]. Although, these nonstructural boundaries of unreinforced masonry walls are imperfect in shear and tensile strength and it is brittle mannerism, inconceivable damages are exposed at time of loading [11, 12].

The lateral strength of infilled frames with variation of infill wall thickness and it was proved that these frames more lateral strength than bare frame [13, 14].
When the infilled wall is subjected to in-plane loading, it generates strut and frame action and it leads to the failure between masonry and frame elements [12, 15]. Therefore, the composite motion of the infilling materials like a traditional brick wall with the predominant frame can be examined. It [4, 16] has been studied that the lateral strength of the infill frame is predominately higher than the bare frame [17, 18]. This study is conventionally showing the strength and stiffness of the brick partitions furnished for encouraged aspects, in shape at the equal time with economy [19, 20]. During the design and analysis of the reinforced concrete-framed structures, the infilled wall is ignored due to its highly nonlinear nature [21]. Also, it is difficult to stimulate and interact with the surrounding frame when the structure is subjected to lateral loads induced by earthquake ground motions [19, 22]. It is necessary to investigate the interaction between RC-framed structures and infill wall panels and large numbers of experimental works with analytical investigation were conducted [23, 24]. The presence of the infill wall increases the stiffness and the strength of the framed building but the infill wall has a negative impact on the integrity of some building due to composite action, irregularities, and soft storey mechanism [16, 25].

2. Objective of Research

The objective of research is to study the behavior of interaction between a RC frame and an infilled wall under static loading. In this work, the different type of specimens was prepared in the form of a single bay single storey rectangular infilled RC frame.

The focus of this investigation is to observe the strength, ductility, stiffness, energy dissipation capacity, and failure mechanism of these specimens [26]. Finally, the results were compared with each other and suitable strengthened infilled wall is identified. Thus, it improves the interaction between the infilled wall and RC frame elements.

3. Methodology of Research Work

The performance of RC frame with miscellaneous types of an infilled wall was examined under an experimental investigation programme. The type of RC frames has cast as a single bay single storey frame with different kinds of the infilled wall by following ways:

- Rectangular RC frame without infill (BF)
- Rectangular RC frame with clay brick masonry (IF-CBM)
- Rectangular RC frame with Autoclave aerated concrete brick masonry (IF-ABM)
- Rectangular RC frame with reinforced clay brick masonry (IF-RCBM)
- Rectangular RC frame with reinforced Autoclave aerated concrete brick masonry (IF-RABM)

The specimens are modeled as 1/10 scale from prototype structure and dimension of infilled RC frames were fabricated in uniform size and it is tabulated in Table 1.

| Frame designation | C/S dimensions (mm) | Main reinforcement |
|-------------------|---------------------|--------------------|
| BF                | 60 50 4 No's, 4 mm φ |                    |
| IF-CBM            | 60 50 4 No's, 4 mm φ |                    |
| IF-ABM            | 60 50 4 No's, 4 mm φ |                    |
| IF-RCBM           | 60 50 4 No's, 4 mm φ |                    |
| IF-RABM           | 60 50 4 No's, 4 mm φ |                    |

In general, horizontal loads are acting at a beam-column joint and this load is transferred as diagonal load or in-plane load to the infilled wall. In this experimental investigation, the lateral load was applied in the form of diagonal load at beam-column joints. Here, a single bay single storey interior panel was selected, and it was rotated diagonally in a vertical plane and in-plane load was given in the form of vertical compressive load. When applying this load, a mild steel plate was provided at the beam-column joint to distribute the load from frame elements to the infilled wall.

4. Material Specifications

4.1. Material Requirements. 53 Grade of ordinary Portland cement was used. The cement was in standard gunny bags and transferred later to airtight steel drums to avoid deterioration of quality. River sand was used for all specimens for experiment work was sieved through a 4.75 mm sieve [27]. The stones were used for all specimens is medium gravel for experiment work and it was sieved through a 10 mm sieve. To construct the RC frame, a combination of the mild steel plate and wooden mould was especially fabricated for the modeling or casting of specimens. Each component of the mould is in a separate segment and the utilization of a bolted joint can effortlessly configure it. The mould is attached with a wooden platform to obtain smoothness in the specimen. The geometry detail of mould specimen is given in Figure 1.

