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Study of a Multi-Storey Brick Infilled Reinforced Concrete Structure

Etude d'une structure à plusieurs étages en béton armé remplie de briques

Untersuchung von mehrstöckigen Stahlbetonkonstruktionen mit Ziegelsteinausfachung

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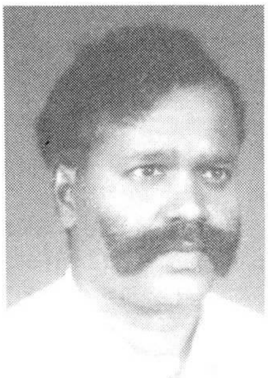

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SUMMARY

The behaviour of two multi-storey, reinforced concrete frames, with brick infill and without, was studied experimentally. The failure modes of both the frames and the effect of brick infill in multi-storey multi-bay infilled frames were assessed. The strength, stiffness, ductility and energy absorption characteristics of both the frames are discussed in this paper.

RÉSUMÉ

Le comportement de deux structures à plusieurs étages, en béton armé, - l'une remplie de briques et l'autre sans briques - a fait l'objet d'une étude expérimentale. Le mode de rupture des deux charpentes et l'effet de la présence ou de l'absence des briques été étudié. La résistance, la rigidité, la ductilité, et la capacité d'absorption de l'énergie des deux charpentes sont discutés dans cet article.

ZUSAMMENFASSUNG

Das Verhalten von zwei, mehrstöckigen Stahl-Betonrahmen werden untersucht. Einer davon ist ohne Ziegelsteinausfachung und der andere ist mit Ausfachung. Die Art des Versagens wird für die beiden Rahmen abgeschätzt. Die Eigenschaften der Festigkeit, der Steifigkeit, der Duktilität und der Energieaufnahme von diesen Rahmen werden hier diskutiert.

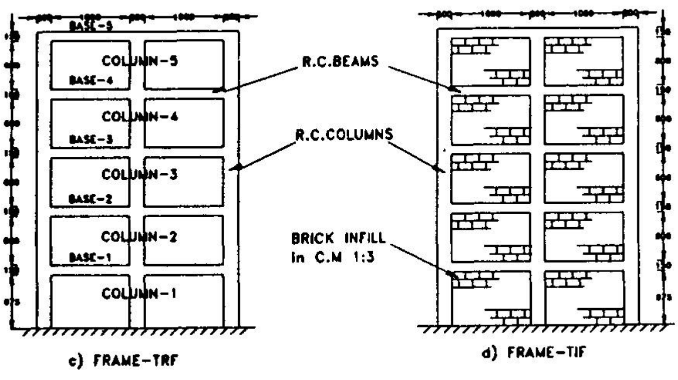
1. INTRODUCTION

A recent United Nations study estimates the world population by the year 2000 A.D. to exceed six billions and that the urban population will be half of the world's total population. With the population explosion and increase in land prices sky rocketing, sky scrapers have become the necessity of the present day. In tall structures, the inplane horizontal loads are a matter of great concern and need extraordinary consideration in the design of multistorey buildings. One method of resisting lateral load is considering the structural stiffness and strength of masonry infill walls. Liauw and Lo [1] and Klinger and Bertero [2] have studied experimentally the factors affecting the stiffness and ultimate load of multibay and multistorey infilled frames.

The object of present investigation is to quantify the parameters like load carrying capacity, stiffness, ductility and energy absorption capacity for a two-bay R.C. frame with and without infill.

2. BASIS OF DESIGN

The elasto-plastic analysis based on beam hinge mechanism was assumed. It has been further assumed [3] that plastic hinges form in all floor beams in both bays before plastic deformation of any kind would occur in any of the columns of reinforced concrete frame without brick infill. The dimensions were fixed using quarter scale and the beams and column sections for the model are shown in Fig.1.a and Fig.1.b. The reinforcement details are shown in Fig.2.



