Experimental Analysis of Mechanical Behavior of Lintels with Murfor® Reinforcement in Structural Masonry

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Abstract: The main goal of this study is analysis the mechanical behavior, failure mode and deflections of masonry beams lintels when subjected to concentrated loading. Walls were built using hollow clay blocks, using horizontal reinforcement on bed joint, and using of Murfor® steel reinforcement. The conclusions of this work was: at middle of span, the load and displacement results present a linear behavior until failure; there two regions of failure, the region “A” presents the association of crushing and the region “B” shows the shear stress between block and mortar; the visual analysis of experimental tests shows the lost of adhesion between the mortar joint and blocks. It was not observed cracks on the mid-span produced by bending; it is possible to detach that the use of plane truss in Brazil as technological alternative is feasible and makes the masonry walls execution more rational, increasing the velocity of production.

Key words: Structural masonry, clay block, lintel, Murfor® reinforcement masonry.

1. Introduction

Nowadays, the structural masonry building has gained space in the Brazilian market, due to its easy implementation, faster construction and economically feasible. According to Lima [1], currently over of 80% of all buildings are constructed using the structural masonry technique. Because of this, it has been necessary to improve the knowledge on the mechanical properties of masonry and determine its efficiency when part of the structure. The masonry building systems have used the walls as support and a small level of tensile stress is allowed, mainly in openings due to the lintels. Where there are lack of studies on the performance of non-traditional lintels. The main goal of this research is to evaluate the mechanical behavior of hollow clay block masonry beams with horizontal reinforcement truss, with or without vertical stirrups, being one technical option for improving productivity on block masonry building.

2. Definition and Applications of Reinforcement® Murfor

The Brazilian standard NBR 15812-1 [2] defines a lintel as a beam under an opening, which has the role of transmitting vertical loads to the adjacent walls. Mamede [3] states that the lintels are essential structural elements in buildings, because they prevent the appearance of undesirable pathological manifestations, such as tensile cracks at the corners of the opening. Normally, the lintels are executed in reinforced concrete or precast, as depicted in Fig. 1.

Gouveia [4], Lourenço [5] and Pfeiffermann [6] have reported that the use of plane truss reinforcement (Murfor®) is quite common in Europe for long, high and seismic masonry walls. The purpose of this product is to provide a better structural performance of masonry when subjected to shear and tensile stresses. However, in Brazil, has been little research related to this type of reinforcement and it is necessary to analyze the mechanical behavior of reinforced lintels with Murfor® in the horizontal mortar joint to check the failure mode and the strength capacity of the samples

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Fig. 1 Reinforced concrete and precast lintels.

for masonry structures built in Brazil.

Lourenço [5] has commented technical aspects of the building stadium in Portugal (Sporting Club of Portugal), which masonry walls had more than 10 m long and 4 m high, reinforced with Murfor® on the bedding mortar joint. For the authors, the introduction of plane truss reinforcement on the bedding mortar joint does not lead to a change on the behavior of the masonry buildings, but avoids the development of the pathologies. It has also mentioned that other advantages in use Murfor® reinforcement are to execute lintels with block U and columns on reinforced concrete to increase the stiffness of the masonry walls. Fig. 2 shows examples using the truss joint reinforcement (Murfor®).

Timperman [7] has reported that steel reinforce in masonry in Europe has been employed in areas subject to earthquakes due to tensile stresses produced by horizontal displacement. The most commonly found on the market is Murfor®, which is inserted in the bedding mortar joint. Murfor® is a prefabricated reinforces which was introduced for the first time in Europe more than 35 years ago.

According to the manufacturer's specification, the truss joint reinforcement—Murfor®—is formed by two longitudinal steel galvanized wires, separated by the distance defined by a sinusoidal shape wire. To ensure good adhesion to the mortar, the steel wires have grooves and the tensile strength of the wires is 600 MPa.

The employment of truss reinforcement on the bedding joint helps to reduce the size of the cracks on masonry walls. Murfor® plane truss is recommended for using with the presence of concentrated loads, walls subjected to horizontal force such as earthquakes and wind; drying shrinkage, for avoiding the stress concentration around openings such as doors, windows and settlements in the foundation. Fig. 3 shows an example of using the plane truss reinforcement on bedding mortar joint for avoiding cracks around the opening.

Mamede [3] has performed theoretical simulations of masonry walls with openings and obtained the stress level for the lintel over openings. In the numerical simulation, it was adopted the following dimensions $3.60 \text{ m} \times 2.72 \text{ m} \times 0.14 \text{ m}$. The compressive strength of concrete block was $f_{bk} = 4.5 \text{ MPa}$, the elasticity modulus

Fig. 2 Plane truss reinforcement Murfor® by Lourenço [5].

