EFFECT OF STIFFENERS ON THE LATERAL STIFFNESS OF INFILL FRAMES WITH OPENINGS

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Abstract

Unreinforced masonry infill has long been known to effect the strength and stiffness of frame. Under the action of lateral load the principal compressive diagonal acts as a strut and increases the initial lateral stiffness of the framed structure. However, in the presence of openings in walls, which is more practical, the behavior of infill changes. Therefore to compensate the effect of openings, stiffeners are provided. The primary objective of this paper is to study the effect of stiffeners on the lateral stiffness of infilled frames with openings. In the study investigation is made on different types of stiffeners. Infilled frames are stiffened by stiffener around the opening and analyzed using ANSYS. From the results obtained, it is observed that stiffness offered by infilled frame increases with an increase in the thickness of stiffener band.

Keywords: *Infilled frame, Initial lateral stiffness, Masonry infills, Stiffener, Lintel Band.*

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1. INTRODUCTION

Masonry infills are most commonly used in buildings for functional and architectural reasons. However their structural contribution is usually neglected in the design process. The difficulties in considering infill walls in the design process are due to the lack of conclusive experimental and analytical results about the behavior under lateral seismic loading. Moreover behavior of infill frame depends upon numerous parameters and there is high degree of uncertainties associated with these parameters.

Research work in the recent past have reported the advantages of infilled frame with infill masonry as they not only serve as partition component but also provides structural resistance to lateral deformation which are likely to occur due to earthquake and high velocity wind. Structural contribution of infill walls cannot simply be neglected particularly in the regions of moderate and high seismicity where the frame-infill interaction may cause substantial increase in both stiffness and strength of frame in spite of presence of openings.

The stiffness offered by infilled masonry is reduced due to provision of openings in the form of doors and windows which are inevitable. Therefore, considerable attention must be paid to the presence of openings and their positions. However, both strength and stiffness of the infill frames with openings are not taken care by most of the codes like IS 1893: 2002[1]. Hence, the behavior of infilled frame with openings needs be studied extensively in order to develop a rational approach or guidelines for design.

Strength and stiffness of infill frame is further depending upon on the modulus of elasticity of masonry. The behavior of infilled frames is understood by studying the possible failure modes of infilled frames.

2. THE METHOD OF ANALYSIS

Significant amount of work has been carried out since 1950's and these studies have come out with several analytical methods to model the infill frame. For modeling of infill Frames, the models can be conveniently classified in to two types known as macro and micro models are discussed below.

2.1 Macro Models

The basic characteristic of the macro models is that they aim at predicting the overall lateral stiffness and failure loads of Infilled Frames, without considering all possible failure modes of local failure. This group of models can be subdivided based on the concept of the equivalent diagonal strut and the concept of the equivalent frame.

2.2 Micro Models

The development of finite element methods offered some relief to the shortcomings pointed out in the previous methods. The first approach to analyze the Infilled Frames by linear finite element analysis was suggested by Mallick and Severn [8]. They introduced an iterative technique taking into account of separation and slip at the structural interface. Plane stress rectangular elements were used to model the infill while standard beam elements were used for the frame. However, as a consequence of the assumption that the interaction forces between the frame and the infill along their interface consisted of normal forces only, the axial deformation of the columns was neglected in their formulation. The effect of slip and interface friction was considered by introducing shear forces along the length of contact. The contact problem was solved by initially assuming that infill and frame nodes have the same displacement. Having determined the load along the periphery of the infill, tensile forces were located in the model. Subsequently the corresponding nodes of the frame and infill were released which allowed them to displace independently in the next iteration. This procedure was repeated until a prescribed convergence criterion was achieved.

2.3 Finite Element Model

The analysis is carried out using ANSYS version 10.0. A 3-D elastic beam4 element is used to model the frame elements. The masonry infill wall is modeled using a 4-noded plane stress element, Plane42. Finally the interface between the frame and masonry infill is modeled by using tension compression only link element, Link8.