ALL DIMENSIONS ARE IN mm

FIG.1 QUARTER SIZE FIVE STOREY TEST SPECIMENS

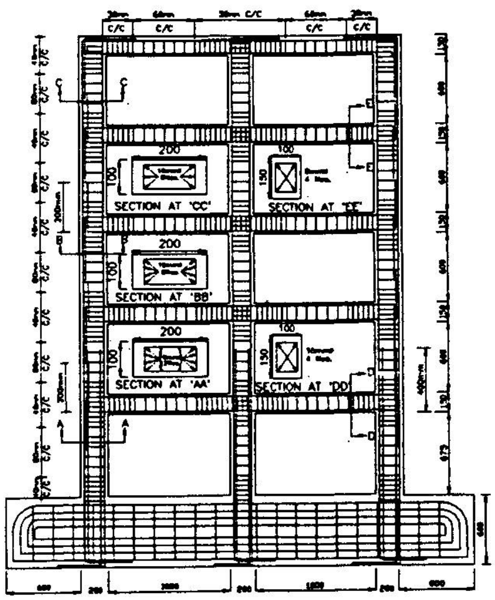


FIG.2. SCHEMATIC DIAGRAM OF REINFORCEMENT DETAILS

3. NUMERICAL SOLUTION

The two-bay infilled frame is analysed by replacing the infill as equivalent strut.[4]. The infilled frame was idealized as a pin jointed truss neglecting bending moments in beams and columns. Using strain energy concept, the forces in different members were determined and the values are shown in Fig.3.a. The collapse base shear works out to 412.338 kN. In the other method, the frame was assumed as a rigid-jointed framework, taking into consideration the bending moments also. The forces and moments calculated are given in Fig.3.b. The calculated ultimate base shear was found to be 444.819 kN.

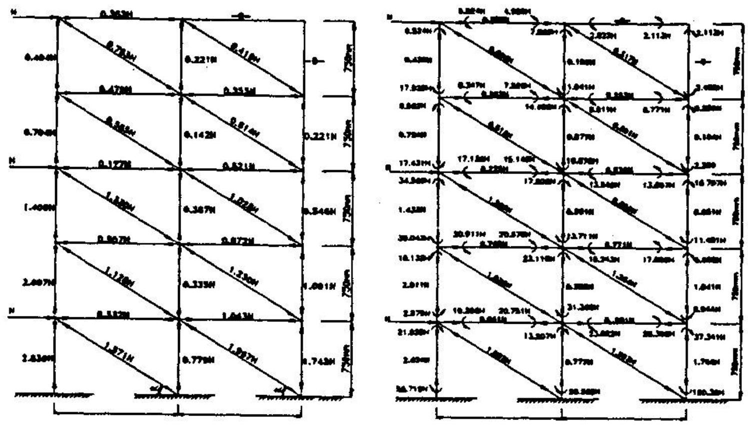


FIG.3 NUMERICAL SOLUTION

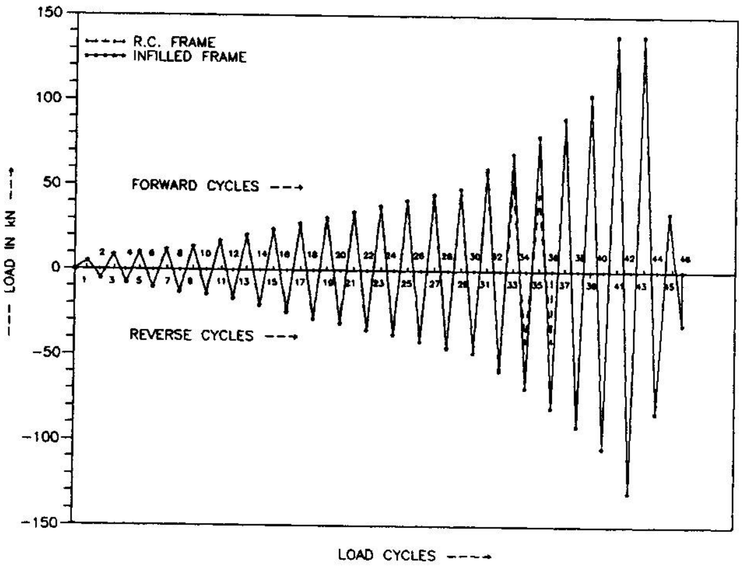


FIG.4 LOAD SEQUENCE FOR FRAMES TRF AND TIF

4. TESTING PROCEDURE

Three load points were located at fifth storey, third storey and first storey levels. Using hand operated oil pumps and double acting jacks, static reversed cyclic lateral load was applied The loading sequence in the beginning for both frames were identical as shown in Fig.4. Near final collapse, the increment of load was controlled based on visible deformation capacity of the frames.

5. EXPERIMENTAL RESULTS AND COMPARISON

5.1. Load Vs. Deflection

The lateral deflection of the frames at all the five storey levels were measured and the displacement due to rigid body rotation of the footing and the foundation block were incorporated in the calculation of net deflection. The deflection at top storey level with respect to maximum base shear of each cycle for frame-TIF is shown in Fig.5. The deflections at later cycles were greater than that in the preceding cycles.

