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A NEW METHOD OF ANALYSIS FOR MASONRY INFILLED FRAMES

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ABSTRACT:

This paper presents a new finite element technique for the analysis of brickwork infilled plane frames subjected to lateral actions. The basic characteristic of this new method of analysis is that the infill/frame contact lengths and the contact stresses are estimated as an integral part of the solution, and are not assumed in an ad-hoc way. In order to implement the method, a specific computer program for a 2D linear elastic analysis of infilled plane frames under lateral static loads has been developed. The validity of the method is demonstrated by comparing the results from the study of an one-story one-bay infilled frame under lateral static load in the beam level, against results derived by other investigators.

1. Introduction

In many countries situated in seismic regions, reinforced concrete frames are infilled by brick masonry panels. Although the infill panels significantly enhance both the stiffness and strength of the frame, their contribution is often not considered because of the lack of knowledge of the composite behavior of the frame and the infill. However, extensive experimental (Smith [1]; Smith et al.[2]; Page et al. [3]; Mehrabi et al. [4]), and analytical investigations (Liauw and Kwan [5], [6], [7]; Dhanasekar and Page [8]; Saneinejad and Hobbs [9]; Mehrabi and Shing [10]; Asteris [11], [12]) have been made. Extensive and in-depth state-of-the-art reports can be found in Tassios [13], Moghaddam et al. [14] and CEB [15].

Although infilled frames have been studied for many years, this structural system has resisted analytical modelling; the following reasons may explain this situation:

- Computational complexity: The particulated infill material and the ever changing contact conditions along its interface to concrete, constitute additional sources of analytical burden. The real composite behavior of an in-filled frame is a complex statically indeterminate problem according to Smith [[1].
- Structural uncertainties: The mechanical properties of masonry, as well as its wedging conditions against the internal surface of the frame, depend strongly on local construction conditions.
- The non-linear behaviour of infilled frames depend on the separation of masonry infill panel from the surrounding frame.

In the present paper, in order to model the complicated behavior of the in-filled plane frames under lateral load similar to an earthquake load, a criterion for the frame-infill separation is used. The main goal of this criterion is to describe the evolution of the natural response of these composite structures subjected to seismic lateral loads as a boundary condition problem.

2. Proposed method of analysis

To overcome the problem of the ever-changing contact conditions between the brick masonry infill and the surrounding frame, a new finite element technique for the modelling of infilled frames has been recently proposed by Asteris [11], [12]. According to this in order to model the complicated behavior of the in-filled plane frames under lateral load similar to an earthquake load, a criterion for the frame-infill separation is used. The main goal of this criterion is to describe the evolution of the natural response of these composite structures subjected to seismic lateral loads as a boundary condition problem. The objective of the present study is to find a valid geometrical equilibrium condition for the composite structure of the in-filled frame under certain loading conditions, given that the real overall behavior of an in-filled frame is a complex statically indeterminate problem according to Smith [1]. The analysis has been performed on a step-by-step basis based on the following:

- The major "physical" boundary condition between infill and frame is that the infill panel cannot get into the surrounding frame; the only accepted "natural" conditions between infill and frame are either the contact or the separation.
- The frame, while directly carrying some of the lateral loads, serves primarily to transfer and distribute the bulk of the loads to the infill. The stiffness response of the infill is influenced, to a considerable extent, by the way in which the frame distributes the load to it. Simultaneously, the frame's contribution to the overall stiffness is affected by the change in its mode of distortion, as a result of the reaction of the infill.

The proposed finite element procedure can be summarised as follows:

Step 1. Initially, the infill finite element models are considered to be linked to the surrounding frame finite element models at two corner points (only), at the ends of the compressed diagonal of the infill. (When the load is applied, the infill and the frame are getting separate over a large part of the length of each side and contact remains only adjacent to the corners at the ends of the compression diagonal).

Step 2. Compute the nodal forces and displacements, and the stresses at the Gauss points of the elements.

Step 3. Check whether the infill model points overlap the surrounding frame finite elements. If the answer is negative, step 5 of the procedure will be followed. If the answer is positive, step 4 will, instead, be followed.

Step 4. When the infill model points overlap the surrounding frame finite elements, the neighbouring points (to the previous linked) are linked and the procedure continues from step 2.

Step 5. This final step is a further check on the acceptance (or not) of the derived deformed mesh. This check will determine if at any one point of the derived contact area tension is occurring. In particular, what is checked is whether the normal stresses along to x-axis (for the linked points on vertical part of the interface) and along the y-axis (for the linked points on horizontal part of the interface) are tensile. If the answer is negative, the procedure is stopped. If the answer is positive, the linked points become unlinked and the procedure continues from step 2.

