DEFORMABILITY OF HOLLOW CONCRETE BLOCKS AND PLATEN EFFECT ON AXIAL COMPRESSION TESTS

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SUMMARY

This paper presents a strain analysis of the face-shells and webs of hollow concrete blocks. It also discusses the platen effect on the strain distribution. Concrete blocks of three strength levels were tested and vertical strains were measured in four different regions. It was observed that the block geometry influences the strain values and the steel platen stiffness may induce non-uniform stress distribution. A summary of recommendations for platen geometry is presented, according to masonry codes and researchers. Numerical linear analyses indicate that the platen geometry may not be adequate despite being in accordance with the current technical recommendations.

INTRODUCTION

The current knowledge of masonry, in some countries, does not clearly establish a group of strength and deformation parameters and their respective weighting and safety coefficients for a Limit State analysis. It is necessary to go forward detailing the factors that are related to the material's properties, the unit production methods, the element tests, the construction procedures and quality control and the assemblage behaviour. To apply the concept of Limit States or other improved probabilistic methods, it is necessary to isolate and to have a better knowledge of each parameter that influences the structural behaviour at service and ultimate stages. However, there are a number of challenges to overcome, especially because many of these parameters are derived from tests and the test conditions are not unique. Block geometry is different from case to case, confinement effects in block and prism tests are variable, steel plate stiffness affects the stress distribution in the tests, etc. This paper presents a summary of recommendations to platen geometry and aims to identify the factors that induce a non uniform stress and strain distribution in block tests. The analyses are based on three strength level series of isolated block tests and on linear numerical analysis. The strain distribution is compared in both cases and the international standardization and recommendations are considered.

SUMMARY OF RECOMMENDATIONS ABOUT UNIT TEST

Platen tests are utilized to provide a uniform distribution of stress and strain in masonry units. According to Kleeman and Page 1990, the friction between units and platens induces to restriction of transversal deformability and causes a complex state of stress in the edges of the elements. Thus, there is an increase in strength due to the triaxial state of compression, unless the unit has sufficient dimensions to scatter this effect. If the force is applied only to the face-shells, the stress distribution is always non-uniform.

According to Atkinson 1991 the uniform distribution depends on both bending and shear of the platen. Therefore a minimum thickness is necessary to avoid higher deformations. The author presents several recommendations of American, Canadian and European standards that indicate the loading system diameter values between 127 and 152 mm and the minimum thickness of steel platen within 48 mm to 145 mm. Some of the values are specific for units or prisms.

Factor K is presented and its values in most codes are between 0.33 and 1. This is an appropriate factor, as it simultaneously evaluates the loading system diameter and the platen dimensions. Equation 1 defines factor K and its variables are depicted in Figure 1.

$$t = K (D - R) \qquad (1)$$

Render 1986 shows that the lowest thickness value of steel platen is equal to 75 mm to avoid the strains dissipating a portion of the load. According to the Brazilian Standard NBR 7184 1992, the surfaces of steel platen must be flat and rigid and can not present unevenness higher than 8×10^{-2} for each 4×10^{2} mm. The minimum thickness is defined to a third of the distance between the edge of the platen and the higher distance of the element. It can not be lower than 25 mm.

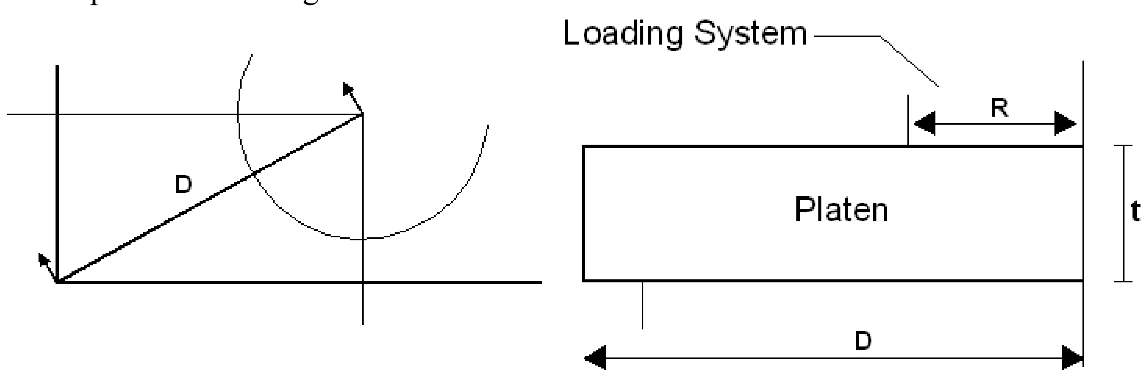


Figure 1. Variables related to factor K to determine the steel platen thickness, Atkinson 1991.

