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COMPRESSIVE TESTS ON MASONRY MADE OF EXPANDED CLAY AGGREGATE CONCRETE UNITS

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Abstract

In the paper test results of strength and deformability of masonry made of expanded clay aggregate concrete units are presented. Tests were performed on masonry made using general purpose mortar and lightweight mortar. Results of the experimental investigations are shown in relation to recommendations of the Eurocode 6 and of the Polish code for masonry structures PN-B-3002:1999.

Key Words

Compressive tests, masonry, concrete units, expanded clay aggregate

1 Introduction

Tests for determination of the compressive strength of masonry, units and mortar are currently carried out in Poland according to the Polish codes PN-EN identical with the respective codes EN, whereas the Polish code for design of masonry structures PN-B-03002:1999 complies in principles with the Eurocode 6 (prENV 1996-1-1:1994). The compressive strength of masonry can be either determined from experimental tests performed according to PN-EN 1052-1:2000 or computed from the appropriate code formulae. In PN-B-03002:1999 for masonry made using general purpose mortar or lightweight mortar the power formula known from the Eurocode 6 (prENV 1996-1-1:1994) is adopted, in which the characteristic compressive strength of masonry is a function of unit and mortar strengths. For masonry made of aggregate lightweight concrete solid units values of coefficient K are not given in PN-B-03002:1999, making their acceptance in subsequent amendments to the code dependent on conducting an appropriate test programme. One of the stages is research of masonry made of expanded clay aggregate concrete units. Presented in the paper tests of masonry made of expanded clay aggregate concrete hollow and solid units were aimed, beside establishing the compressive strength, at gathering data concerning deformability and failure mode of masonry. Conclusions from the tests were used in preparation of technical information for designers and contractors of masonry structures.

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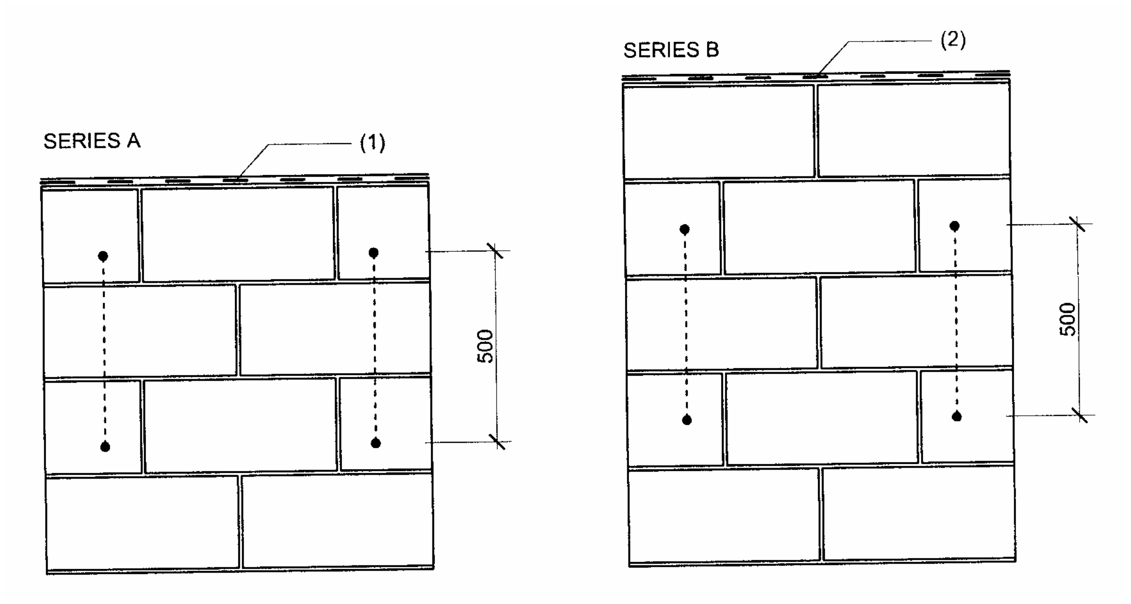
2 Description of the experimental tests

The tests were performed on masonry made of expanded clay aggregate concrete hollow units (series A) and of solid units (series B). According to the producer's statement the units were made using concrete mix with expanded clay aggregate of fraction 1-10 mm (density of concrete in dry state 600-700 kg/m^3). Masonry composed of the hollow units was made using general purpose cement mortar, whereas masonry composed of the solid units was made using lightweight mortar. The masonry tests were performed in compliance with PN-EN 1052-1:2000 (identical with EN 1052-1).
A scheme of probe specimens and position of strain gauges are shown in Fig.1.