2.4 Procedure for Analysis

The analysis procedure can be summarized in the following steps:

- Modeling of frame infill and the interface using the above mentioned elements.
- Assigning corresponding properties to the elements.
- Applying the load and assigning the constraints.
- Solving the problem.

2.5 Input Parameters

The model used by Choubey 1990 [10] in structural engineering laboratory at Indian Institute of Technology, Delhi. Masonry infill had the size of 1170× 1770× 110 and outer dimension of specimen was 2000×2000. Material properties are presented in table 1. Strength, stiffness, ductility, separation between infill and frame were discussed. At the lateral load of 16.43 kN, initial stiffness of specimen was 25.4 kN/mm. The specimen failed due to formation of diagonal cracks originating from the loaded corner of infill that spread diagonally. Extensive cracks at the beam-column junction and shear cracks at interface between bricks and mortar were also observed. Fig. 1 shows the geometry and failure mode of specimen.

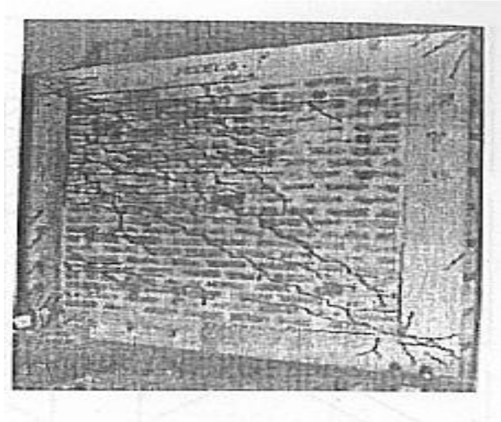

Fig. 1 Failure mode of Specimen (Choubey, 1990[10])

Table 1: Properties of validation model

Section	Cross section mm×mm	Center line length mm	Compressive strength Mpa	Modulus of Elasticity Mpa
Beam	230X150	2000	40.01	31620
Column	230X150	2000	40.01	31620
Base	230X150	2000	40.01	31620
Infill	1770X110	1770	6.24	3432

3. ANALYTICAL INVESTIGATION

The above reinforced concrete infill frame was analyzed.

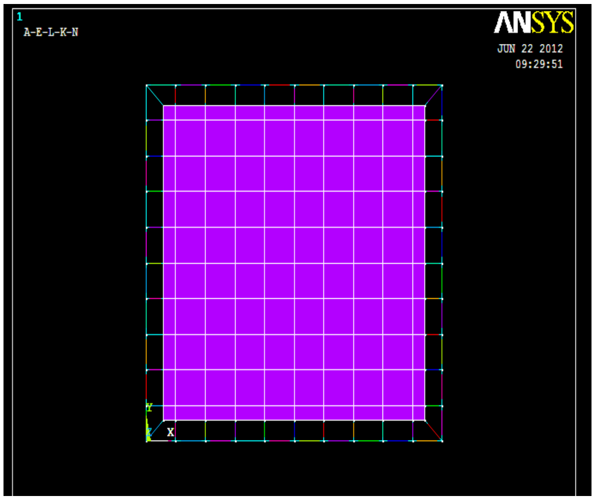

Fig. 2: Validation model before mesh

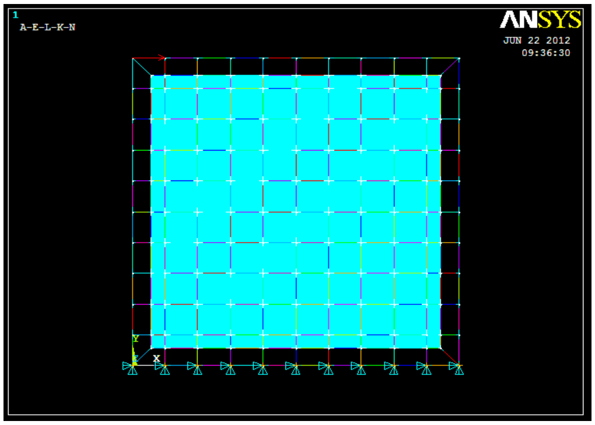

Fig. 3: Validation model after mesh

Table 2: Comparison of F.E model and Experimental model

Model	Load kN	Displacement (ANSYS) mm	Expt. Result Stiffness kN/mm	Ansys result Stiffness kN/mm	%Error
Single bay, single storey, infilled frame	16.43	0.631	25.4	26.03	2.48

3.1 Effects of Openings on Infilled Frames

The openings in the form of doors and windows are inevitable, which leads to reduction in the stiffness of structure. In order to compensate the reduced stiffness, frames are stiffened by additional members which increases the stiffness of the infilled frames called stiffeners.