3. Application

In the example presented, the proposed finite element technique has been applied. The response of an one-story one-bay infilled frame (Fig. 1) under a lateral static load in the beam level is studied. The frame is constructed with reinforced concrete 30/40 cm sections for both columns and beams. The mechanical characteristics for both the reinforced concrete and the infill masonry walls are the ones shown on Table 1.

Fig. 2 shows the successive deformed meshes of the studied one-story one-bay infilled frame generated by the proposed method of contact points. In particular, Fig. 2a depicts the deformed mesh based on the assumption that infill and frame are linked only at the two points A and B. According to this deformed mesh, two neighbouring points of B and one neighbouring point of A of the infill model points overlap the surrounding frame finite elements. Thus, according to the fourth step, these three neighbouring points (to the previous linked) are linked and the procedure continues. The process is iterated (Figs. 2b to 2h), until a final equilibrium condition is reached (Fig. 2h).

According to the derived deformed mesh (Fig. 2h), different contact lengths between infill wall and surrounding frame members are observed, as is expected. In particular, the infill/frame contact lengths are varied between windward column and infill, beam and infill, and between infill and rigid base, thus demonstrating how unrealistic and inadequate is the modelling of the infill panel by a number of parallel compression inclined struts.

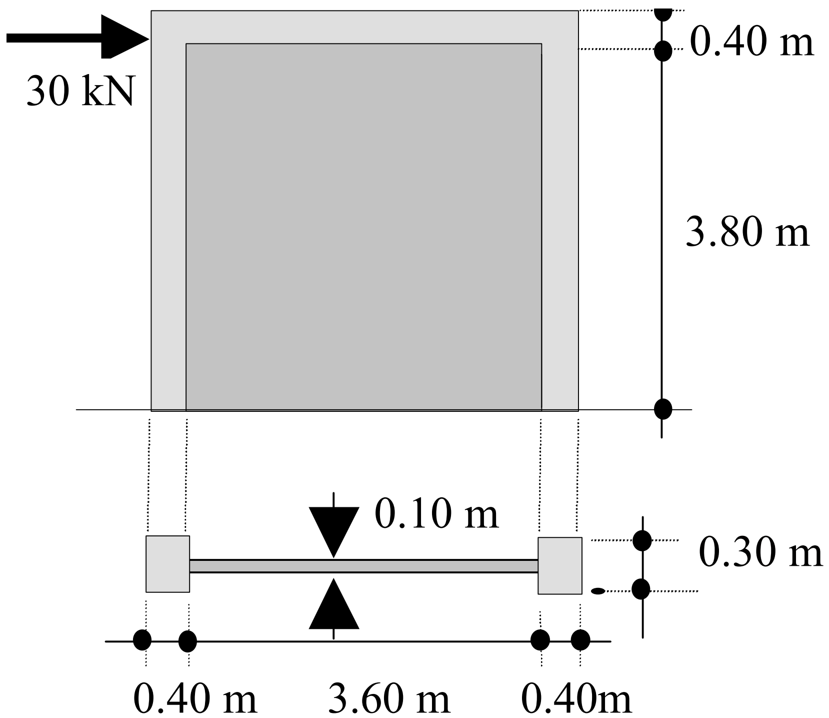

Fig. 1 Geometry and loading of an one-story one-bay brick masonry infilled frame

Table 1 Materials elastic properties

Material	Moduli of elasticity		Poison's ratios	
	E_x (kN/m^2)	E_y (kN/m^2)	ν_{xy}	ν_{yx}
(1)	(2)	(3)	(4)	(5)
Concrete	2.9×10^7	2.9×10^7	0.20	0.20
Masonry*	4.5×10^6	7.5×10^6	0.19	0.32**

* The values of this masonry material have been estimated experimentally by Page [16].

** $\nu_{yx} = \frac{E_y}{E_x}\nu_{xy}$.

In Figs. 3 to 5, the contours of normal and shear stresses are plotted respectively. They seem to be in good agreement with previous experimental (Smith [1]) and analytical results (Galanti, Scarpas and Vrouwenvelder, [17]). As is expected, the higher values of stresses are spread in a zone "parallel" to the compression diagonal as well as at the loaded corners. This could explain the two modes of infill failure, which were observed experimentally by Smith [1]. According to Smith, two modes of infill failure are observed. The first failure, developed as a crack extending from the center of the infill along the diagonal towards the loaded corners. The second failure mode occurs at one of the loaded corners, and the crushed region takes the shape of a quadrant bounded by the lengths of the contact as radii.

