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THE STRENGTH AND DEFORMABILITY OF THE LARGE-FORMAT POROUS CERAMIC BLOCKS MASONRY UNDER SHEAR

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Abstract

The article presents the results of experimental studies of shear strength, shear modulus and the limit value of the angle of shear deformations of masonry made of porous ceramic blocks with groove connection system of vertical joints. Studies of these parameters were carried out by the method of diagonal compression of masonry specimens, the vertical joints of which were made without filling and with filling with mortar. It is established that when filling vertical joints of masonry with a mortar on a mineral binding material, its shear strength and shear modulus significantly increase. It is indicated that it is necessary to take these factors into account when designing wall-stiffening diaphragms, multi-loaded load-bearing walls, floor-by-floor supported walls and partitions constructing using masonry from porous ceramic blocks.

Keywords: masonry, ceramic porous blocks, diagonal compression, shear strength, shear modulus.

ПРОЧНОСТЬ И ДЕФОРМАТИВНОСТЬ ПРИ СДВИГЕ КАМЕННОЙ КЛАДКИ ИЗ КРУПНОФОРМАТНЫХ ПОРИЗОВАННЫХ КЕРАМИЧЕСКИХ БЛОКОВ

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Реферат

В статье приведены результаты экспериментальных исследований прочности при сдвиге, модуля сдвига и предельного угла сдвиговых деформаций каменных кладок из поризованных керамических блоков с пазогребневым соединением вертикальных швов. Исследования данных параметров осуществлялись методом диагонального сжатия образцов каменной кладки, вертикальные швы которой были выполнены без заполнения и с заполнением раствором. Установлено, что при заполнении вертикальных швов каменной кладки клеевым раствором на минеральном вяжущем существенно возрастает ее прочность на сдвиг и модуль сдвига. Указано на необходимость учета данных факторов при проектировании стен-диафрагм жесткости, разнонагруженных несущих стен, поэтажно опертых стен и перегородок, возводимых с применением каменной кладки из поризованных керамических блоков.

Ключевые слова: каменная кладка, керамические поризованные блоки, диагональное сжатие, прочность при сдвиге, модуль сдвига.

Introduction

Recently, during the construction of walls, masonry from large-format porous ceramic blocks with a width equal to the thickness of the wall has become widespread. These masonry products have profiled side faces that form a groove connection system in the joint during the construction of masonry. At the same time, vertical joints of masonry are allowed not to be filled with mortar, which significantly increases labor productivity and reduces the consumption of masonry mortar. However, as practice has shown, the walls made with the use of masonry with groove connection system of masonry units have disadvantages. The absence of mortar in vertical joints leads to a violation of the continuity of masonry and, as a consequence, an increase in the degree of anisotropy of its strength and deformation characteristics [1-5]. This circumstance negatively affects the shear and bending strength of masonry, as well as the crack resistance of masonry structures under force and temperature and humidity influences.

It should be noted that the studies of the mechanical characteristics of masonry with groove connection system without filling of vertical joints have been performed significantly less than traditional masonry, which to a certain extent constrains their use in construction practice.

Experimental research methodology

The main mechanical characteristics of masonry, which determine the stiffness and crack resistance of walls during shear, are the shear modulus, the strength of masonry during shear, as well as the limit value of the angle of shear deformations (skewness) of masonry. In order to obtain these characteristics, two series of specimens of masonry from porous hollow ceramic blocks with groove connection system with dimensions of 250x250x138 mm on standard mortar joints were manufactured and tested. Each series included three specimens of masonry. The DC-1 series specimens were manufactured with ceramic blocks with groove connection system without filling of vertical joints by the mortar. The DC-2 series specimens were manufactured with ceramic blocks with groove connection system with filling of vertical joints by the mortar for thin-layer joints of masonry. The normalized value of the compressive strength of ceramic blocks, established in accordance with STB EN 772-1, was 13.0 MPa, and the average value of the compressive strength of the masonry mortar according to STB EN 1015-11 was 15.3 MPa. After manufacturing, a vertical uniformly distributed compressive load was applied to each test specimen, so that the compressive stresses in the specimen cross section were about $2.5 \cdot 10^{-3}$ MPa. In the loaded state, the specimens covered with polyethylene film were cured for 28 days before the test at a temperature of +15...20 ° C and an air humidity of 60...70 %.