The specimens are made up of infilled reinforced concrete structures and it consists of reinforcement, concrete, and brick masonry infilled walls [28]. The size of main reinforcement was 4 mm in diameter. The reinforcement arrangement of specimen is shown in Figure 2. For concrete, M20 grade of concrete was designed by design mix proportions. In the infilled masonry wall, first-class clay bricks of size 190 mm × 90 mm × 90 mm were used for constructing brick masonry work and it is the prototype under the dimensions of 60 mm × 30 mm × 30 mm was used as infilled wall. Similarly, autoclave-aerated concrete block was used as the masonry structure for another type of specimen with a size of 60 mm × 30 mm × 30 mm.

4.2. Casting and Curing of the Frame. The mould is arranged on a clean, flat, and nonabsorbent surface. The inner and bottom of the mould were well oiled to prevent the specimen from sticking on it. The steel reinforcement of the frame is placed in the mould with the proper side and bottom clear cover. In the casting of the frame, the concrete was filled in the mould in three layers. In each layer, the specimen was
compacted under the table vibrator. The mould was dismantled after 24 hours; then, the specimen was placed in water for curing. The frame was cured for 28 days [29]. Figure 3 shows the casting of infilled RC frame and reinforcing band also arranged.

4.3. Testing Arrangements. Before the testing, the specimen was dried to avoid moisture in concrete. After the specimens were whitewashed, the specimen was arranged in the universal testing machine (UTM) to test the performance of the structure. The loading arrangement of the infilled RC frame specimen is shown in Figure 4. Here, UTM is available with electronic and computerized functioning, and it is based on a forced based system and strain was also measured. A singly bay single storey interior frame was cast and load is applied at in-plane loading in the form of diagonal load. The specimen was subjected to uniform rate of loading and load vs deflection was recorded [30].

5. Result and Discussion

5.1. Load-Deflection Behaviour. The utilization of the infilled wall in an RC-framed structure influences strength and serviceability of structural members. The load-deflection curve is to understand the performance of load carrying capacity, stiffness, ductility, and energy dissipation capacity of the infilled RC framed-structure. Here, different kinds of the masonry wall were used in the infilled wall and it makes significant usage of framed structure. Normally, the infilled wall is weak in tension and it is not effective to carry in flexure and shear. Adding of reinforcement band in infilled wall enhances the serviceability conditions in the infilled wall. From Figure 5, it can be understood that the bare frame specimen has more deflection when compared with the infilled RC frame because of stiffness and this stiffness does not permit the deflection in the infilled RC frame. In a multistorey framed structure, masonry wall is necessary to partition and suppose to carry the load from structure. Therefore, it is significant to improve the deflection in masonry wall by introducing the reinforcing band in between a layer of the masonry structure. Figure 5 shows that specimen IF-RCBM and IF-
RABM are more effective in deflection limit when compared with that of IF-CBM and IF-ABM specimens, respectively.

5.2. Ultimate Load Carrying Capacity. In this investigation, two different kinds of masonry structure were used as the infilled wall such as brick masonry wall and autoclave-aerated concrete brick masonry wall. These masonry structures were strengthened with a reinforcing band because it does not carry tensile strength. When compared with an ordinary masonry infilled wall, reinforced masonry wall attains more ultimate load carrying capacity. Figure 6 shows ultimate load carrying capacity of all specimens. From Figure 6, it is specified that autoclave-aerated concrete brick masonry provide comfortable strength against bare frame and ordinary brick masonry.

5.3. Initial Stiffness. Initial stiffness means force induced due to unit displacement at the time of yielding of structural member (Figure 7). When compared with bare frame, specimen IF-CBM and IF-ABM produce more initial stiffness because of the infilled wall is not permitted the deflection in RC-framed structures. Infilled RC frame has high stiffness value except IF-RABM specimen. Thus, reinforcing band allows yielding with maximum load carrying capacity.

