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**EXPERIMENTAL DETERMINATION OF MECHANICAL
PROPERTIES OF AUTOCLAVED AERATED CONCRETE
MASONRY WITH VERTICAL HOLLOWES CONFINED WITH
DISPERSE REIN-FORCED CONCRETE**

BY

**RĂZVAN-ANDREI IERNUȚAN* and
MARIA-NICOLETA ROMAN-PINTICAN**

Technical University of Cluj-Napoca
Faculty of Civil Engineering

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Abstract. The present paper aims at finding solutions alternative to the conventionally reinforced masonry, namely by replacing the confinement with reinforced concrete columns and girders with vertical and horizontal hollows in the autoclaved aerated concrete (AAC) masonry. The voids are filled with disperse steel fibre reinforced concrete.

The use of the disperse reinforced concrete in structural masonry walls, in low seismic areas, is seen to allow the replacement of confined or reinforced concrete masonry, erected according to present-day standards. A substantial advantage can be reached, then, in areas where reinforcing transport and shaping is difficult to achieve. In this way, buildings of type P (groundfloor)+1,2 levels will be easier to built.

The principles of the present research concern the experimental determination of the mechanical characteristics of masonry sections made from AAC blocks with vertical hollows, confined with disperse reinforced concrete. A comparison was made between findings in the unreinforced concrete sections and masonry sections made with vertical hollows, confined with disperse reinforced concrete; for this purpose, shear, bending and compression strength tests were carried out on both types of sections of masonry and eventually the modulus of elasticity of every form of masonry was determined.

*Corresponding author: *e-mail*: Razvan.Iernutan@ccm.utcluj.ro

Key words: steel fibre; force; unit stress; specific deformation.

1. Introduction

The novelty of the research concerns the use of disperse reinforced concrete masonry and respectively mortars in erecting structural masonry walls. Mention should be made that there is a lack of research in civil engineering with respect to the masonry made with disperse reinforced concrete confined hollows (Madularu & Pop, 2010; Pop & Madularu, 2009).

Tests were performed in the Laboratory of the Faculty of Civil Engineering from Cluj-Napoca in the interval November 2013-March 2014.

The samples were tested with a hydraulic press. A 1000 KN gauge was used to measure forces, for data recording an HBM Spider 8 data acquisition system was used, connected to a laptop with a special data recording and retrieval software, namely Catman Easy.

2. The Experimental Determination of the Masonry Shear Strength, in the Horizontal Joint

2.1. Determination of Characteristic Unit Shear Strength of the Masonry

The initial characteristic unit shear strength of the masonry subjected to unit compression stress is equal to zero f_{vk0} and it was found from the results of the tests on the masonry; the reference standard used was SR EN 1052-3:2003. In this standard, it is established determination method for the initial shear strength in the horizontal masonry joints, where a section of masonry is subjected to shear (CR6, 2013; SR EN 771, 2005).

The initial shear strength of the masonry was deduced from the strength of the masonry sections subjected to stress until ultimate breaking.

The initial shear strength is defined by the linear regression curve for a null stress.

The materials used for the masonry are:

The moisture content in the silico-lime masonry member weight and for AAC masonry member is in conformance with SR EN 772-10 (SR EN 772-1, 2005; CR6, 2013).

The mortar used fulfilled the requirements for the mixing procedure and scattering values, according to SR EN 998-2 provisions. The mortar used was similar to that in compression test masonry, namely M2,5.

Samples of fresh mortar were taken, in specimens of $40 \times 40 \times 160$ mm and the average compression strength was calculated in the moment masonry sections were tested, according to SR EN 1015-11 (CR6, 2013; SR EN 771, 2005).

2.2. Preparation and Preservation of Masonry Sections

Three unreinforced masonry sections and three metal fibre reinforced concrete masonry sections were built according to the provisions in SR EN 1052-3.

To determine the shear strength of the masonry, a hydraulic press to which a spherical joint and a force gauge were mounted (Fig. 1), connected to a data acquisition system (Fig. 2).



Fig. 1 – Sections made from unreinforced BCA masonry.



Fig. 2 – Sections made from confined disperse reinforced concrete BCA masonry.

- $l_s = 300$ mm
- $t_{bj} = 10$ mm
- $h_2 = (h_1 - t_{bj})/2 = 95$ mm.

2.3. Preservation and Conditioning of Masonry Sections

The masonry sections were tested at 28 days and the mortar resistance to compression was also tested at 28 days, according to SR EN 1015-11.

Positioning the masonry section in the test machine

The extremities of the masonry section were supported on the test machine (see Fig. 3) with minimum 12 mm thick steel plates, well polished where necessary, for a tighter contact. The load ball diameter should be 12 mm and the minimal length of t_u .