Fig. 3 Application plane truss reinforcement around openings.

of masonry was 800 times of the compressive strength of block, equal to 3.6 GPa, the Poisson ratio was 0.20, the size of opening was 1.20 m $\times$ 1.20 m and the dead load was 34 kN/m (3,400 kgf/m). The Fig. 4 shows the numerical analysis of the stresses obtained in the directions X and Y .

Mamede [3] had used as reference the British code BS 5628-1 [8], which establishes the maximum permissible shear of 0.015 kN/cm² and the compression stress for masonry unreinforced of 0.036 kN/cm². From numerical results, it was possible to observe that the compressive stress was greater than the value adopted as a maximum permissible on the upper corners of the openings. The authors concluded that at the corner, for absorbing these stresses it is important the presence of the lintel and its length should extend beyond the opening.

3. Experimental Tests

The walls were built using hollow clay blocks with average size of 29 cm $\times$ 19 cm $\times$ 14 cm (length, height and width), evaluated according to the Brazilian

standard NBR 15270-2 [9]. Fig. 5 shows the dimensions and the geometries of the block. The mortar type used on experimental program was 1:0, 5:4 (cement: lime and sand), as recommended by BS 5628-part 1 [8]. The used plane truss reinforcement had 4 mm in diameter and 115 mm length.

In order to analyze the mechanical behavior of the lintels, five small walls were made with the following dimensions of 239 cm $\times$ 79 cm $\times$ 14 cm (length, height and width), using hollow clay blocks and plane truss reinforcement Murfor® on the bedding mortar joints (Fig. 6). Fig. 7 shows the construction of walls for testing.

Preliminary tests were done on materials and components and the results are presented in Table 1.

The walls were tested at an age of 28 days. The walls were subjected to a concentrated force, as it can be seen in Fig. 8. The velocity of loading application was 1.0 MPa/min, following the Brazilian standards recommendations of NBR 12142 [13]. The deflections were measured at middle of the span with an analogical clock model Mitutoyo with resolution of 0.01 mm. Table 2 presents the results of the experimental tests.

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Fig. 4 Numerical analysis results: horizontal and vertical stress (in kN/cm²).

Fig. 5 Block geometries.

Fig. 6 Details of the implementation of the wall.

Fig. 7 The constructions of the walls.

Table 1 Compressive strength of block, mortar, prism and plane truss.

	Compressive strength (MPa)	Standard reference
Block	Medium compressive strength: $f_{bm} = 10.0$ MPa	NBR 15270-3 [10]
	Characteristic compression strength: $f_{bk} = 7.14$ MPa	NBR 15270-3 [10]
Mortar	Medium compressive strength: $f_{am} = 7.12$ MPa	NBR 13279 [11]
Prism	Medium compressive strength: $f_{pm} = 4.23$ MPa	NBR 15812-2 [12]
Plane truss	Characteristic tensile strength: $f_{yk} = 600$ MPa	Manufacturer catalog

Fig. 8 Test setup of masonry walls.

Table 2 Ultimate load and maximum bending moment of walls.

Wall	Ultimate load (kN)	Maximum bending moment (kN-m)
Wall 01	32.5	10.97
Wall 02	22.0	7.42
Wall 03	20.0	6.75
Wall 04	21.0	7.09
Wall 05	19.0	6.41

Fig. 9 Load versus displacement results.

Fig. 10 Failure mode of walls.

Fig. 9 presents the load and the displacement results obtained in experimental tests, showing a linear behavior until near failure. The line 1 depicted in Fig. 9 identifies the beginning of cracking.

The visual failure mode results for walls are shown

in Figs. 10 and 11. All failures modes for lintels were very similar. It is possible to observe two regions of failure: the region “A” presents the association of crushing and the region “B” presents the shear between block and mortar. On the left side, it is possible to see

Fig. 11 Failure mode of walls.

the lost of adhesion between the mortar joint and blocks. It was not observed cracks on the middle of span.

4. Conclusions

Based on the experimental results, the following conclusions are drawn:

- At middle of span, the load and displacement results present a linear behavior until failure;
- There two regions of failure, the region “A” presents the association of crushing and the region “B” shows the shear stress between block and mortar;
- The visual analysis of experimental tests shows the loss of adhesion between the mortar joint and blocks, which was not observed cracks on the mid-span;
- It is possible to conclude that the use of plane truss in Brazil, as technological alternative, is feasible and makes the masonry walls execution more rational, increasing the velocity of production.

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