t: thickness of steel platen;

D: distance between the center of the circumference of the loading system to the corner of the platen;

R: Radius of the circumference of the loading system.

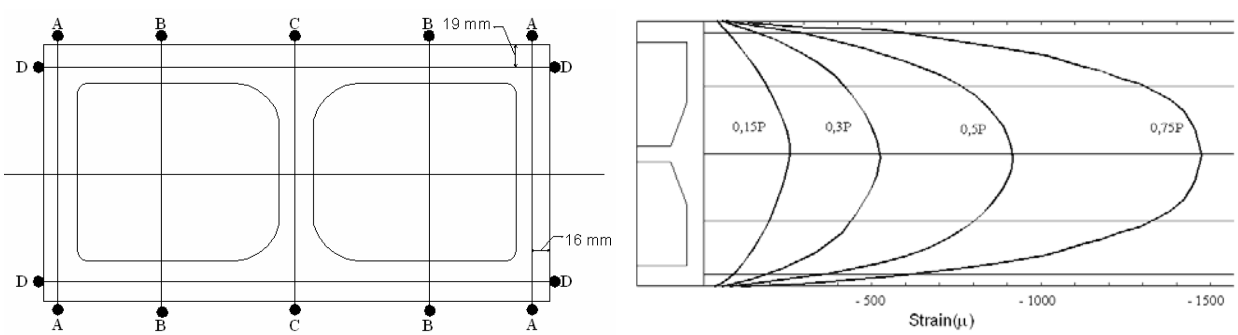
Self 1975 observed that the increase in the thickness of the platen from 25 mm to 83 mm induced a decrease in the face-shell strains, between the center and the edges, close to 50%. The increase in the loading system diameter from 216 mm to 254 mm induced an increase in the compressive strength between 7% and 13%.

By means of Finite Element analyses, Hamid and Chukwunenye 1986 observed differences between the lateral tensile stress when using platen thicknesses equal to 50 mm, 100 mm and 200 mm. The higher differences were found when compared the results of tests carried out with platen thicknesses equal 50 mm and 200 mm. The loading system diameter was 140 mm and three hollow blocks prisms (face-shell mortared and fully bedded mortared) were tested. The authors concluded that the higher flexibility of the 50 mm thickness platen induced different values of lateral tensile stress.

The deformability of blocks and masonry walls is an important property for masonry design. The elastic modulus and Poisson ratio are related to the masonry deformation and also to its failure mode.

There is no standard test to establish the elastic modulus value of the block and many times the prism test are utilized for this purpose. Some authors adopt the formulations of concrete technology to determine the elastic modulus of the block.

Becica and Harris 1983 measured in pre-defined regions the longitudinal strains of isolated hollow concrete blocks: near the edges, near the center of each hole and in the middle of the block length (Figure 2). It can be observed that for all force levels there are differences of strain values between edge points and the central point where the highest strain value was reached.



(a) (b)

Figure 2. Instrumented points throughout the hollow block (a) and strain curves in function of the levels of maximum force (b).

