A method of analysis for infilled frames

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Infilled frame construction has been used very commonly in seismic and non-seismic areas, but design engineers have been reluctant to make use of the in-plane stiffening and strengthening influence of infilling on bare frames in their design calculations. Such an attitude seems to be due to the difficulty of achieving a tight fit between the frame and the infill. Most of the research workers have pointed out this difficulty and no attempt has been made by the Authors to deal with this practical problem while suggesting some design formulae for the composite action of infilled frames.

64. The infilled frame type of composite construction is very suitable for designing earthquake resistant structures due to the diagonal bracing effect. Structures are subjected to cyclic loading during vibrations and alternating stresses are produced along the diagonals. That is, the variation of the external lateral load between the limits $\pm H$, say, is accompanied by a variation of stress along one diagonal from large compression stress to small tensile stress as a result of the formation of boundary cracks. The other diagonal experiences the same variation of stress, from large compression to small tension as the load varies from $\mp H$. For composite structures, such as infilled frames having a tightly fitting unbonded infill initially, the simple situation assumed by the Authors does not exist. The infill after a few cycles of loading becomes quite loose inside the frame: thus the belief that a reasonable degree of composite action occurs when the loads are applied is dangerous.

65. Another fear is that in the conventional infilled frame construction, where the brick panel is contained in a reinforced concrete or steel frame, the failure by yielding of one of the loaded corners is sudden and without warning. Once this type of failure has occurred, the infilling becomes ineffective and the stiffness and strength of the structure is basically that of a bare frame.

66. I have been doing research to find solutions to these above mentioned problems.⁸ If the decision on the plan of a building regarding the position of walls to resist the lateral loads has been finally taken, then most of the practical difficulties can be overcome by using infilled frames with shear connectors as shown in Fig. 12. For brick masonry panels these connectors can be strips projecting from the columns and penetrating into the seams of brick panels at definite spaces. The provision of shear connectors increases the length of contact and hardly any boundary cracks appear up to the application of approximately two-thirds of the ultimate load. Hence, the distribution of stress is changed, thus increasing the lateral stiffness of the infilled frames as can be seen from Fig. 12.

67. When such a frame is subjected to cyclic loading it behaves reasonably as a composite structure. I have made use of very simple formulae for predicting the lateral stiffness of these frames. Infilled frames with shear connectors could be as much as 67% stiffer than the frames without shear connectors.⁹ It can be seen from Fig. 13 that the spacing of shear connectors does not affect the behaviour of infilled frames appreciably.

68. The effect of the position of openings on the lateral stiffness and strength of infilled frames has not been considered by the Authors. It has been experimentally observed⁹ that if an opening is provided at either end of the loaded diagonal of an infilled frame, the stiffness is reduced by 60–70%, and strength by 80–85%. Thus the openings at either end of the loaded diagonal are structurally unsuitable. From dynamic considerations openings should not be located at the ends of either diagonal. It is recommended that the door opening can best be located in the centre of the lower

Fig. 12. Load-deflexion curves of square infilled frame without opening

half of the panel and the window opening in the mid height region of the left or right half of the panel as near to the vertical edge of the panel as possible.

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The Authors wish to thank **Dr Mallick** for his comments on their Paper.

70. The reluctance of engineers to include the stiffening and strengthening effect of infillings in their calculations has not been so much due to the difficulties of achieving a tight fit between the frame and infill but more to their lack of knowledge about the interaction behaviour and the absence of an appropriate design method. Several methods exist for ensuring a tight fit between the frame and infill; for example, in South America, it is usual practice to omit the top course of bricks and substitute diagonally inclined clay tiles jammed into position with mortar packing. The purpose of the Paper was to present a reasonably practical and rational method for the design of infilled frames, taking into account the significant factors.

71. The Authors also have investigated the effect of bonding the infill to the frame but have concluded that as a practical proposition it is inconvenient and structurally of doubtful benefit. Admittedly, by increasing the length of contact it provides greater stiffness than is given by the non-bonded condition; however, it has little influence on the strength of the most probable modes of infill failure, i.e. by diagonal cracking or, in brickwork, by shearing at the centre of the panel; this is

Fig. 13. Load/deflexion curves of square infilled frame with connectors

readily appreciated from St Venant's principle. Indeed, in brickwork panels, the use of strip connectors penetrating the horizontal joints is likely to result in separation of the courses when the frame tends to distort under lateral load.

72. The design curves for brickwork are used to show the most probable mode of failure for which an adequate load factor against collapse of the structure must be ensured. Dr Mallick's comment that the corner compressive mode of failure occurs suddenly and without warning is not really relevant to the design process nor, from the Authors' experience, accurate. Their laboratory experiments have shown that under slow loading conditions, this mode of failure is invariably preceded by rapidly increasing deflexions with the essential characteristics of a plastic, rather than brittle, failure. Further, after failure, the strength has not reduced to that of the bare frame but has been maintained, over very large deflexions, within the region of 50–80% of the ultimate load.

References

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