The mechanical characteristics of masonry under shear were determined by the method of diagonal compression of experimental masonry specimens in accordance with RILEM TC [6]. A general view of the masonry specimen with installed measuring devices is shown in Figure 1.

Figure 1 − A general view of the masonry specimen

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The masonry specimens were loaded using an installation equipped with a hydraulic jack with a load capacity of 250 kN and a force measuring device. The force was transferred uniformly to the specimen, while the loading speed was chosen so as to achieve the failure of the specimen within 15-30 minutes from the appying of the load. The masonry deformations in the vertical and horizontal directions were determined using clock-type displacement indicators with a graduation of 0.001 mm.

Based on the tests of the specimens, the shear strength of the masonry f_{vvo} was determined according to the equation (1):

$$f_{vvo} = \frac{0{,}707 \cdot F_{max}}{A_n} \quad (1),$$

where F_{max} – failure load;

A_n – specimen area (net).

$$A_n = \left(\frac{w+h}{2}\right) \cdot t \cdot n \quad (2),$$

where w – specimen width;

h – specimen height;

t – specimen thickness;

n – coefficient that takes into account the void ratio of masonry products (for porous ceramic blocks n = 0.48);

The value of the angle of shear deformations γ_{obs} (мм/м) was determined by the equation (3):

$$\gamma_{obs} = \frac{\Delta V + \Delta H}{g} \quad (3),$$

where ΔV – vertical compression deformations (mm);

ΔH – horizontal tensile deformations (mm);

g – distance between displacement indicators (m).

The shear module of masonry G_{obs} was determined according to the equation (4) at a load of 30% of the failure load and before the failure of the specimen.

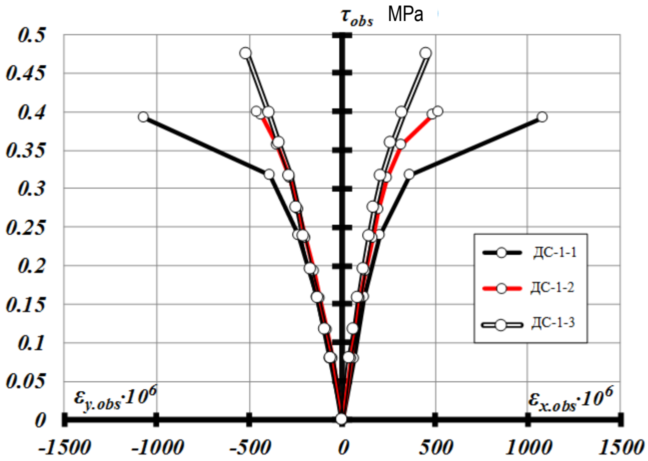
$$G_{obs} = \frac{f_{vvo}}{\gamma_{obs}} \quad (4).$$

Results of experimental studies

The failure of the DC-1 series masonry specimens was plastic and occurred as a result of their cracking along a zigzag trajectory passing along vertical and horizontal mortar joints at loads F_{max} = 49.28-59.96 kN, which corresponded to the value of shear stresses τ_{max} = 0.39-0.47 MPa. The type of the failure of the specimens and the graphs of the dependence "shear stresses τ_{obs} – strains in the horizontal $\varepsilon_{x.obs}$ and vertical directions $\varepsilon_{y.obs}$" are shown in Figure 2.

a)

b)



a) – the general view of the failure of the specimens;

b) – the relationship «τ_{obs} - ε_{obs}»

Figure 2 – Test results of DC-1 series specimens

Analysis of masonry deformation diagrams (Figure 2b) shows that with an increase in shear stresses τ_{obs} to a level of about 0,7τ_{max}, the masonry worked almost elastically, both in the direction along of action of the compressive load and in the orthogonal direction to it. At the same time, the limit value of the angle of shear deformations γ_{max} was about 1 mm/m. The average value of the shear modulus G_{obs} at τ_{obs} = 0,3τ_{max} was equal to 620 MPa, and at the stage close to failure – 360 MPa.

The values of the mechanical characteristics of masonry obtained from the test results of the DC-1 series specimens are shown in Table 1.