4. Conclusions

In the present paper, a new finite element technique is presented for the analysis of brick masonry infilled plane frames. Using this technique, the behavior of single-story one-bay infilled frames under lateral has been investigated. The main advantages of the method can be summarized as follows:

- The ability to calculate the infill/frame contact lengths as an integral part of the solution and not assumed in an ad-hoc way.
- The capability to model the behavior of infilled frames both in the case of single-story and in the case of multi-storey fully or partially infilled.

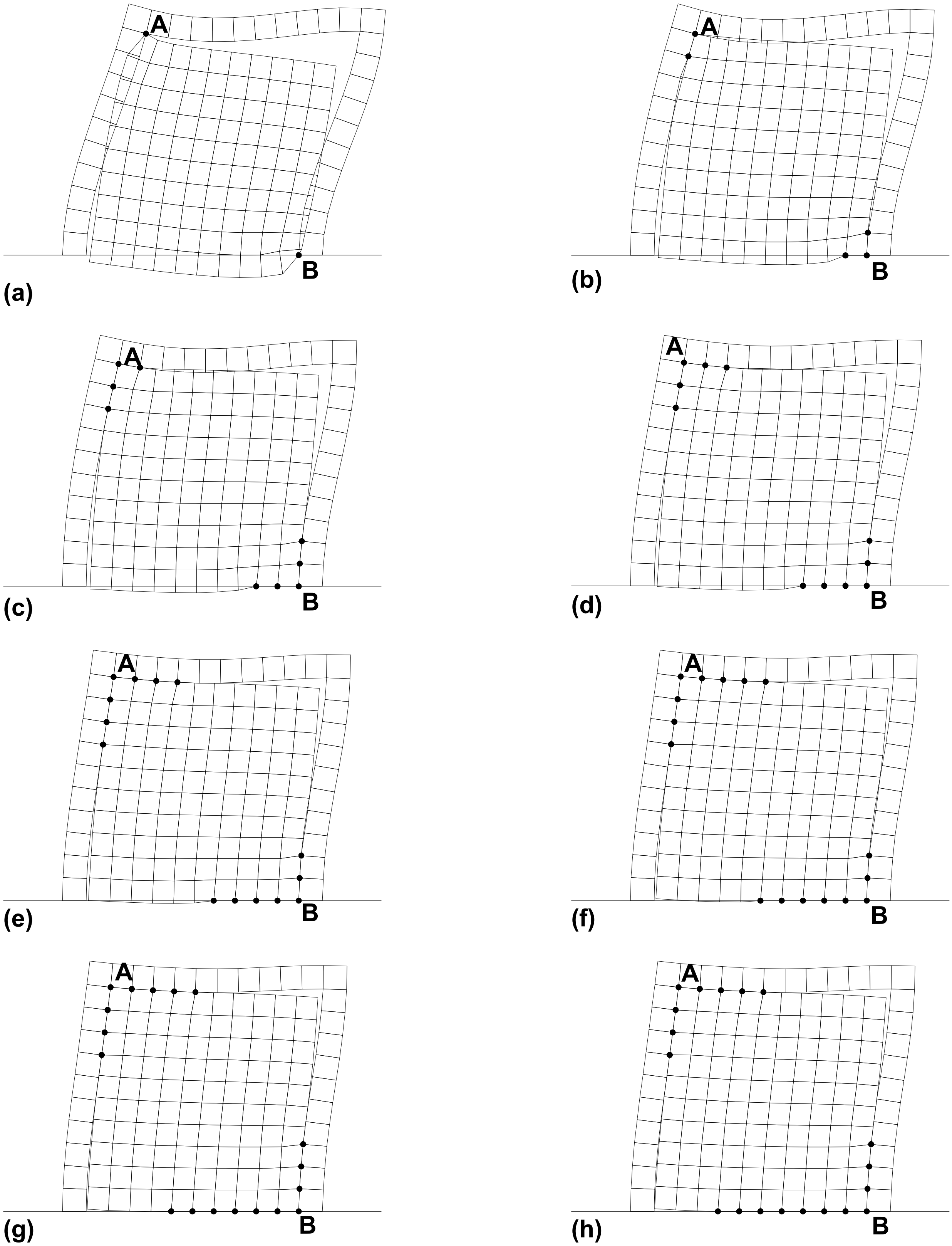

Fig. 2 Successive deformed meshes of an one-story one-bay infilled frame using the Method of Contact Points