hollow units 500x365x240 mm
compressive strength of units
f_b=2,56 MPa
coefficient of variation of strength of the units 4,5 %
general purpose mortar
compressive strength of mortar
f_m=12,8 ÷ 14,6 MPa
(1) softboard
place of tests:
Building Research Institute Warsaw

solid units 500x240x240 mm
compressive strength of units
f_b=3.05 MPa
coefficient of variation of strength of the units 7%
lightweight mortar
compressive strength of mortar
f_m=5,3 ÷ 6,1 MPa
(2) general purpose cement mortar
place of tests:
Institute for Building Materials and Structures, Cracow University of Technology

Figure 1 Probe specimens for tests

In each series 6 specimens were tested. At successive load stages the strain recordings were taken (in series A every 50 kN load increment, in series B every 25 kN load increment). The elasticity modulus was established for a load level equal to 0.33 times the load-carrying capacity. The test results are collected in Table 1.

Table 1 Compressive strength and deformability of masonry made of expanded aggregate concrete units – test results

Series	f_{mean} [MPa]	f_k [MPa]	E [MPa]	E/f_{mean} [-]	E/f_k [-]	$\varepsilon_{>90}$ [mm/m]
A	1.76	1.38	2236	1270	1620	$0.61 \div 0.81^{(1)}$
B	1.57	1.27	1929	1229	1519	$0.61 \div 0.79^{(2)}$

$^{(1)}$ established in tests of 4 probe specimens $^{(2)}$ established in tests of 3 probe specimens

f_{mean} is the mean value of masonry strength;
f_k is the characteristic strength of masonry;
E is the modulus of elasticity;
$\varepsilon_{>90}$ is the maximum recorded strain at load level >0.9 load-carrying capacity.

In Fig.2 the load-strain relationships are presented for masonry in cases where strain recordings were taken up to high levels.

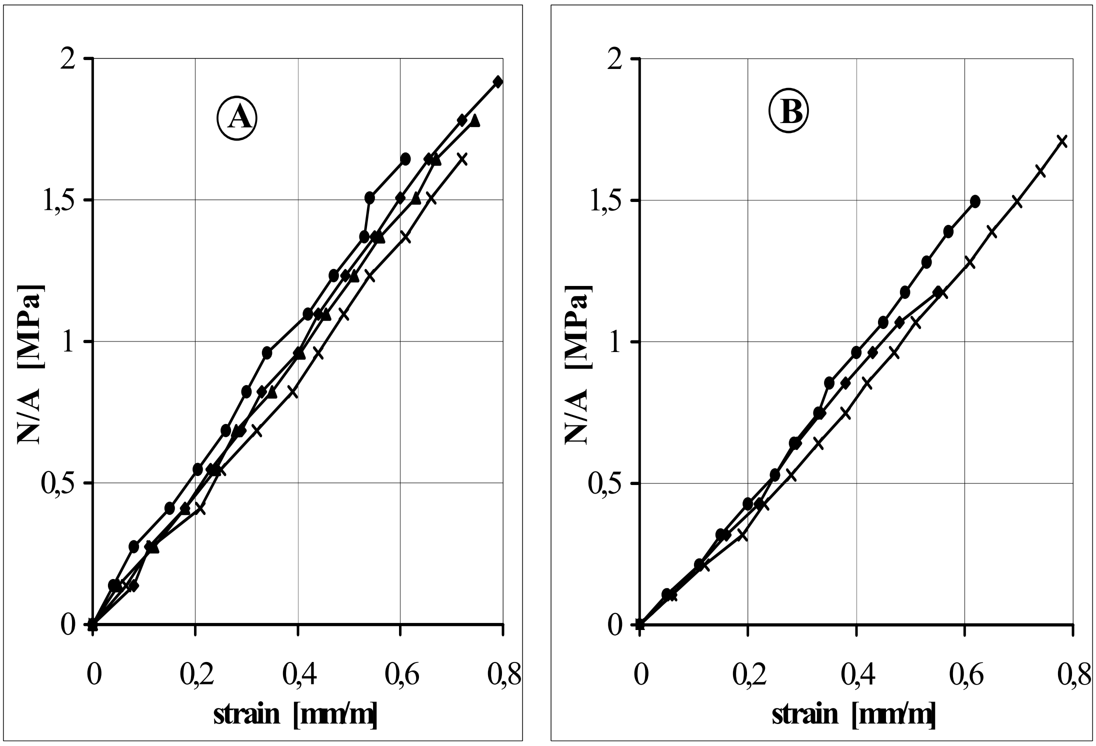


Figure 2 The relationships N/A (ε) for masonry made of expanded clay aggregate concrete units

