Static Analysis of a New Wall System realized by Modular Concrete Blocks

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ABSTRACT

Building blocks made of modular concrete elements without the use of mortar have multiple beneficial effects. The speed of process, the simplicity and the accuracy when handling, provide a substantial economy considering the manpower, the raw materials and a clean surrounding on a construction site. The minimisation of the environmental impact of the developed product, in accordance with the current legislation, is researched in function of the optimum between the thermal performance, the mechanical resistance and the costs.

The load-bearing behaviour of these masonry walls will be discussed.

1. DISPOSITION OF THE MODULAR CONCRETE ELEMENT

The developed module is made of two concrete side walls which are connected to each other by concrete cross-connections, and as a first step a C50/60 concrete is used (~2500 kg/m³). For thermal, acoustic or even mechanical reasons, the hollow sections can be filled out with insulations, steel bars and concrete or other materials.

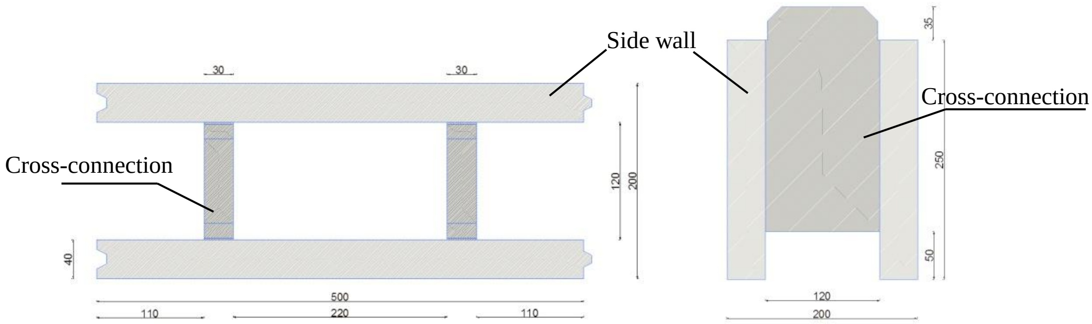

Figure 1 – Plan view (left) and transverse section (right) of the modular concrete block.

The plug-in system is provided by the male and female parts, preventing the relative movements in the horizontal plane.

2. THERMAL BEHAVIOUR OF THE MODULAR CONCRETE ELEMENT

The concrete block without integrated or external insulation, presents experimentally a conductivity of 0.78 W/(mK). This relatively high value compared to traditional concrete blocks (ranging from 0.40 to 0.60 W/(mK)) with similar mechanical resistances, can be explained by the nature of the used concrete. We know that the conductivity of concrete increases exponentially in function of its density /Leufgens 2010/. With an integrated insulation of 120 mm thickness, of the type polystyrene 0.035 W/(mK) within the core of the block, the conductivity of the module reduces from 0.78 to 0.39 W/(mK). With an external insulation of 50mm (without integrated insulation), the conductivity of the modular concrete element reduces to 0.11 W/(mK). Although the integrated insulation plays a beneficial role in the thermal behaviour, it loses its utility when an external insulation is applied additionally. In this case, the thermal performance increases in a more significant way by avoiding the thermal bridges due to the cross-connections. The heat transmission through the concrete element can be regulated by the thickness of the cross-connections and the external side walls, the number of cross-connections, the type of the used concrete and the integration of internal or external insulation /Agaajani 2011/.

3. MECANICAL BEHAVIOUR AND GENERAL STABILITY OF THE WALL

3.1 Consequences of the non-application of mortar

The mortar equalises the contact surface, which becomes perfectly uniform between the elements. In this way, the dimensional differences of the traditional blocks are “absorbed” by the mortar. In particular, when modular blocks are employed without the use of mortar, stress concentrations are produced by point-contacts and the general stability of the wall is prematurely weakened; the achievement of the service limit state is accelerated.

Full scale tests showed that mortar can be omitted, when the modular elements are grinded after their production in order to get regular and even contact surfaces. It is noteworthy that the European norms do not establish production tolerances /NORMES EN 771-3/ nor static behaviour calculations /EN 1996-1-1:2005/ for these kind of elements for wall constructions.

3.2 Wall resistance under uniform compression in function of the height

The stability of different kinds of walls has been verified experimentally, by applying a uniform, vertical loading (Figure 2) which is ensured by a hydraulic cylinder system connected to metal bars. These crossing metal bars are fixed in a specific basis.