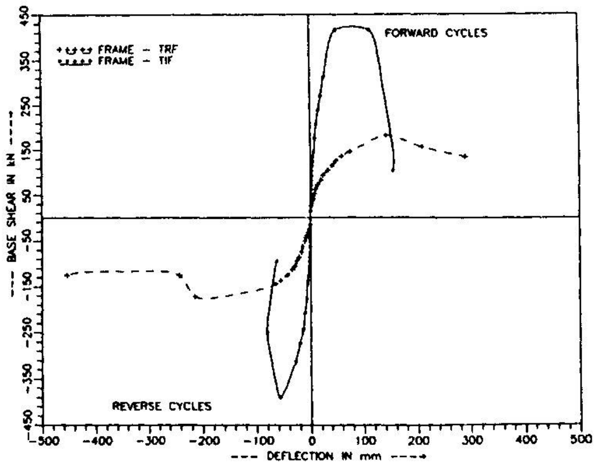


FIG.5.BASE SHEAR VS TOP STOREY DEFLECTION FOR FRAMES TRF AND TIF

5.2. Stiffness

The stiffness of both the frames is defined here as the base shear required to cause unit deflection at the top storey level. In both the frames TRF and TIF there was general degradation of stiffness with respect to increase in load cycles as can be seen from Fig.6. The stiffness of frame-TIF was always greater than that of frame-TRF during all stages of loading.

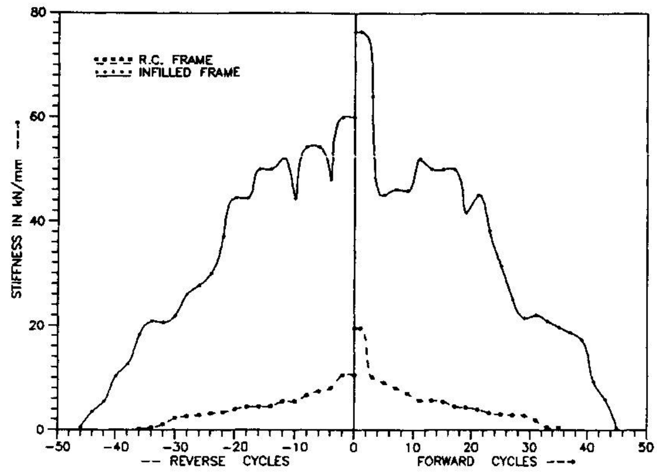


FIG.6 COMPARISON OF STIFFNESS FOR FRAMES TRF AND TIF

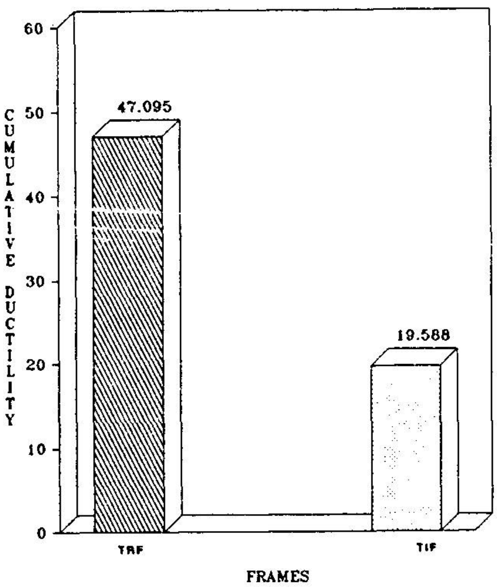


FIG.7 COMPARISON OF CUMULATIVE DUCTILITY

5.3. Ductility Factor

The ductility factors for the frames are calculated as the ratio of maximum deflection at any load level and the first yield deflection. The yield deflection is obtained by assuming bi-linear behaviour of the frames. The yield deflection for frame TRF is 21.Ø mm and for frame TIF is 13.6 mm. The ductility factor values for various load cycles of the specimens were worked out and the cumulative ductility factor for both the frames are calculated and given in Fig.7.

5.4. Energy Dissipation

It is important for a building in a seismic zone to be resilient, i.e. absorb the shock from the ground and dissipate this energy uniformly throughout the structure. The proportionate energy dissipation during various load cycles was calculated as the sum of the areas under the hysteresis loop. The cumulative energy dissipated by the frame-TRF is 167.6 kN-m in thirty six cycles whereas the total energy dissipated by the frame-TIF was 11Ø.633 kN-m. The cumulative energy dissipated for both frames are shown in Fig.8.

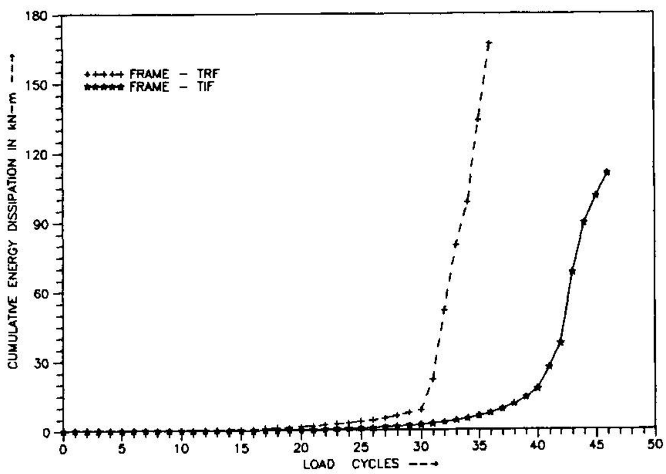


FIG.8. COMPARISON OF CUMULATIVE ENERGY DISSIPATION CAPACITY

5.5. Mode of Failure

In bare frame, the crack width increased when the load is increased further and further. The steel in floor beams got yielded due to excessive deformation of the structure (Fig.9). After all the floor beams plastified, the windward column steel yielded and crushing of concrete took place in leeward column and then in the middle column.