The failure of masonry had a sudden character for both series A and B. First symptoms of destruction were recorded for high load levels (as a rule, for load > 0.9 load-carrying capacity, in many cases without warning). The most damage appeared in the first bottom and top layers of masonry units.
In series A for 5 of 6 tested specimens failure took place in the first layer of units, in these cases damage in mortar layers was not observed. In series B masonry vertical and diagonal cracks in probe specimens were recorded going through two first layers of masonry units and mortar. The typical failure modes are presented in Fig.3.

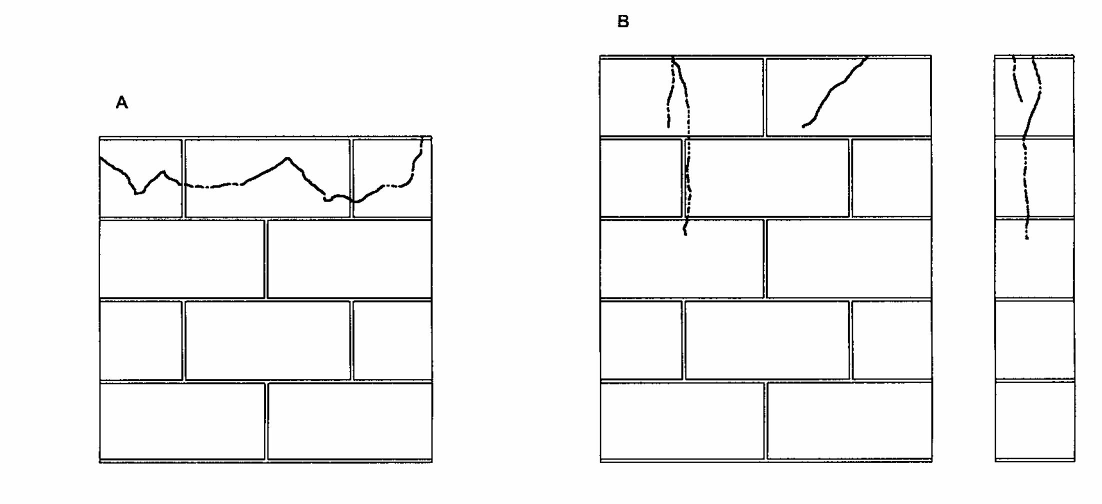


Figure 3 Failure modes for masonry made of expanded clay aggregate concrete units under compression

Additionally 2 specimens made of expanded clay aggregate concrete solid units were tested under constant rate of testing machine piston movement (0.2mm/min). Obtained in these tests relationships N(ε) are presented in Fig.4. Considering the limited range of recordings (strain recordings on gauge lengths 500mm) as well as a number of specimens these tests have to be regarded as preliminary ones.

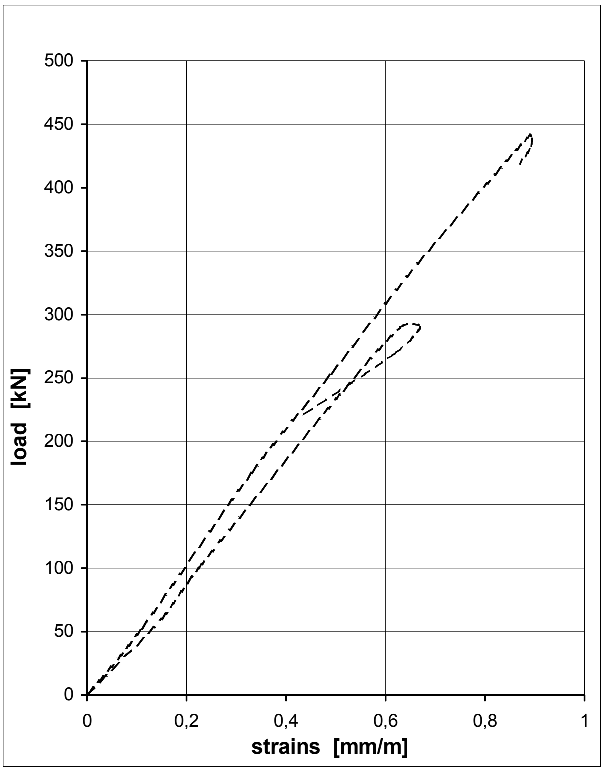


Figure 4 Relationship N(ε) for masonry made of expanded clay aggregate concrete solid units under displacement control

3 Discussion of results

Making an analysis of the test results, the compressive strengths of masonry given in Table 1 were compared with values computed from the known power formulae given in subsequent versions of the Eurocode 6 and in the Polish code for masonry structures PN-B-03002:1999 – see Table 2.