Different type of stiffeners have been proposed by earlier researchers are (a) window opening without stiffener, (b) lintel, (c) lintel and sill, (d) lintel band, (f) stiffener frame around the opening, (g)stiffener frame horizontally extended, (h) stiffener frame vertically extended, (i) stiffener fame all side extended are shown in the fig 4. Assemblies with openings in infill stiffened by Reinforced Concrete Stiffeners are shown in fig. 4 (Polyakov [5]). The stiffness of infill frame is influenced by the stiffener adopted. Hence in the present study effect of stiffener frame around the opening and lintel band type of stiffener on the lateral stiffness of infill frame has been studied and their comparative studies are reported.

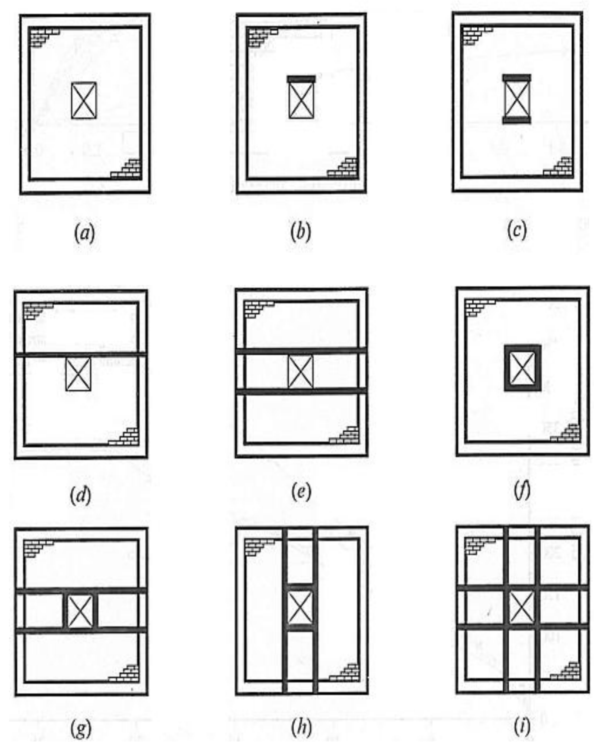

Fig. 4: Different types of stiffeners (Polyakov [5]).

In the present study, the stiffener around the opening has been provided in the masonry having central opening of 500mm×500mm. To study the effect of varying thickness of stiffener on the infill frame, the thickness of stiffener varied from No stiffener (NS), 85mm, 95mm, 105mm and 150mm. The properties considered for the parametric study are tabulated below i.e. Table 3.

Table 3: Geometric and material properties

Element	Cross section mm	Centre line length mm	Modulus of elasticity MPa	Poisons ratio
Beam	250x400	5400	12.5	0.2
Column	400x400	3400	17.5	0.2
Lintel (stiffener)	t=250	5400	12.5	0.2
Masonry	3000x250	5000	2.5	0.18
Link	250x400	-	17.5	0.2

Observations on Effect of Thickness of Stiffener

The following observations are made on the effect of thickness of stiffener:

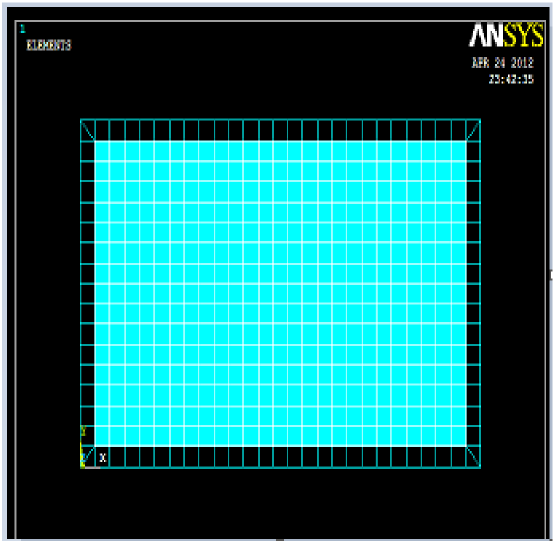

Fig. 5: FE model of solid frame

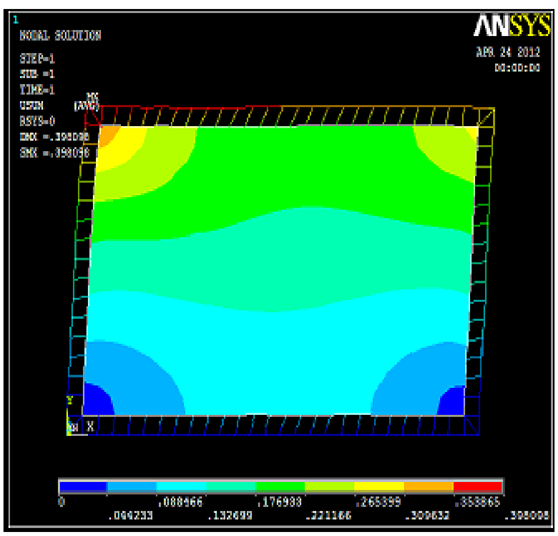

Fig. 6: FE analysis using ANSYS

Observations on Lateral Stiffness of Infill Frame with Openings and with no Stiffener

To determine the lateral stiffness of infill frames with opening, infill frames are modeled with no stiffener to compare with the frames stiffened by Lintel band. In the present study openings are provided in such a way that height of opening (ho) kept constant for one value and width of opening (Wo) is varied for particular set of models.

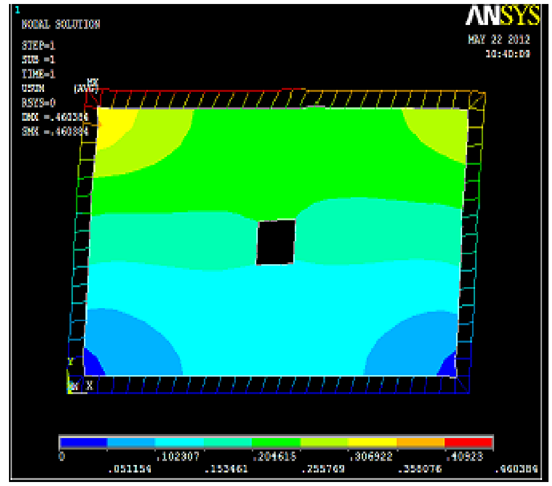

Fig. 7: Model with 500X500mm opening

Observations on Lateral Stiffness of Infill Frame with Openings and with Varying Thickness of Stiffener (LB)

To determine the lateral stiffness of infill frames with opening, infill frames are stiffened by 100mm, 125mm and 150mm stiffener. Stiffened models are compared with unstiffened models.

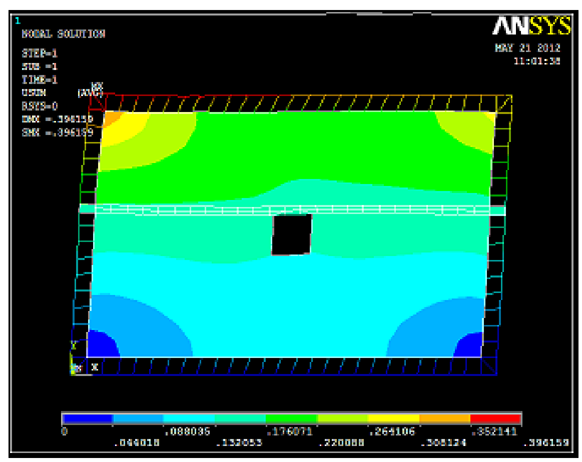

Fig. 8: 100mm LB stiffened model with opening of 500X500mm

Comparative results of infill frames with opening and without Lintel band (LB) and infill frames with varying thickness of Lintel bands are shown in the figures of 9 to 13. Where, 'W' is the width of infill frame, 'Wo' is the width of opening. 'H' is the height of infill frame and 'ho' is the height of opening.