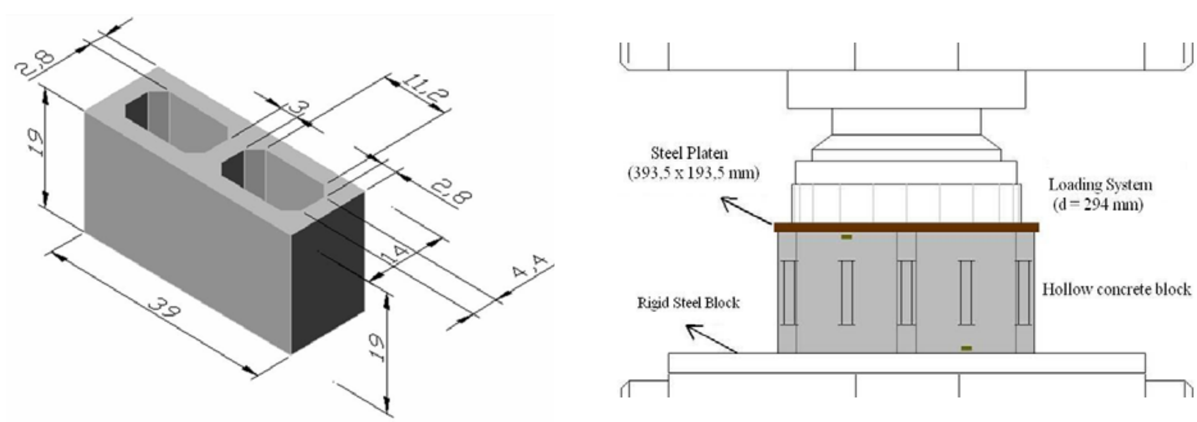
EXPERIMENTAL ANALYSIS

Hollow concrete blocks were moulded and three levels of strength were defined – 10 N/mm², 20 N/mm² and 30N/mm² (B-1, B-2 and B-3). Their dimensions correspond to 140 x 190 x 390 mm (width x height x length), with gross area equal to 54600 mm² and net area of 30663 mm² (Figure 3a). The elements were subjected to axial compression force in a servo-hydraulic machine and tested in the linearly controlled displacement mode. The controlled displacement mode allows for the acquisition of the stress-strain diagram, including its descending or softening branch.

The distribution of the applied force was accomplished with 25 mm thick rectangular steel platen (394 mm x 194 mm). On the top, the contact of this platen with the loading system was accomplished with a 294 mm diameter rigid steel cylinder and the base, there was a very rigid steel block. The dimensions of the platen follow the recommendations of Atkinson 1993 and the NBR 7184 1992. The tests are detailed in Figure 3b. Flat thin sulphur was disposed on the top and bottom of the block.

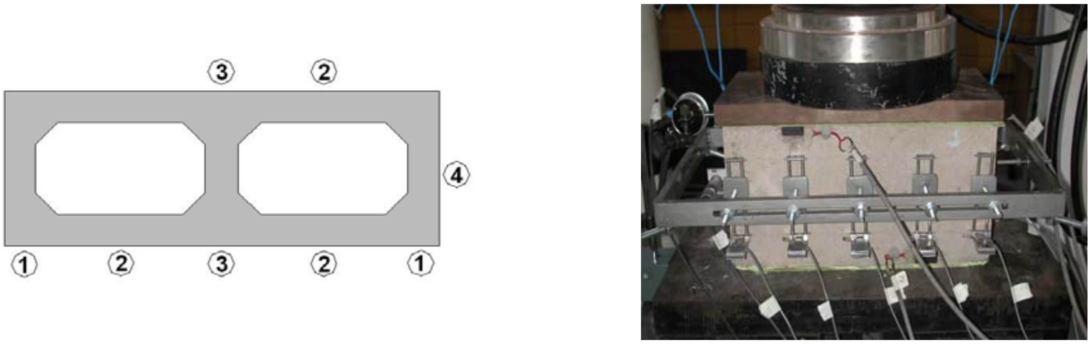
Factor K in the test configuration corresponds to 0.34 and the platen thickness is in accordance with NBR 7184 1992, which establishes a minimum value of 25 mm.

Eight displacement transducers (base length = 100 mm) were positioned on the blocks along vertical reference lines to measure the average strain. The localization of the measurement lines is shown in Figure 4. For example, reference line 2 locates a transducer that is disposed on the main face of the block, in the middle of the hollow. The constant displacement rate induces to a deformation rate of $25\mu/s$.



(a) (b)

Figure 3. Block geometry (a), in centimeters, and block test configuration (b).