The load was applied in the middle of the top steel plate mounted on balls:

- a) unreinforced masonry;
b) metal fibre reinforced concrete masonry.

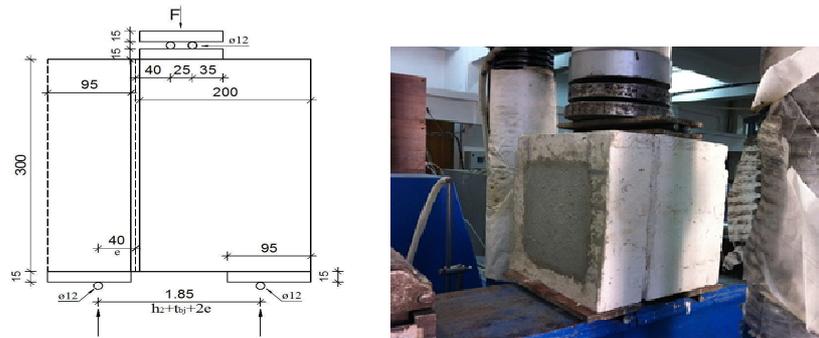


Fig. 3 – Testing the metal fiber reinforced concrete masonry.

2.4. Interpretation of Results

In unreinforced masonry, in all three samples, the failure occurred between the mortar and the masonry stone, while in BFM masonry (steel fibre reinforced concrete) the failure occurred when the member cracked until final detachment (GP-075-02, 2003).



Fig. 4 – The failure of the metal fiber reinforced concrete masonry.

2.5. Calculations

The shear strength and precompression stress were calculated for every masonry section with a precision of 0.01 N/mm^2 , using the formulas below:

- a) unreinforced concrete masonry – average values

$$f_{voi} = F_{i,\max} / 2A_i = 0.038 \text{ N/mm}^2, \quad (1)$$

b) metal fibre reinforced concrete masonry – average values

$$f_{voi} = F_{i,max} / 2A_i = 0.74 \text{ N/mm}^2. \quad (2)$$

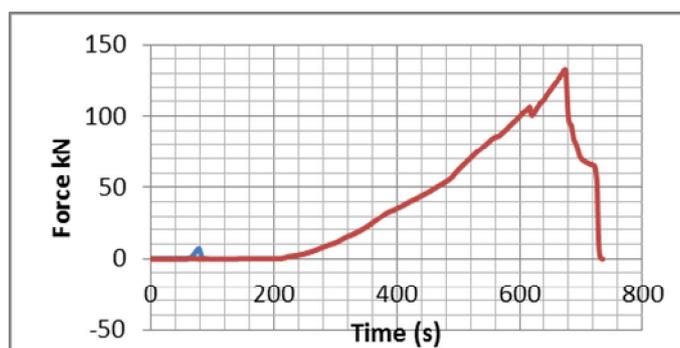


Fig. 5 – Evaluation of results, comparative graph (force-time) between unreinforced masonry sections and confined disperse reinforced concrete masonry sections.

3. Experimental Bending Strength of BCA Masonry

3.1. Building BCA Masonry Sections

There were made five sections of unreinforced masonry of the dimensions listed as follows: length $l_s = 91$ cm, height $h_s = 75$ cm, thickness $t_s = 30$ cm; the masonry was made with AAC blocks of GBN50 type of sizes: $l_u = 600$ mm, $h_u = 250$ mm and $t_u = 300$ mm; the masonry mortar used was M2,5; the joint was 10 mm.

Other sections with a vertical hollow were built of size 200 x 200 mm to confine the disperse steel fibre reinforced concrete masonry. The dimensions of this masonry section are identical to those of unreinforced sections. The sections were built from AAC, of the dimensions: $l_u = 600$ mm, $h_u = 250$ mm and $t_u = 300$ mm; the M2,5 masonry mortar was used and joints were of 10 mm. In the vertical hollows, concrete of grade C16/20 was poured; it was built with steel fibres of type WHS 50/09/H. The concrete formula comes in agreement with the Standard NE-12/1-2007 (Normativ pentru producerea betonului și executarea lucrărilor din beton, beton armat și beton precomprimat/ Norms for producing concrete and performing concrete, reinforced concrete and prestressed concrete works) and the Guidelines GP-075-02 „Ghid pentru stabilirea criteriilor de performanță și a compozițiilor pentru betoanele armate dispers cu fibre metalice”/ Guidelines to establish performance criteria and composition of disperse metal fibre reinforced concrete (Pop & Madularu, 2008; GP-075-02, 2003; SR EN 1052-3, 2003).