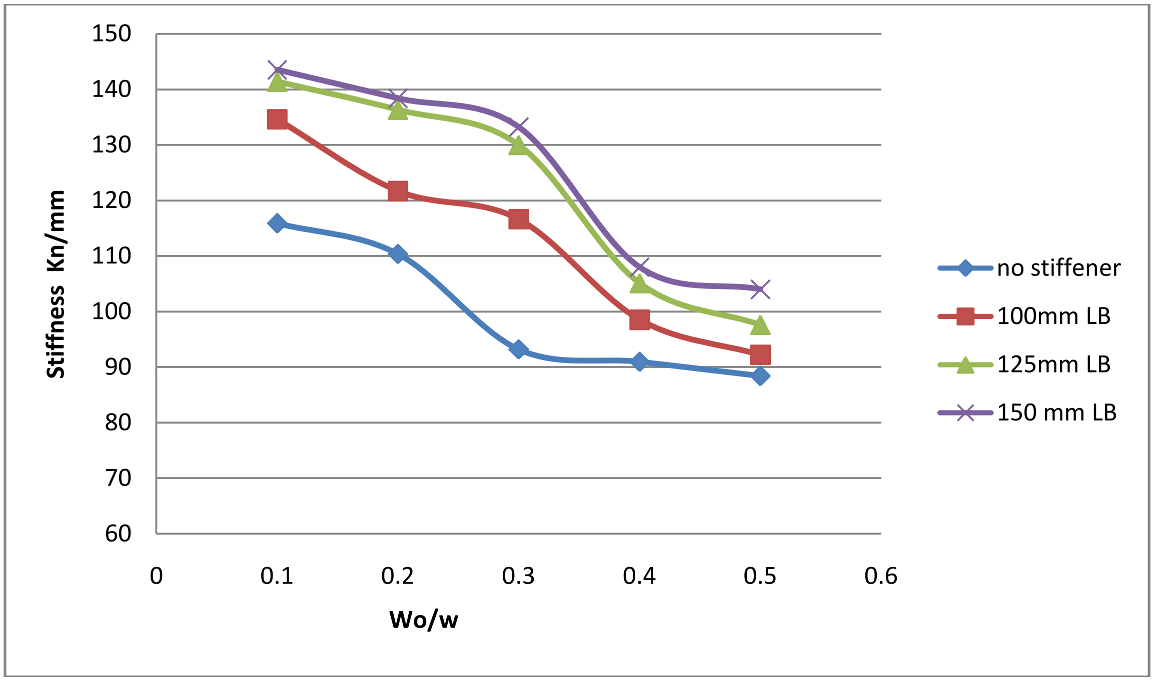

Fig. 9: Comparision of infilled frames stiffened by varying thickness of LB and having ho/H=0.16.

