Nature of change in relative deformations of non-autoclaved cell concrete under pure shear conditions

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Abstract. Results and analysis of experimental data on tests of non-autoclave gas concrete in a biaxial stressed “compression-tension” state are presented. In addition, the shear modulus of non-autoclaved gas concrete was determined based on the results of testing the prisms in axial state without eliminating the friction. Corresponding conclusions based on test results have been drawn.

1. Introduction
Low average density of non-autoclaved cell concretes with sufficiently high strength and frost resistance and low thermal conductivity, as well as a simple technology for the manufacture of products provides a decrease in the mass of panels by 45% less than the mass of the most effective clay-expanded concrete panels, and their real cost is 18% lower. The energy intensity of the production of non-autoclaved cell concrete is 75-80% less than the energy intensity of production of clay-expanded concrete and 60-80% less than that of bricks. Non-autoclaved cell concretes allows widely using local industrial waste, such as ash from thermal power plants, waste from the chemical industry and non-ferrous metallurgy [1], local natural materials (dune sands, etc.)

Non-autoclaved cell concrete in construction is mainly used for the production of enclosing structures as a structural and heat-insulating material. The main types of products made of non-autoclaved cell concrete are as follows: small wall blocks, reinforced and unreinforced large wall blocks, reinforced wall panels, reinforced roofing and attic floor slabs, thermal insulation boards.

However, despite the existing experience in the production and use of non-autoclave cell concrete, the area of their application in construction remains limited. One of the reasons hindering the widespread use of products made of non-autoclave cell concrete is the lack of research.

In this regard, complex experimental and theoretical studies of the operation of the based varieties of non-autoclave cell concrete, both with short-term and long-term action of compressive loads, as well as with a biaxial stress state were carried out at the Scientific research, design and technological Institute of concrete [2,3].

2. Methods
Experiment has been carried out according to the methodology and on the installation [4], consisting of a U-shaped vertical frame fixed to the load-bearing floor and a suspended horizontal frame with a reverse for creating a tensile force, as well as two hydraulic jacks with a capacity of 50 kN, connected to the pumping station by application of a tensile and compressive load in steps of 0.05-0.1 of the breaking
load on axial tension. Uniform stretching was carried out using thick steel plates of self-centering grips glued to the sample with epoxy glue through wooden lugs 60 mm thick with wood fibers arranged in the direction of the tensile force. When a load was applied, the bosses were deformed across the fibers, which reduced the effect of friction on the stretched faces of the cubes.

The compressive force was applied to the sample through the ground steel plates. To eliminate the effect of friction between the plates and the sample, two celluloid plates 0.5 mm thick were installed, between which a thin layer of graphite grease was applied.

Efforts were monitored using a pumping station pressure gauge and a glass-type dynamometer installed between the frames and rigid support pads (or reverse). Dynamometers of glass type with paper-based strain gauges glued to their surface with a base of 20 mm allowed taking into account the frictional forces in jacks that arise during loading when determining the forces acting on the sample.

Tests of non-autoclave gas concrete samples with dimensions of 15x15x15 sm were carried out 162 days from the date of their manufacture under conditions of a biaxial stress state "compression-tension", equivalent to pure shear.

\[ G_1 = -G_2 = \tau_{xy} \]  

(1)

According to [5, 6], when a "compression-tension" load with equal in magnitude and opposite in sign principal stresses \( G_1 \) and \( G_2 \) is applied to the test sample, an element isolated inside with sides located at angle of 45° to the principal axes of sample will be in pure shear conditions, that is, only tangential stresses \( \tau_{xy} \) will act on the edges of this element.

The measure of deformations caused by shear stresses is characterized by the shear angle or simply shear strains \( \gamma \), which is related to the shear modulus \( G_B \) and the magnitude of the shear stresses \( \tau_{xy} \) by the following relation.

\[ G_B = \frac{\tau_{xy}}{\gamma} \]  

(2)

Where \( \gamma \) is shear angle, which is defined as double deformations of elongation of the diagonals of the element, along the edges of which shear stresses act in the zone of elastic work of non-autoclaved cell concrete. In order to avoid the influence of the presence of shrinkage cracks in the cubes, the shortening deformations were not taken into account.