Fig. 6 – Building the vertical hollow masonry section.

3.2. Testing BCA Masonry for Resistance to Bending

After mounting the samples in the test location, the load test was uniformly distributed on the two supports placed on the masonry section.

The sample bending stress test was performed with a hydraulic cylinder mounted perpendicularly to the masonry wall. A metal profile stand was also used.

In order to assess the deformations, every masonry section was provided with two comparison mechanical gauges, arranged as shown in the Figs. 7 and 8.



Fig. 7 – The bending strength of unreinforced masonry test.



Fig. 8 – The bending strength of disperse reinforced confined masonry test.

3.2. Bending Strength Calculations

Calculations

The bending strength of every masonry section is calculated with a precision of 0.01 N/mm^2 with the help of the formula:

$$f_{\gamma_i} = 3F_{i,\max} (l_1 - l_2) / 2bt_u^2, \text{ [N /mm}^2\text{]}. \quad (3)$$

The average bending strength of the masonry is calculated (f_{med}).

Results evaluation

The characteristic bending strength is calculated with an accuracy of 0.01 N/mm² leaving from:

$$f_{\text{sk}} = f_{\text{med}} / 1.5 \text{ for 5 masonry sections.} \quad (4)$$

One calculates the values y_1, y_2, y_3, y_4, y_5 , from $y_n = \log_{10} f_{\gamma_n}$ and y_{med} from

$$y_{\text{med}} = \sum y_n / n, \quad (5)$$

$$y_c = y_{\text{med}} - ks. \quad (6)$$



Fig.9 – Unreinforced masonry failure.



Fig. 10 – Confined dispersive reinforced concrete failure.

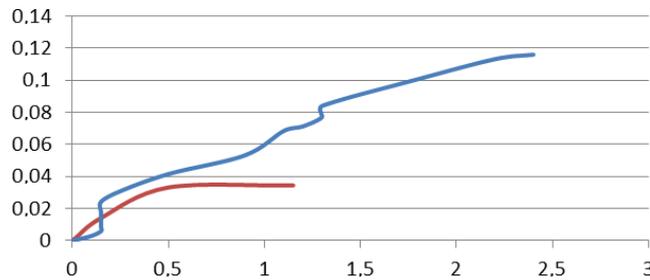


Fig. 11 – Comparison graph (unit stress- specific deformation) between the unreinforced masonry sections and confined dispersive reinforced concrete sections.

3.3. Testing BCA Masonry for Resistance to Compression

After mounting the samples in the testing location with a crane, we provided a uniform distribution all along the member surface, with the help of spherical joint and a metal device placed under the stress measurement gauge.

In order to assess the specific deformations, we supplied every masonry section with four mechanical comparing gauges, two on one face and two on the other face, as shown in the Fig. 12 (SR EN 771, 2005; SR EN 772-1, 2005).



Fig. 12 – Compression tests on masonry sections.

3.4. Member Loading for Measuring Resistance to Compression

A uniformly distributed load was applied at the member top. The force was constantly/gradually increased so that the failure occurred in maximum 30 min. since loading start (SR EN 771, 2005; SR EN 772-1, 2005).

In order to determine the modulus of elasticity, every sample was subjected to several loading/unloading cycles until the stress reached $s_r = 0.33$ of the maximum stress to which the first sample resisted.

3.5. Data Recording

For every sample, a test bulletin was filled in with the following data:

- a) sample number;
- b) member loaded section dimensions;
- c) maximum load $F_{\max}(N)$;
- d) load at which the first crack occurred;
- e) marking and numbering of cracks on the samples;
- f) monitoring in time of the size and development of cracks;
- g) recording of the time interval passed from the beginning of the test and the moment when the sample failed.

3.6. Interpretation of Results

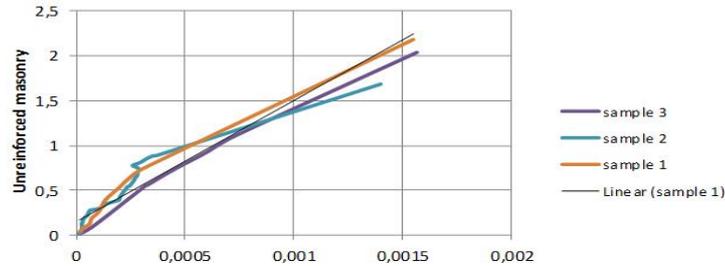


Fig. 13 – Relationship between the unit stress and the specific deformation ($s - \varepsilon$) in unreinforced BCA masonry.