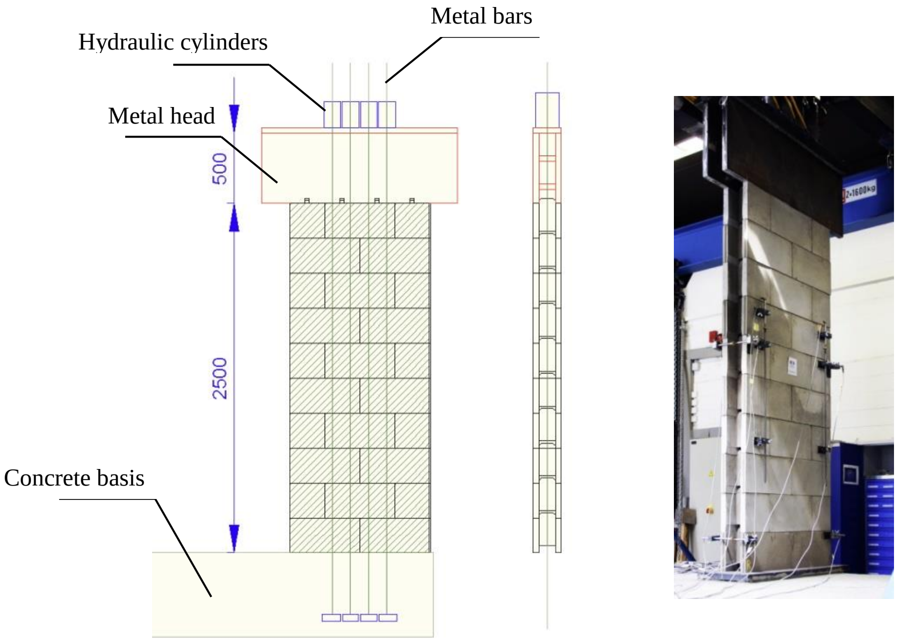

Figure 2 – Loading of a wall of 2.50 m height, made of modular concrete blocks.

The modular elements have been tested with or without grinding the later loaded surfaces. The modular concrete blocks are those described in Figure 1 and are used *without* mortar joints; the classical concrete-blocks are traditional hollow concrete blocks of 240 mm thickness, and are tested *with* mortar joints. The compression surface, used for the calculations of the vertical stress, is the brute surface of the wall; the hollow sections are included. As we can see in Figure 3, the influence of the specific treatment has a direct influence on the mechanical resistance of the wall under a uniform loading: the bearing capacity of the structure of a height of 1.25 m is increased by 100%.

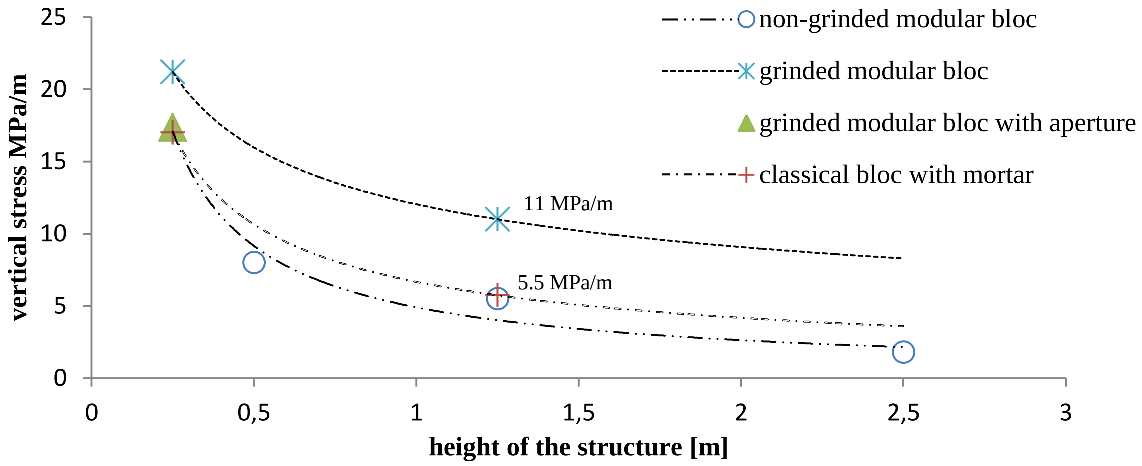

Figure 3 – Mechanical behavior of walls in function of their height under a uniform vertical compression.