Table 2 The characteristic compressive strength of masonry made of expanded clay aggregate concrete units f_k [MPa] – comparison of test results with values computed using code formulae

Series	tests	prENV:1994	prEN:2003	PN-B-03002:1999
A	1.38	$0.55f_b^{0.65}f_m^{0.25} = 1.28$	$0.45f_b^{0.7}f_m^{0.3}=1.42$	$0.35f_b^{0.65}f_m^{0.25} = 0.82$
B	1.27	$0.8f_b^{0.65} = 1.65$	$0.45f_b^{0.7}f_m^{0.3}=1.59$	(-)

(-) not given

Values f_k obtained in the tests of masonry made of expanded clay aggregate concrete hollow units are close to values computed using formulae given in prEN (2003) and prENV (1994) (differences do not exceed 10%), on the other hand they are clearly larger than those computed using formulae given in PN-B-03002:1999. In PN-B-03002:1999 a formula for specifying f_k for masonry made of the aggregate lightweight concrete units belonging to the group 1 is not given. The compressive strength of masonry made of expanded clay aggregate concrete solid units obtained in the tests is about 25% less than those computed using the power formulae proposed in prEN (2003) and prENV (1994).

Taking into account strain recordings the value of accidental eccentricities (e_a) is estimated, which took place in masonry tests. Assuming a linear load-strain relationship and the planar cross-section principle, a formula can be derived:

$$\frac{e_a}{t_s} = \frac{\Delta\varepsilon}{12\bar{\varepsilon}} \qquad (1)$$

t_s is the masonry thickness;

$\Delta\varepsilon$ is the difference in strain at opposite surfaces;

$\bar{\varepsilon}$ is the mean strain.

In 11 of 12 tested specimens (series A,B) eccentricities computed using Eq.1 did not exceed $0.02t_s$. It is more difficult to assess influence of shear stress. Vermeltfoort (1997) shows that for masonry made of calcium silicate units use of teflon pads results in about 10% decrease of the load-carrying capacity. Similar influence for tests of concrete specimens was described in the work of Vonk (1992). It can be estimated that altogether the influence of aforementioned factors (eccentricities, shear stress) on the masonry strength obtained in the tests did not exceed few percent.

The values of the ratio E/f_{mean} obtained in the masonry tests (see Table 1) comprise in values given in literature for masonry made of aggregate lightweight concrete (Schubert, Glitza 1981, Meyer, Schubert 1992, Schubert 2001): E = (1000÷1500)f_{mean}. It stems from an analysis of the load-strain relationships (Figs 3,4) that the elasticity modulus of masonry changed in the course of loading very slightly (differences up to 10%).

The failure of masonry made of expanded clay aggregate concrete units had a sudden character, similar to that obtained in the tests of the compressive strength of the hollow and solid units. Damage at slightly lower load levels was recorded in the series B masonry, where the weaker mortar was used. Brittle failure at small strain values and close to linear shape of the load-strain curve (see Figs 3,4) suggests acceptance of the linear-elastic model without plastic plateau for masonry made of expanded clay

aggregate concrete units. Meyer and Schubert (1992) proposed the linear-elastic model for masonry made of aggregate lightweight concrete units, in which the maximum strain is equal to 1.2 mm/m. In the tests described in the paper slightly smaller values of the maximum strain were obtained but the strain gauges did not cover the whole height of specimens (localisation of damage – see Fig.3). The precise establishing of a computational model for masonry made of expanded clay aggregate concrete units needs supplementary research.

4 Conclusions

Presented in the paper the test results point out that expanded clay aggregate concrete hollow and solid units can be used for structural masonry walls subjected to vertical loading in low-rise buildings, mainly in housing buildings. Employing mortars with strength larger than 5 MPa, the characteristic compressive strengths of about 1.3 MPa for the tested masonry were achieved. In the light of the performed tests it is justified to assume the linear-elastic-brittle model in computations of masonry made of expanded clay aggregate concrete units.

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