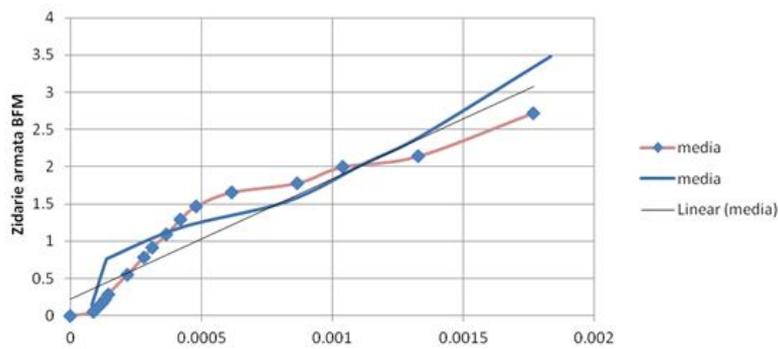


Fig. 14 – Relationship between the unit stress and the specific deformation ($s - \varepsilon$) in BCA masonry reinforced in the vertical hollows with BFM C16/20.

3.7. Experimental Determination of the Modulus of Elasticity

On the basis of the experimentally found data, we further calculated the modulus of elasticity values for unreinforced AAC masonry and for masonry with a vertical hollow reinforced with metal fibre concrete. Modulus values were compared and specific conclusions were drawn (SR EN 772-1, 2005).

Table 1

Determination of the Longitudinal Modulus of Elasticity in Unreinforced Masonry

Sample	Modulus of elasticity E_z per member, [N/mm ²]	Average modulus of elasticity E_z , [N/mm ²]
1.	1,983.31	1,918
2.	1,870	
3.	1,902.02	

Table 2

Determination of the Longitudinal Modulus of Elasticity in Disperse Reinforced Concrete Masonry in the Vertical Hollow

Sample	Modulus of elasticity E_z per member, [N/mm ²]	Average modulus of elasticity E_z , [N/mm ²]
1.	3,852.60	3,809
2.	3,694.00	
3.	3,881.37	

4. Conclusions and Recommendations

The analysis of the experimental results leads to the following conclusions:

Relationship $s - \varepsilon$ comes close to the linear deformation, both for unreinforced masonry and for the masonry with disperse reinforced concrete, as provided in CR 6-2013.

The bearing capacity and the maximum deformation values increase in the case of the masonry with disperse reinforced concrete. The bearing capacity increases by about 59%, while the ultimate deformation value increases with 12%

The modulus of elasticity found experimentally differs by 10% in the experimental masonry as compared to the theoretical value for the modulus of elasticity.

The ratio between the modulus of elasticity of the masonry with disperse reinforced concrete and the unreinforced masonry is 1.10.

On the basis of the experimentally determined data, calculations were performed and we can conclude that the C16/20 disperse reinforced concrete confined masonry with vertical hollows can replace the conventional reinforcement with reinforced concrete columns in unreinforced masonry, in areas of low seismic values, in the case of one or two floored buildings. It is for this reason that further research will concern the use of the data found for the purpose of this article in a numerical simulation performed with specific software for strengthening the present findings.

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DETERMINAREA PE CALE EXPERIMENTALĂ A CARACTERISTICILOR
MECANICE A MODULELOR DIN ZIDĂRIE REALIZATE DIN BLOCURI DE BCA
CU GOLURI VERTICALE CONFINATE CU BETON ARMAT DISPERS

(Rezumat)

Se urmărește găsirea unor soluții alternative la clasică armare a zidărilor, și anume confinarea cu stâlpișori și grinzi de beton armat prin înlocuirea lor cu goluri verticale și orizontale în zidăriile de BCA. Aceste goluri din zidărie după ce au fost realizate au fost umplute cu betoane armate dispers cu fibre metalice.

Utilizarea betonului armat dispers în pereți structurali din zidărie la construcții, în zone seismice cu seismicitate redusă, se consideră că va permite să înlocuiască zidăriile confinate sau armate conform codurilor actuale. Un avantaj substanțial se poate obține în zonele în care transportul și fasonarea armăturilor se realizează greu. Aceasta va ușura realizarea unor construcții de tip P+1-2 Etaje.

Principiile pe care au stat la baza cercetării sunt determinarea pe cale experimentală a caracteristicilor mecanice a modulelor din zidărie realizate din blocuri de BCA cu goluri verticale confinate cu beton armat dispers. Astfel s-a făcut o comparație între rezultatele obținute pe module din zidărie simplă și rezultatele pe module din zidărie confinate cu betoane armate dispers, în acest sens s-au testat experimental modulele de zidărie simple și cele confinate cu BAD la forfecare, încovoiere și compresiune iar la final s-a determinat și modulele de elasticitate pentru fiecare zidărie.