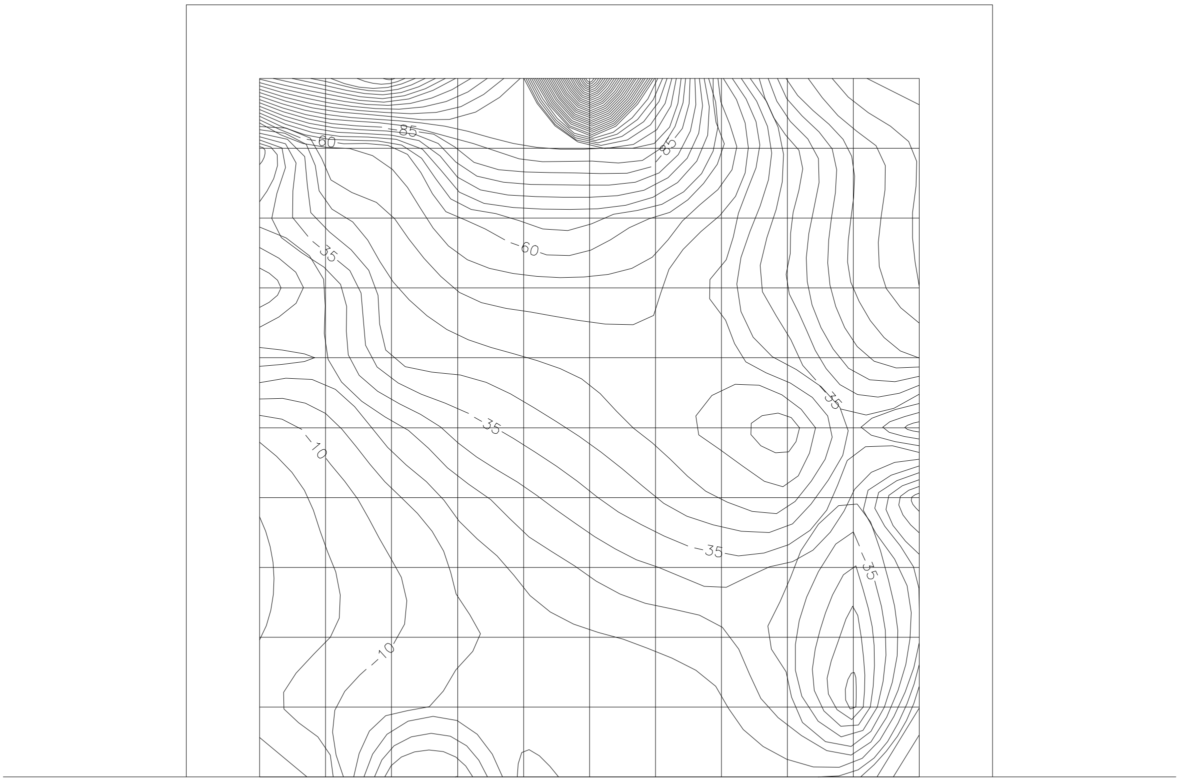

Fig. 3 Contours of normal stress σ_{xx} *in the brick masonry infill plane*

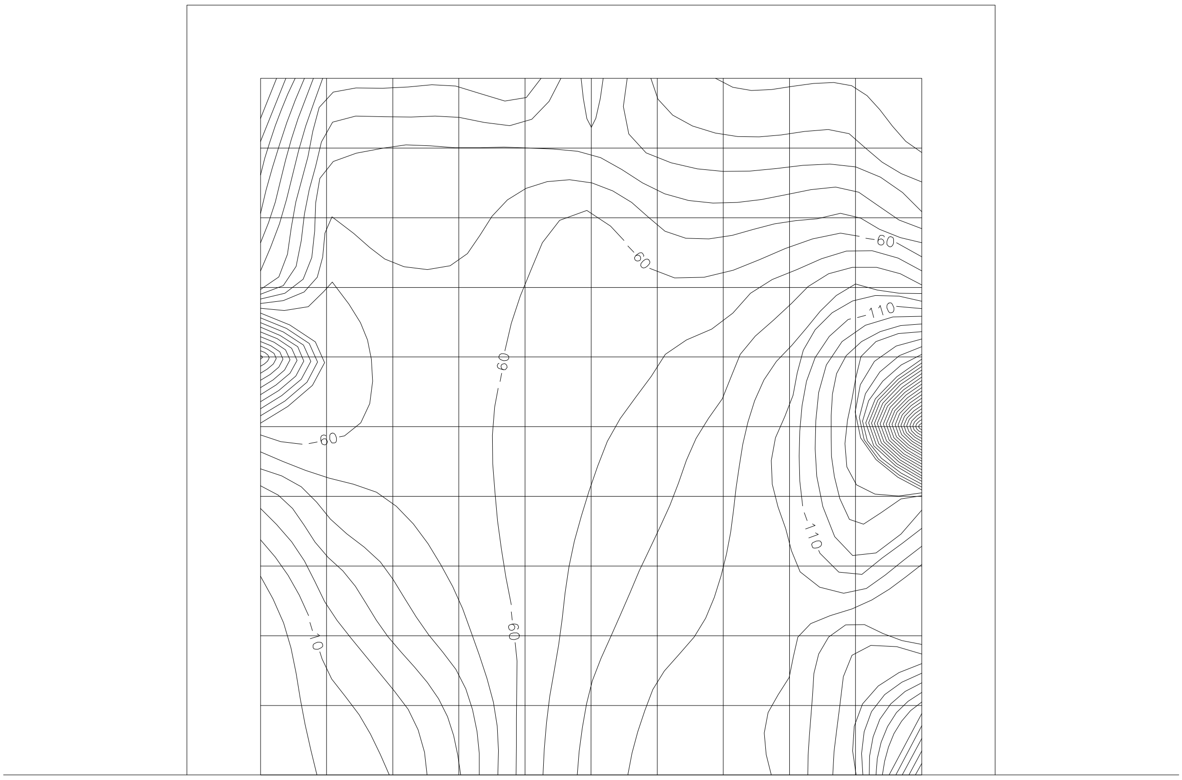

Fig. 4 Contours of normal stress σ_{yy} *in