Table 1 – Mechanical characteristics of masonry specimens of the DC-1 series

Series No.	Specimen No.	Failure load $F_{i,max}$ (N)	Shear strength f_{vvoi} (MPa)	Limit value of the angle of shear deformations, γ_{obsi}(mm/m)	Shear modulus at τ_{obs}=0,3 τ_{max}, $G_{obs,i}$ (MPa)	Shear modulus at τ_{max}, $G_{obs,i}$ (MPa)
DC-1	DC-1-1	49280	0,39	-	543	182
	DC-1-2	50910	0,40	0, 98	650	408
	DC-1-2	59960	0,47	0, 97	656	488
Average value			**0,42**	**0, 975**	**620**	**360**

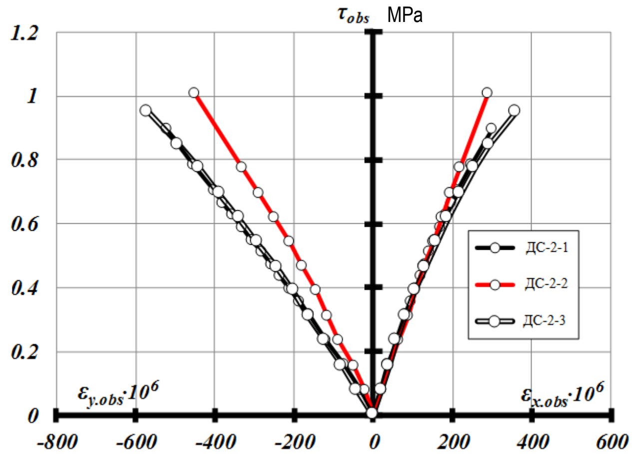
The failure mode of the DC-2 series masonry specimens was brittle because of their cracking along a diagonal trajectory at loads F_{max} from 114 to130 kN, which was more than 2 times higher than the failure load for specimens of the DC-1 series. At the same time, until the failure of the specimens, the proportionality between the increment of shear stresses and strains in the masonry remained. The type of the failure and deformation diagrams of DC-2 series masonry specimens are shown in Figure 3.

As was shown above the average value of the shear modulus G_{obs} at τ_{obs} = 0,3τ_{max} of the DC-2 series specimens was more than 2 times higher than the DC-1 series specimens. At the same time, the average value of the limit value of the angle of shear deformations of masonry specimens of the DC-2 series γ_{max} was 0.83 mm/m, which is 15 % lower than for specimens of the DC-1 series.

The values of the mechanical characteristics of masonry obtained from the test results of the DC-2 series specimens are shown in Table 2.

a)

b)



a) – the general view of the failure of the specimens;

b) – the graphs of the dependence «τ_{obs} - ε_{obs}»

Figure 3 – Test results of DC-2 series specimens

Table 2 – Mechanical characteristics of masonry specimens of the DC-1 Series

Series No.	Speci-men No.	Failure load $F_{i,max}$ (N)	Shear strength f_{vvoi} (MPa)	Limit value of the angle of shear deformations, γ_{obsi} (mm/m)	Shear modulus at τ_{obs}=0,3 τ_{max}, $G_{obs,i}$ (MPa)	Shear modulus at τ_{max}, $G_{obs,i}$ (MPa)
DC-2	DC-2-1	114000	0,89	0,82	1194	1090
	DC-2-2	130000	1,01	0,74	1475	1362
	DC-2-2	123110	0,95	0,93	1184	1023
Average value			**0,95**	**0,83**	**1280**	**1160**

Conclusion

Based on the above, the following conclusion can be made:

1. The technology of performing vertical joints of masonry from porous ceramic blocks has a significant impact on the strength and deformation characteristics of masonry under shear. According to the results of experimental studies, it was found that when filling the joint with groove connection system of blocks with the mortar, the shear strength of masonry and its shear modulus increase by more than two times
2. The results obtained are recommended to be taken into account when designing wall-stiffening diaphragms, multi-loaded load-bearing wall, floor-by-floor supported walls and partitions constructing using masonry from porous ceramic blocks. It is recommended to revise the provisions of the building regulations governing the requirements for the design of foundations in terms of the limit values of the difference in the foundation settlement of masonry walls, which are made of masonry units with groove connection system.

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