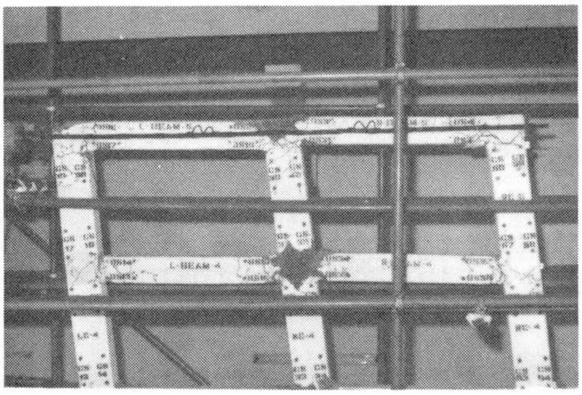


FIG.9. FAILURE OF FRAME -TRF

In frame-TIF, it is seen that the infill cracked along the bed joints as well as along the diagonal. During the reverse cycle, the cracks, which formed during the forward cycle, closed and new cracks developed across the tension diagonal of the brick panel. The cracking which occurred during forward and reversed cycles reflect the fact that the infilled frame behaved as an integral unit. At failure the frame-TIF exhibited spalling of brick fragments as shown in Fig.10.

FIG.10. SPALLING OF BRICKS

The damaged brick infill is likely to cause flying fragments in the case of infilled walls and needs protection. The complete failure of the Frames TRF and TIF are shown in Fig.11 and Fig.12.

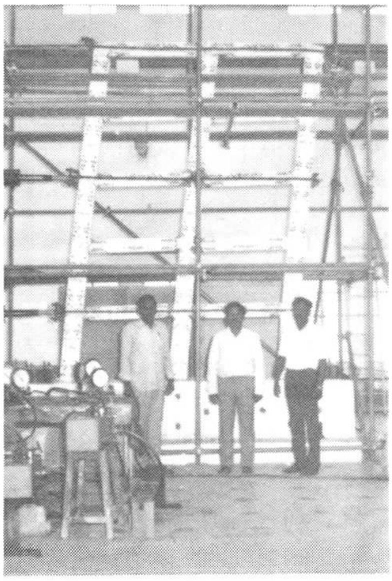


FIG.11. FRAME - TRF AT FAILURE

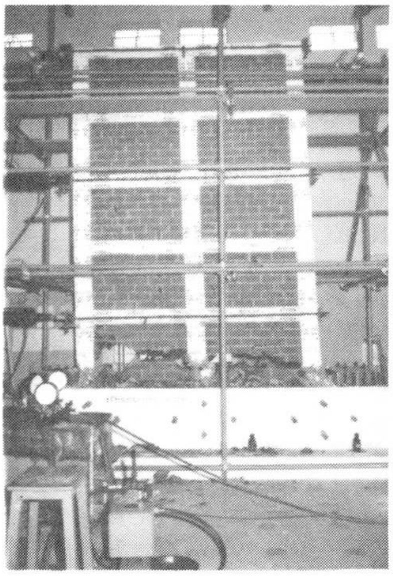


FIG.12. FRAME - TIF AT FAILURE

6. CONCLUSIONS

1.The load capacity of infilled frame increases by 2.29 times as that of bare frame. The initial cracking load of infilled frame is 2.5 times more than that of the bare frame.

2.In the initial stage, the infilled frame is 3.93 times stiffer than the bare frame. The stiffness of infilled frame is always greater than that of bare frame during all stages and all cycles of loading.

3.The R.C.frame is 1.73 times more ductile than the infilled frame. The R.C. frame can absorb 1.51 times more energy than the infilled frame.

4.As the stiffness of the infilled frame is higher than that of the bare frame, larger load is being resisted. It is to be noted that the frame TRF is designed as a bare frame and hence this type of enormous stiffness will mean that unduly large forces are to be resisted by the infilled frame. This may even cause rigid body movements at foundation levels endangering the stability of the whole structure.

5.The behaviour and failure mechanism of bare frame are different from that of the infilled frame. In infilled frame plastic hinge hinges did not form in all the beams before column hinges developed whereas in the R.C. frame, plastic hinges formed in all beams before final collapse of the frame.

7. ACKNOWLEDGEMENT

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