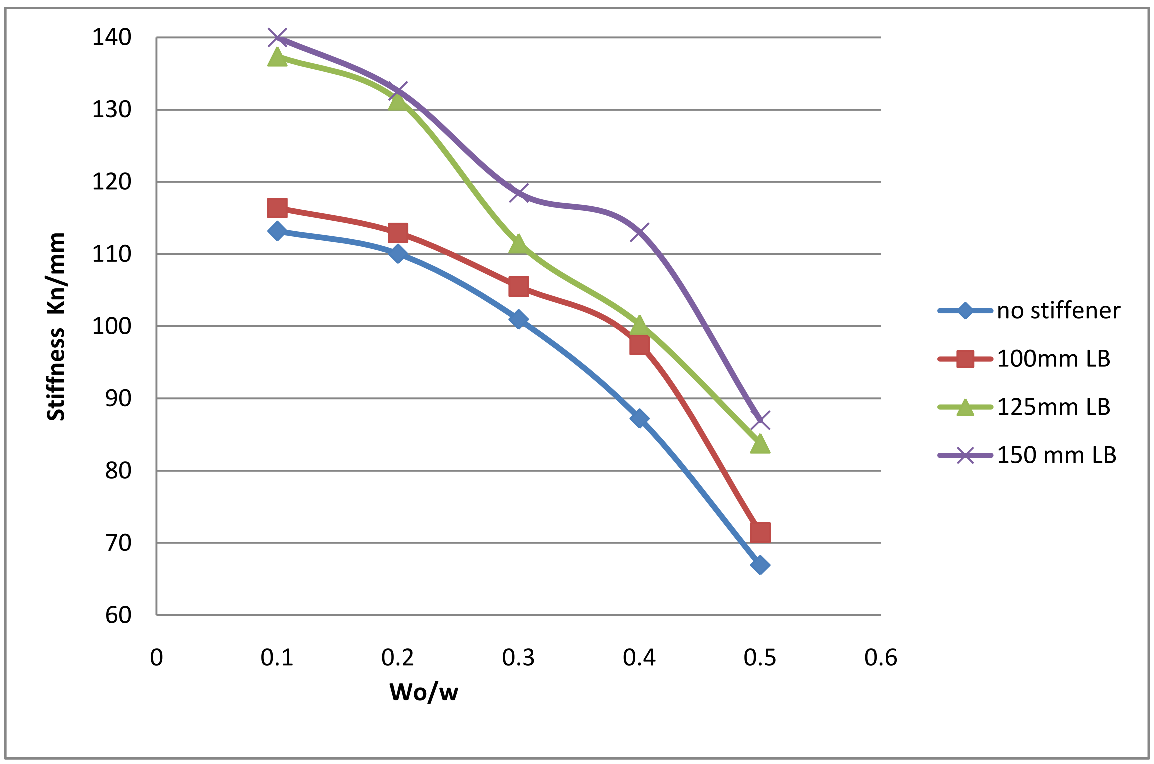

Fig. 10: Comparision of infilled frames stiffened by varying thickness of LB and having ho/H=0.33