5.4. Ductility. Ductility is a significant factor to understand the flexible behaviour of the structure. It is the ratio between ultimate deflection to yield deflection. Figure 8 shows the ductility of various specimens. From Figure 8, it is understood that the ductility of infilled RC frame is same with various types of masonry infilled walls. However, reinforced masonry infilled RC frame attains more ductility when compared to other specimens. It denotes that reinforcing band improves the ductility in the infilled wall.

5.5. Energy Dissipation Capacity. The principle of energy dissipation capacity is simulating the energy released by structural elements when a member is subjected to loading. Here, in this investigation, the area enclosed under the load deflection curve is noted as energy absorption capacity. From Figure 9, it is clearly indicated that the reinforced infilled RC frame has more energy capacity when compared to the ordinary infilled RC frame. After yielding the reinforcing band, it allows deformation up to the maximum limit. The energy capacity of reinforcing infilled wall is 3.19 times more than an ordinary infilled wall. Figure 9 refers to the ordinary infilled RC frame and bare frame has similarly energy dissipation capacity.

5.6. Failure Mechanism. The study and analysis of the failure pattern is significant to know about the performance of the structure. Generally, the infilled RC framed structure is subjected to different kinds of failure pattern in the structure. Due to in-plane diagonal loading, compressive force is developed along the loading direction and opposite direction tension force is induced. Therefore, the member reflects shortened and elongated along the diagonal length of RC frame structure. Figure 10(a) represents the failure pattern of RC bare frame. Besides, beam-column joint failure also happened during testing. Normally, the infilled wall is provided in between frame members and when it is subjected to loading, a diagonal crack occurs (Figure 10(b)). This type of failure induces a sudden debris of the infilled wall and load also not distributed evenly to infilled wall (Figure 10(c)). When comparing with an autoclave concrete block, brick masonry wall is weak in strength and it induces spalling of the brick element (Figure 10(d)). From the analysis of failure pattern of the infilled RC frame, it is understood that there is not much interaction between infilled wall and frame, and it leads to failure of bedding joints in the specimens. But using of this reinforcement
Figure 6: Ultimate load carrying capacity of specimens.

Figure 7: Initial stiffness of specimen.

Figure 8: Ductility of specimen.
band, it enhanced the interaction between infilled wall and frame.

6. Conclusion

Infilled wall is a mandatory nonstructural element for the framed structure but this element is not designed. When the structure is subjected to loading, infilled wall carries a load partially itself and it induces a major damage suddenly. The conclusion of this concern is to introduce the reinforcing band to infilled wall to improve the performance of structure testing with different kinds of infilled wall. In this research work, two types of infilled wall like clay brick masonry and autoclave-aerated concrete brick masonry were used. The conclusion drawn based on the experimental investigation on a one-tenth model scale of the RC frame with infilled under static loading are discussed below.

(i) The ultimate load carrying capacity of the frame with reinforced autoclave-aerated concrete brick masonry is 25.96% greater than that of the frame with ordinary autoclave-aerated concrete brick masonry.

(ii) The ultimate load carrying capacity of the frame with reinforced autoclave-aerated concrete brick masonry is 21.87% greater than that of the frame with reinforced clay brick masonry.

(iii) The initial stiffness of the frame with reinforced clay brick masonry is 33.80% greater than that of the frame with reinforced autoclave-aerated concrete brick masonry.

(iv) The initial stiffness of the frame with reinforced clay brick masonry is 49.64% greater than that frame with clay brick masonry.

(v) The ductility for the frame with reinforced clay brick masonry is 29.34% greater than that of the frame with autoclave-aerated brick masonry.

(vi) The ductility for the frame with reinforced clay brick masonry is 31.24% greater than that of the frame with ordinary clay brick masonry.

(vii) The energy dissipation capacity for the frame with reinforced clay brick masonry is 1.11 times greater than that of the frame with clay brick masonry.

(viii) The energy dissipation capacity for the frame with reinforced clay brick masonry is 3.19 times greater
than that of the frame with ordinary clay brick masonry.

(ix) Finally, it is proved that a reinforcing band in the infilled wall enhances the structural behavior of the RC-framed structure.

**Data Availability**

All data used to support the findings of this study are included in the manuscript.

**Conflicts of Interest**

The authors declare that they have no conflicts of interest.