the brick masonry infill plane*

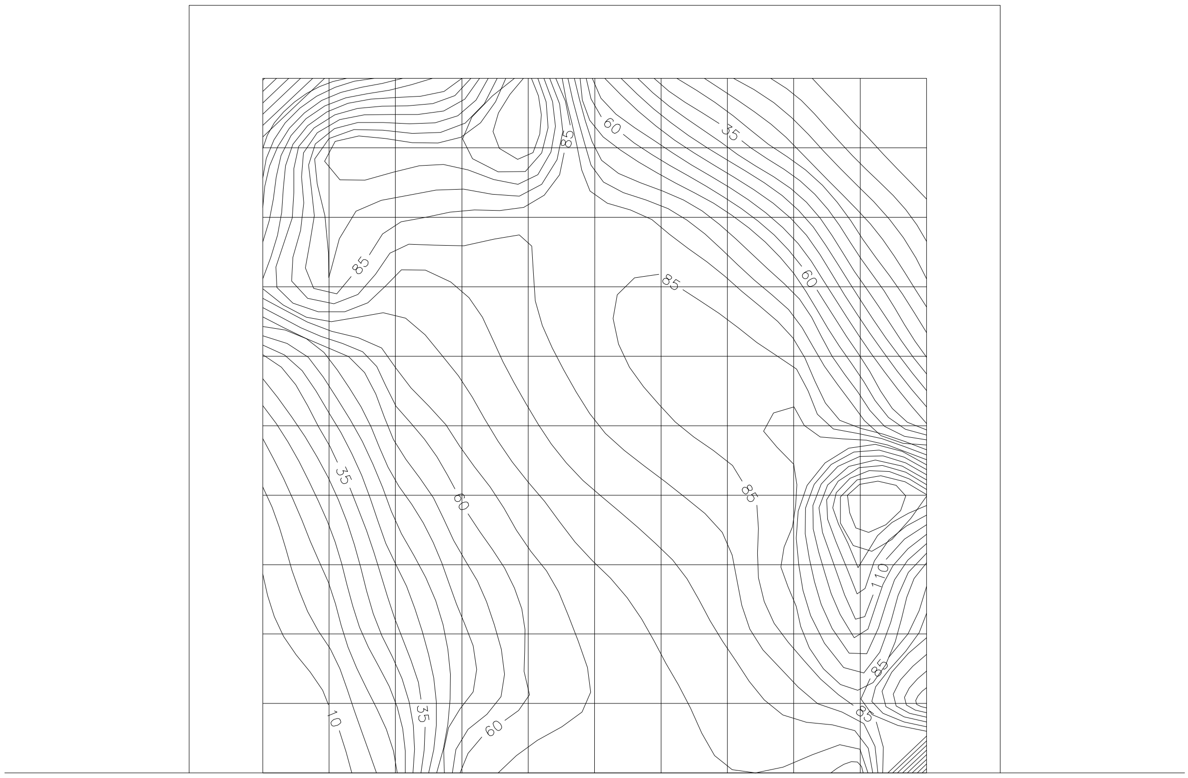

Fig. 5 Contours of shear stress s_{xy} in the brick masonry infill plane

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