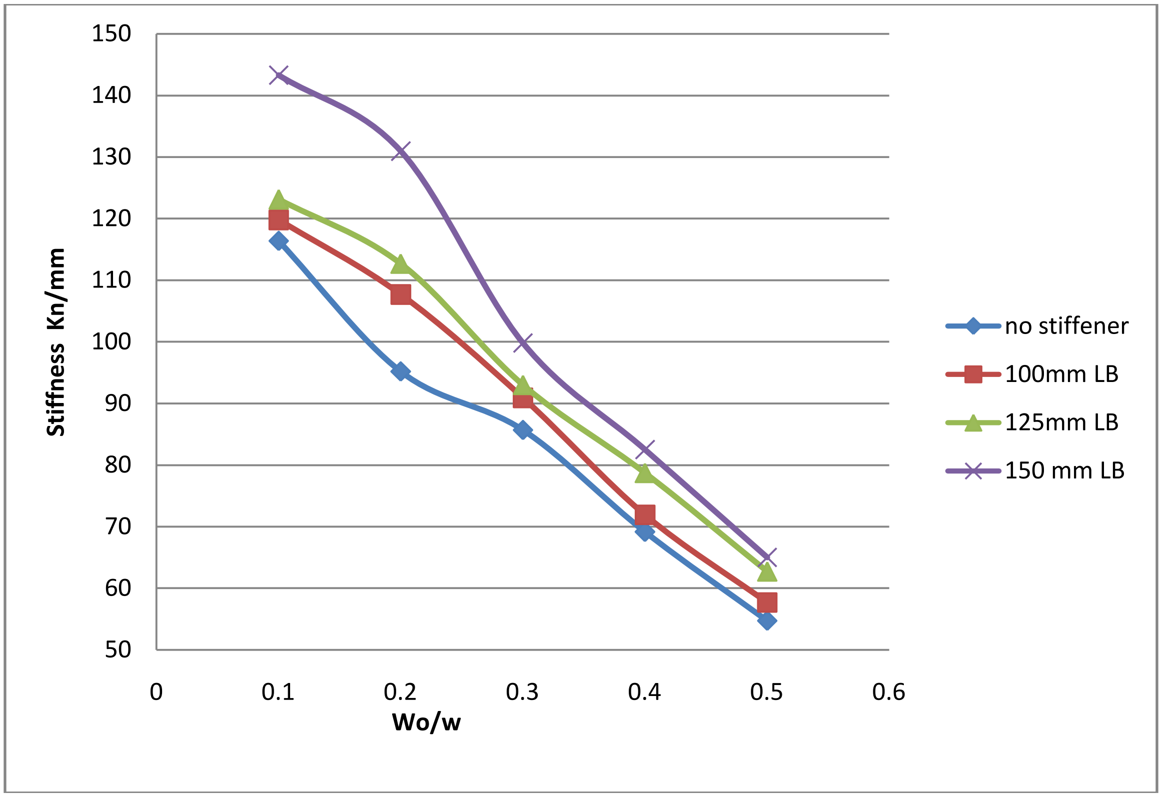

Fig. 11: Comparision of infilled frames stiffened by varying thickness of LB and having ho/H=0.5

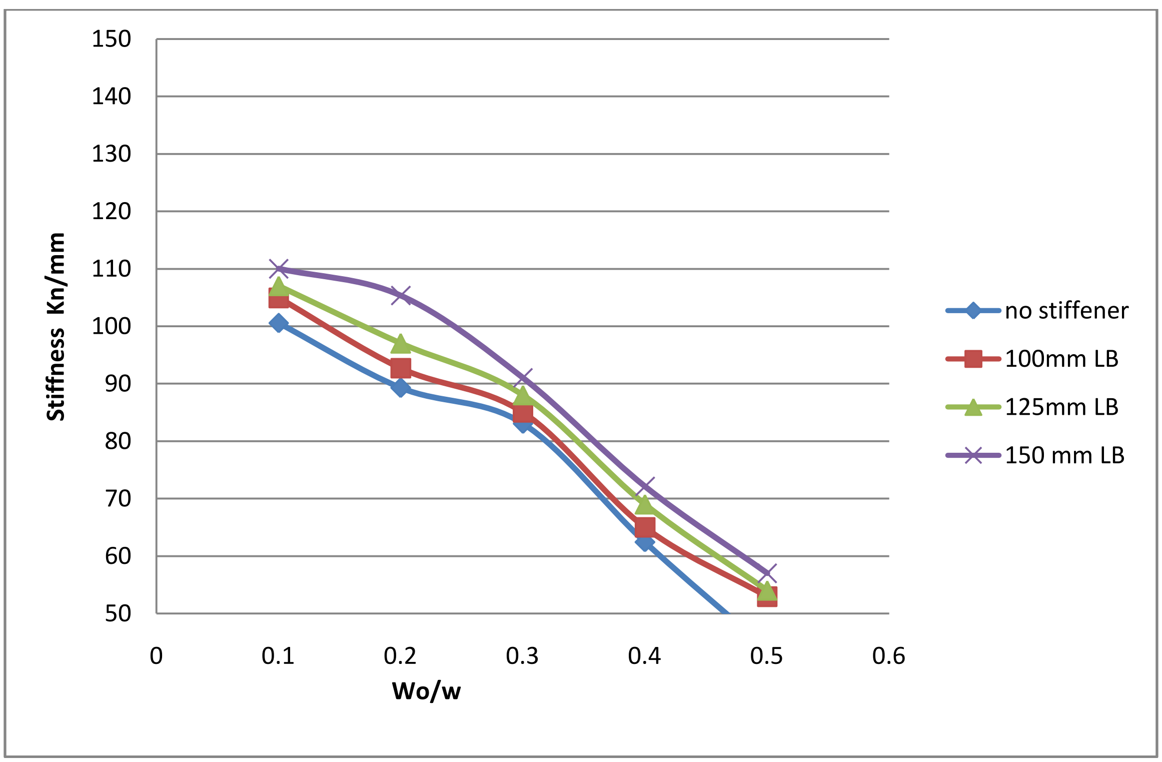

Fig. 12: Comparision of infilled frames stiffened by varying thickness of LB and having ho/H=0.67