**References**

[1] S. Praburanganathan, N. Sudharsan, Y. Bharath Simha Reddy, C. Naga Dheeraj Kumar Reddy, L. Natrayan, and P. Paramasivam, "Force-deformation study on glass fiber reinforced concrete slab incorporating waste paper," *Advances in Civil Engineering*, vol. 2022, Article ID 5343128, 10 pages, 2022.

[2] N. Sudharsan, S. Praburanganathan, B. S. R. Yeddula, and P. Pavan Kumar, "Interaction of Anthracite Coal Ash and Archis Hypogaea Shell Ash on an Innovative brick: An Experimental and Simulation Study," *International Journal of Coal Preparation and Utilization*, vol. 2022, Article ID 2089127, 7 pages, 2022.

[3] G. Ma, H. Li, J. Wang, and J. Wang, "Experimental study of the seismic behavior of an earthquake-damaged reinforced concrete frame structure retrofitted with basalt fiber-reinforced polymer," *Journal of Composites for Construction*, vol. 17, no. 6, 2013.

[4] H. Moniri, "Evaluation of seismic performance of reinforced concrete (RC) buildings under near-field earthquakes," *International Journal of Advanced Structural Engineering*, vol. 9, no. 1, pp. 13–25, 2017.

[5] J. Li, D. C. Feng, X. Gao, Y. Zhang, and Y. Zhang, "Stochastic nonlinear behavior of reinforced concrete frames. I: experimental investigation," *Journal of Structural Engineering*, vol. 142, no. 3, 2016.

[6] N. Sudharsan and B. C. J. Grant, "Comparison of static response of laced reinforced concrete beams with conventional reinforced concrete beams by numerical investigations," *International Journal of Civil Engineering & Technology*, vol. 9, no. 8, pp. 700–704, 2018.

[7] S. Shanmugan, S. Velusamy, J. L. Nallasamy et al., "Critical study on corrosion inhibitors in U-shaped RCC beams," *Advances in Materials Science and Engineering*, vol. 2022, Article ID 4762524, 8 pages, 2022.

[8] P. Selvaraj, S. Chithra, N. Divyah, S. N. Y. B. Simha Reddy, and V. S. "Value-added waste substitution using slag and rubber aggregates in the sustainable and eco-friendly compressed brick production," *Revista de la construcci´ on*, vol. 21, no. 1, pp. 5–20, 2022.

[9] A. B. Liel, C. B. Haselton, G. G. Deierlein, M. Asce, G. Gregory, and F. Deierlein, "Seismic collapse safety of reinforced concrete buildings. II: comparative assessment of nonductile and ductile moment frames," *Journal of Structural Engineering*, vol. 137, no. 4, pp. 492–502, 2011.

[10] N. Sudharsan, C. J. B. Grant, P. Murthi, K. Poongodi, and P. Mahesh Kumar, "A comparative experimental investigation on laced reinforced concrete beam and conventional beam under monotonic loading," in *Proceedings of the IOP Conference Series: Earth and Environmental Science*, vol. 822, June 2021.

[11] F. Di Trapani, L. Giordano, and G. Mancini, “Progressive collapse response of reinforced concrete frame structures with masonry infills,” *Journal of Engineering Mechanics*, vol. 146, no. 3, 2020.

[12] N. Qian and B. Li, “Effects of masonry infill wall on the performance of RC frames to resist progressive collapse,” *Journal of Structural Engineering*, vol. 143, no. 9, 2017.

[13] A. S. A. Tawfik Essa, M. R. Kotp Badr, and A. H. El-Zanaty, “Effect of infill wall on the ductility and behavior of high strength reinforced concrete frames,” *HBRC Journal*, vol. 10, no. 3, pp. 258–264, 2014.

[14] C. Zhai, X. Wang, J. Kong, S. Li, and L. Xie, “Numerical simulation of masonry-infilled RC frames using XFEM,” *Journal of Structural Engineering*, vol. 143, no. 10, 2017.

[15] P. Jagadeesan and T. Palanisamy, “Study on performance of infilled wall in RC framed structure using basalt fibre in cement mortar,” *Journal of Structural Engineering*, vol. 45, no. 6, 2019.