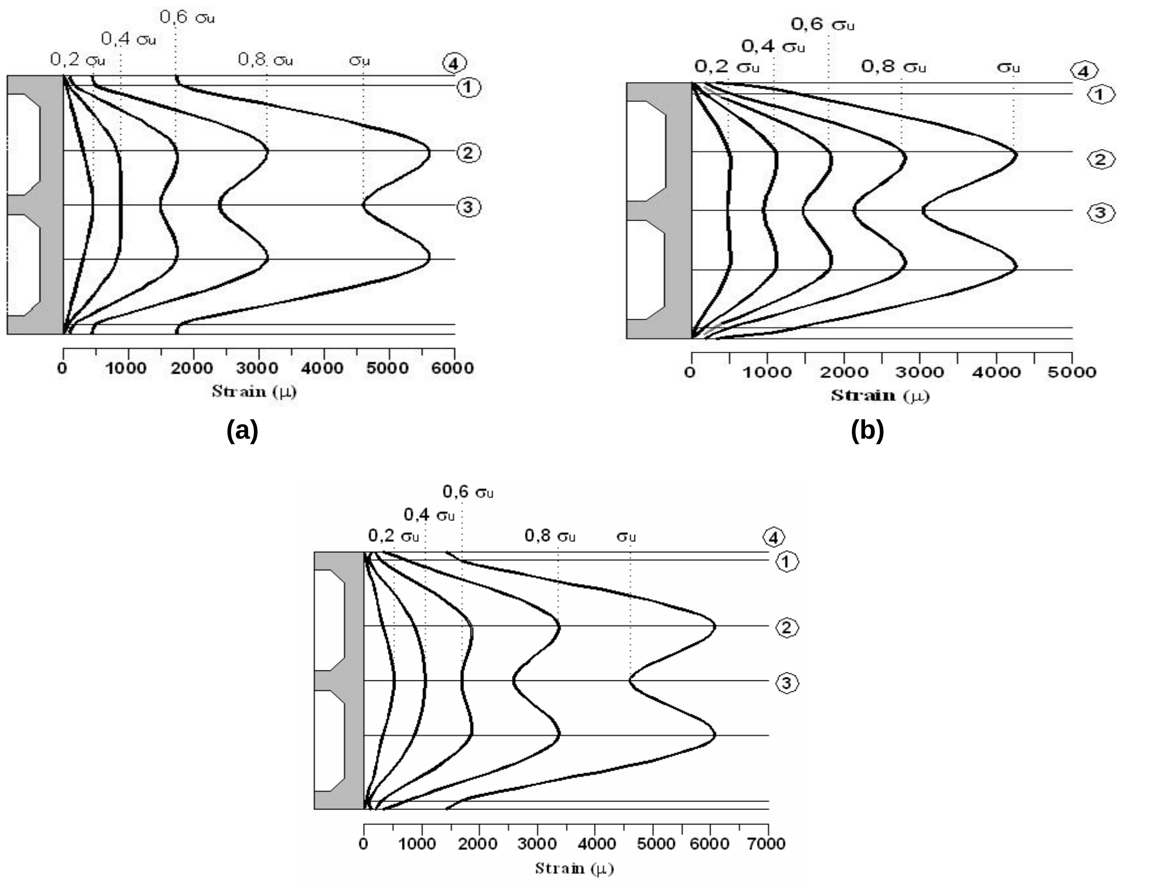
(a) **(b)**

Figure 4. Localization of instruments to measure the longitudinal displacements (a).
Instruments utilized in block compression test (b).

A general and detailed analysis of the blocks' behaviour was achieved by drawing strain variation lines as a function of the maximum stress (Figure 5). Due to the block's geometry, the strain measured throughout face-shells and webs presents different values. At $0.2\sigma_u$, the strains in points 1 and 4 are almost insignificant and the strains in points 3 and 4 are similar. The strains increase in the middle of the block at 40% of maximum stress and the difference of strain value between points 2 and 3 increases, too. At $0.6\sigma_u$, the difference of the strain between the middle and outer points is higher than at initial stress levels. Starting from $0.6\sigma_u$, point 2 presents higher strain than point 3. The value of the strain obtained above 80% σ_u is strongly influenced by the cracking of the concrete. The previous description corresponds to a general behaviour of three groups of blocks.