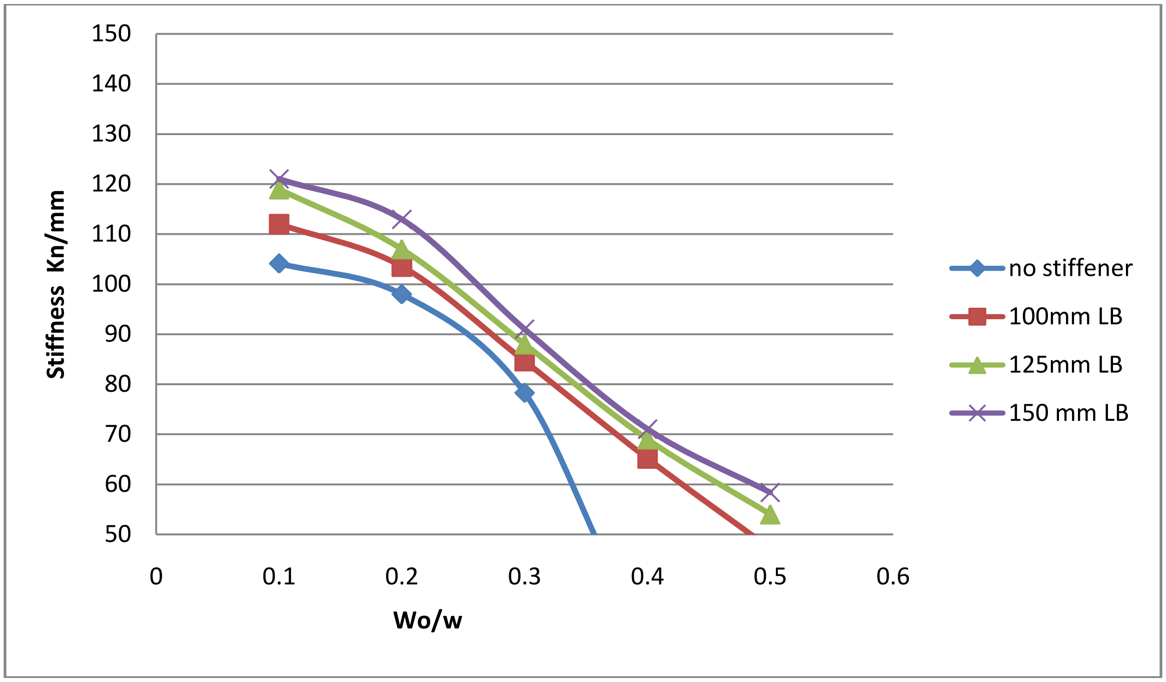

Fig. 13: Comparision of infilled frames stiffened by varying thickness of LB and having ho/H=0.83

4. CONCLUSIONS

- The presence of stiffeners in the infilled frame increases the lateral stiffness offered by the masonry and compensate the reduced stiffness due to opening.
- From the results of parametric study it is observed that as there is an increase in the area of opening, stiffness offered by the infill reduces.
- In the present study, provision of stiffeners such as Stiffener around the opening and Lintel band stiffener have shown significant increase in the stiffness of infilled frame which compensate the reduced stiffness due to opening.
- From the comparison of stiffeners used in the study, Lintel Band has performed significantly than the stiffener around the opening.
- From the results it is observed that, some of the models stiffened by LB have shown an increase in the stiffness and stiffness is greater than the stiffness offered by solid infill frame.

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