A premature cracking of the elements due to imperfections does not appear when the surfaces have been grinded. In these cases the mechanical resistance of the structure is considerably increased: 11 MPa/m, instead of 5.5 MPa/m for the same structure without grinding (in case of a wall of 1.25 m height). In Figure 3 the tendency of load-bearing behaviors of the different wall systems are also indicated. To confirm them, additional tests have to be performed.

The vertical strain involved by the vertical stress introduces horizontal expansion which can clearly be identified on the cross-connections: the first cracks appear in these sections (Figure 4) and with them the damage of the structure is initiated. This situation is improved when we ensure a uniform load deflection, which is obtained with the grinding of the elements. It has been experimentally verified that the friction coefficient between the modular blocks are 0.6, respectively 0.4 for the grinded elements.

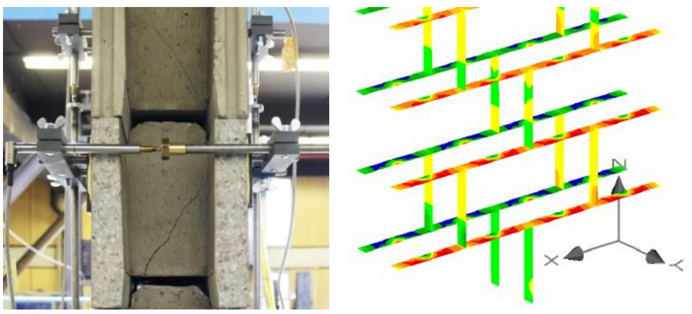

Figure 4 – Development of first cracks on the cross-connections; numerical simulation of the contact surfaces of the modular blocks /ATENA 2010/.

The effect of small openings has also been checked for the simulation of future passage of ducts/pipes; the loss of mechanical resistance is about 20% for a single modular concrete element with one opening of 60 mm of diameter (Figure 5), and for a uniform and vertical applied compression. Numerical and experimental simulations will confirm that this loss of resistance of a single block will be less important on a complete wall-structure with openings, where the redistribution of stress is possible.

Figure 5 – Opening of 60 mm in diameter for the simulation of future passage of ducts/pipes.

The modular block, being constituted of two relative fine bearing side walls (Figure 1), eccentric loads will imply a further reduction of the load-bearing capacity of the structure. As the support of slabs at the head of front walls introduce eccentric loads, this will also be analyzed in the future. It will be possible that this problem can only be solved by additional precast concrete elements on the head of the front walls in order to get a better load distribution.

4. CONCLUSION AND FUTURE WORK

The experimental tests have allowed showing the possibility to build load-bearing walls made of modular concrete blocks without the use of mortar between the joints by grinding the modules after their production. Although such treatment leads to higher production costs, the benefit on manpower, raw materials and speed of construction will make the marketing of these elements interesting.
Additional tests have to be undertaken in order to verify the stability of the walls in function of punctual, eccentric and horizontal forces. Life cycle analysis will also allow making judicious choices in internal or external insulations in order to minimize the ecological impact of the products on the environment. A possible integration of phase changing materials will also be studied.

REFERENCES

Leufgens, N., Waldmann, D., 2010,
„Mechanische und Thermische Untersuchungen zur Entwicklung eines Wärmedämmsteines aus Leichtbeton“, RUES, University of Luxembourg, pp 72.
Agaajani, S., Waldmann, D., 2011,
« Nouveaux systèmes de murs isolants en béton », Accepted Paper for RF2B 2011, Editor : Courard, L. ; Waldmann, D. ; Lecomte, A., RUES, University of Luxembourg
NORMES EN 771-3:2003 (F) Partie 3,
« Eléments de maçonnerie en béton de granulats courants et légers », EN 771-3:2003 + A1:2005.
EN 1996-1-1:2005 (F), Partie 1-1,
« Eurocode 6 : Calcul des ouvrages en maçonnerie – Règles générales pour ouvrages en maçonnerie armée et non armée »
ATENA, Cervenka, V., Jendele, L., Cervenka, J., March 2010,
“Program documentation – Theory”, Prague.