During the tests, tensile and compressive deformations were measured by wire strain gauges with a base of 50 mm, their readings were measured with an AID-IM strain meter. For the purpose of mutual control, the strain gauges were glued symmetrically to opposite faces of the sample, free from loading, and their direction would coincide with the diagonals of the sample element, along the edges of which shear stresses act.

3. Results
Before testing under biaxial “tension-compression” state, in order to determine the effect of friction on durability of uniaxial compression and tension, some of the samples were tested on the same installation with friction elimination.

Table 1. Results of tests at uniaxial compression and tension with elimination of friction.

| Series | Testing form                  | \( \rho, \text{ kg/m}^3 \) | \( R, \text{ MPa} \) | Deformation at increasing moment 10-5 |
|--------|-------------------------------|-----------------------------|-------------------|--------------------------------------|
| IX     | Under axial compression       | 1191                        | 3.55              | 177.5                                |
|        | Under axial tension           | 1124                        | 0.37              | 15.25                                |

Results of comparing the experimental data obtained under uniaxial compression and tension with elimination of friction with the experimental data obtained under the same loads without elimination of
friction (table 1) show that elimination of friction in the bearing surfaces led to a decrease in the compressive durability by average of 12%, and the tensile durability, measured with the self-centering grips, decreased by 6.5%. The results obtained are consistent with the previously experimental data on other types of concrete obtained in [7].

4. Discussion
Destruction of samples tested with elimination of friction under axial compression occurs due to longitudinal cracks parallel to the action of the compressive force. In addition, with axial tension, their destruction occurs along a plane perpendicular to the action of tensile stresses.

In tests on biaxial “tension-compression” (at pure shear), it was established that the ultimate stress is 13.5% lower than at axial tension, i.e. is 0.32 MPa.

Results of these tests are shown in figure 1 a, b. Note: in the table, the ρ values are given in a naturally humid state.

Figure 1. The nature of the change in relative deformations of non-autoclaved gas concrete (on non-milled sand, IX series) during a) central compression and b) tension) (with the elimination of the effect of friction).

Similar results were obtained in [7]. The results of measuring the relative deformations are shown in figure 2. From figure 2 it can be seen that the nature of change in relative deformations of shortening and elongation is almost the same. However, to calculate the shear modulus by the formula, (2), the elongation deformations were taken into account. At the same time, it was determined that the values of the elasticity modulus in shear of non-autoclaved gas concrete is 1200 MPa, which is equal to 0.414 of its initial elasticity modulus in compression.
In addition, according to the test results of six prisms with a size of 15x15x60 cm under axial compression without eliminating friction, the shear modulus of non-autoclaved gas concrete was determined according to the well-known formula:

\[ G_B = \frac{E_B}{2(1+\mu)} \]  

Where, \( E_B = 2900 \, \text{MPa} \), \( \mu = 0.21 \).

The shear modulus value according to formula (3) is 1198 MPa, i.e. 0.413 \( E_B \).

\[ G_1 = G_2 \, \text{MPa} \]

**Figure 2.** Changes in relative deformations of non-autoclaved gas concrete under pure shear conditions.

5. **Conclusion**

Hereby, it was experimentally established that shear modulus of non-autoclaved gas concrete, determined by experiments under pure shear conditions, is equal to 1200 MPa, which makes GB = 0.41EB.

Durability of non-autoclaved gas concrete in biaxial “compression-tension” state increases. The largest increase is 20% when the ratio of the main compressive stresses is 0.4-0.6 and with uniform compression, this increase is 8-10%.

It was experimentally established that the thickness of non-autoclaved gas concrete under biaxial “compression-tension” state is 13.5% lower than under axial tension.

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