This behaviour can be justified considering that point 1 is part of the outer transversal web and point 4 is close to the face-shells. Otherwise, point 2 of the block presents higher strain values and influences the behaviour of point 3. The values represent only a general parameter to comparisons and it is emphasized that the non-uniform stress value presented refers to the average stress applied at the top of the block. Considering the properties of concrete for the whole homogeneous block, it is known that the stress in each point is not constant leading to different strain values.

The block´s geometry is a factor that defines the stress distribution throughout the face-shells and webs of block, however, there was no uniform displacement of the top of the block. The steel platen between the load surface of the block and the loading system was not able to transmit a uniform force to the central and extreme regions due to its probable bending.



(c)

Figure 5. Stress-strain diagrams and strain variation along the main face and webs of hollow concrete block. Series B-1 (a), series B-2 (b) and series B-3 (c).

A BRIEF DISCUSSION ABOUT NUMERICAL ANALYSES

Linear numerical analyses were carried out to improve the knowledge of the behaviour of hollow concrete blocks under compression. The analyses also aimed to complete the experimental tests. Two different models were analysed: in the first one a force is applied to the steel platen in a similar region to the experimental analysis and the second model had the value of elastic modulus considerably increased.

Mechanical properties were defined from the experimental analyses of Series B-1. The Elastic modulus for concrete and Poisson ratio value, were, respectively, 16200 N/mm² and 0.19. For the steel platen. E = 205000 N/mm² and $\nu = 0.35$. The value of the applied force corresponded to 40% of the maximum experimental value. Later, to improve a uniform displacement of the top of block, the elastic modulus of the platen was increased to 20500 GPa.
Figure 6 presents the vertical stresses distribution throughout the block for two models. In model 1, the non-uniform displacement of steel platen induces a concentration of stresses in the middle of the block opposing the uniform distribution occurred in model 2.

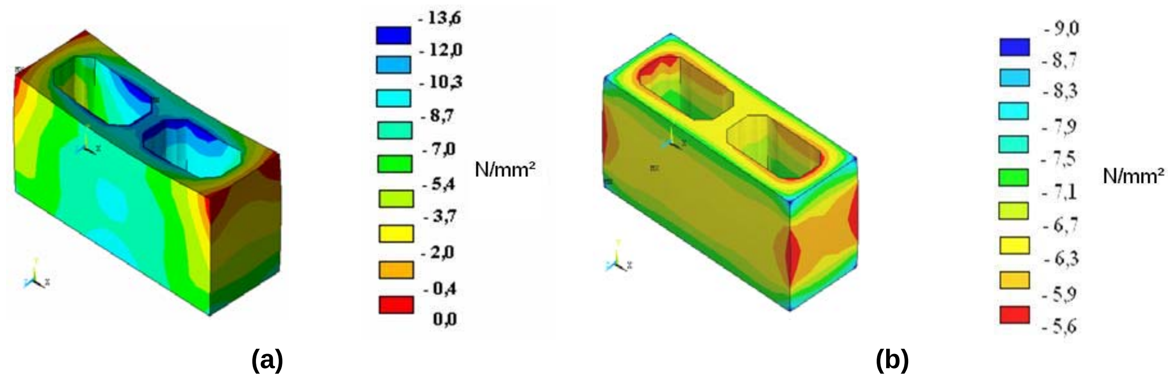


Figure 6. Vertical stress distribution throughout block. Non-uniform (a) and uniform distributions (b).

Model 1 presents the displacement in the middle of the steel platen close to 3.5 times higher than the ones of the edges. (Figure 7).