[16] K. A. Korkmaz and A. E. Karahan, “Investigation of seismic behavior and infill wall effects for prefabricated industrial buildings in Turkey,” *Journal of Performance of Constructed Facilities*, vol. 25, no. 3, pp. 158–171, 2011.

[17] R. M. Oinam, R. Sugumar, and R. S. Dipti, “A Comparative Study of Seismic Performance of RC Frames with Masonry Infills,” in *Proceedings of the 11th International Symposium of Plasticity and Impact Mechanics*, pp. 1784–1791, Elsevier Procedia Engineering, Netherlands, Europe, July 2017.

[18] K. Shailendra, D. Damodor, and K. Sunil, “An experimental investigation on the ultimate strength of epoxy repaired braced partial infilled RC frames,” *International Journal of Advanced Structural Engineering*, vol. 49, 2014.

[19] H. Helmy, H. Hadhoud, and S. Mourad, “Infilled masonry walls contribution in mitigating progressive collapse of multistory reinforced concrete structures according to UFC guidelines,” *International Journal of Advanced Structural Engineering*, vol. 7, no. 3, pp. 233–247, 2015.

[20] S.-J. Lee, “P–s–s–eong eun eunjung yu investigation of diagonal strut actions in masonry-infilled reinforced concrete frames,” *International Journal of Concrete Structures and Materials*, vol. 6, 2021.

[21] L. N. Koutas and D. A. Bournas, “Out-of-plane strengthening of masonry infilled RC frames with textile-reinforced mortar jackets,” *Journal of Composites for Construction*, vol. 23, no. 1, 2019.

[22] N. L. Smith, M. J. Tait, W. W. El-Dakhakhni, W. F. Mekky, F. Asce, and W. F. Mekky, “Response analysis of reinforced concrete block infill panels under blast,” *Journal of Performance of Constructed Facilities*, vol. 30, no. 6, 2016.

[23] A. Zafar, B. Andrawes, and A. M. Asce, “Seismic performance of RC moment resisting frame with steel, GFRP, and SMAFRP reinforcement,” in *Proceedings of the Structures Congress 2012*, ASCE Library, Chicago, IL, USA, March, 2012.

[24] M. Peruch, E. Spacone, and P. B. Shing, “Cyclic analyses of reinforced concrete masonry panels using a force-based frame element,” *Journal of Structural Engineering*, vol. 145, no. 7, 2019.

[25] H. Wijaya, P. Rajev, E. Gad, and A. Amirsardari, “Effect of infill-wall material types and modeling techniques on the seismic response of reinforced concrete buildings,” *Natural Hazards Review*, vol. 21, no. 3, 2020.
[26] P. Jagadeesan and T. Palanisamy, “Structural response of RC frame with infilled wall using Confinement,” *Journal of Structural Engineering*, vol. 42, no. No. 4, 2015.

[27] A. R. Krishnaraja, P. Kulanthaivel, P. Ramshankar et al., “Performance of polyvinyl alcohol and polypropylene fibers under simulated cementitious composites pore solution,” *Advances in Materials Science and Engineering*, vol. 2022, Article ID 9669803, 7 pages, 2022.

[28] S. Velusamy, A. Subbaiyyan, K. Ramasamy et al., “Use of Municipal Solid Waste Inert as a Powerful Replacement of fine Aggregate in Mortar Cube,” *Materials Today: Proceedings*, vol. 65, no. 2, pp. 549–553, March 2022.

[29] M. Shanmugamoorthy, S. Velusamy, A. Subbaiyyan, R. Yogeswaran, R. Krishnanbabu, and S. Rubesh, “Obtaining high durability strength using bacteria in light weight concrete,” *Materials Today Proceedings*, vol. 65, no. 2, pp. 920–924, March 2022.

[30] V. Nandhini, D. Ambika, V. Sampath Kumar, S. Dhinu Priya, G. Poovizhi, and V. Santha Rubini, “An analysis on low cost and energy efficient materials for sustainable housing,” *International Journal of Engineering Trends and Technology*, vol. 68, pp. 88–96, Feb 2020.