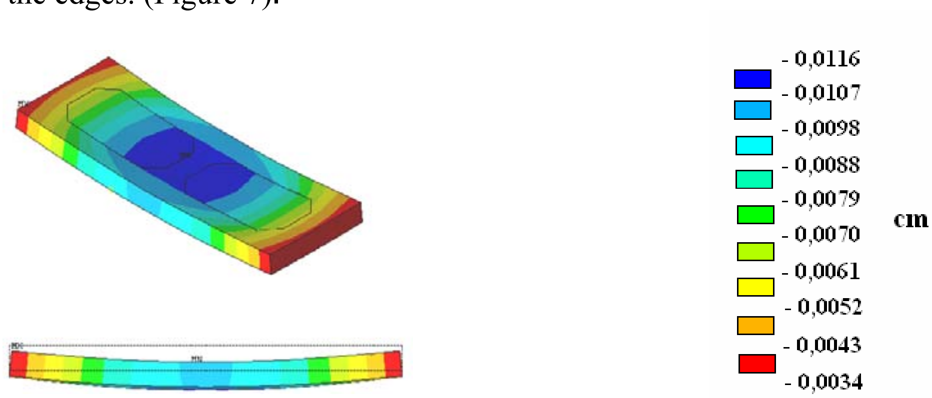


Figure 7. Steel platen displacement and its deformation.

The theoretical and experimental strains are distinct, but numerical model 1 presents the similar differences of the strain between the middle and the edges of the block. The uniformity of strains obtained in the curve of the model is completely different from the other two (Figure 8).

Although the experimental and theoretical models are distinct (due to the simple numerical model adopted) the comparison between them allowed a better comprehension of behaviour of hollow concrete block under these particular test conditions. It can be affirmed that the experimental results were influenced by a non uniform displacement of the platen test, increasing the differences of the strains throughout the block. More refined models can be elaborated utilizing non-linear analyses and better boundary conditions, which can result in a behaviour nearer the experimental results.

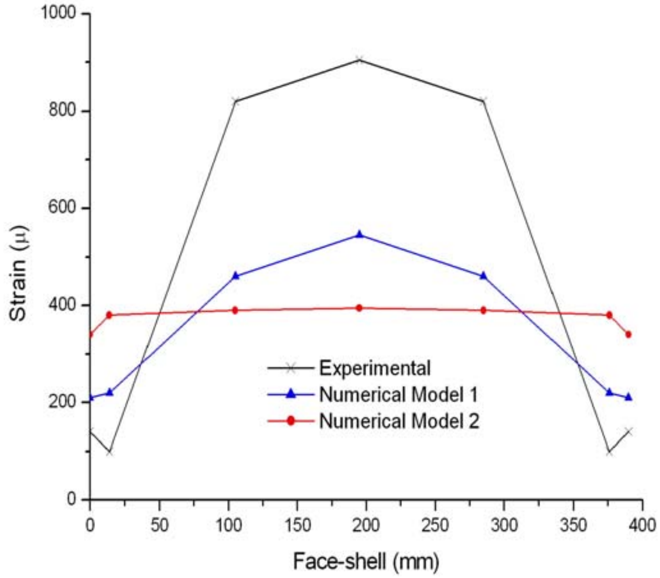


Figure 8. Strains throughout face-shells and webs of hollow concrete block.

CONCLUSIONS

Several tests varying the thickness of the steel platen and the diameter of the loading system were realized leading to different results of compressive and tensile strength and strain distributions. The same masonry element can supply different values of strength or elastic modulus only if it is tested under distinct boundary conditions.

In the experimental analyses, the geometry of the block influences the stress distribution and its respective strains, however, the non-uniform steel platen displacement leads to a non-uniform stress distribution. The geometry and dimensions of steel platen are in accordance with NBR 7184 1992 and several masonry standards related by Atkinson 1991.

Becica and Harris' 1983 tests obtained a strain distribution similar to the experimental tests. The strain values at central points of the hollow block are higher than five times the values of the edge region. In the tests carried out by Becica and Harris 1983, the dimensions of the hollow block correspond to 190 x 190 x 390 mm with 49 mm platen thickness and 250 mm diameter loading system. Apparently, the increase in the platen thickness induces a better stress distribution than the increase in the diameter of the loading system.

Numerical simulations show that the platen influences the stress distribution throughout the block. When a non-uniform strain occurs in the platen, the central regions of the block present higher strains, influenced by the direct load of the loading system. When the platen has a uniform displacement, induced by the high stiffness, the strain values are uniform.

It is necessary to elaborate a specific code to determine the elastic modulus of the block and other masonry components, mainly because some factors may alter the values like speed of the test, size of the element, jeopardizing the direct comparison between several research values.

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