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STRENGTH AND DEFORMATION OF NON-AUTOCLAVED CELLULAR CONCRETE UNDER STATIC AND DYNAMIC LOADING

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Annotation. Results and analysis of experimental data on testing of samples - prisms made of non-autoclaved cell concrete at non-multiply load are given. According to the test results, the equations for non-autoclave cell concretes, as well as the values of the coefficient of dynamic hardening and the coefficient of operating conditions $\mathbf{m_{kr}}$, taking into account the growth of durability of non-autoclave cell concrete, have been revealed.

ПРОЧНОСТЬ И ДЕФОРМАЦИЯ НЕАВТОКЛАВНОГО ЯЧЕИСТОГО БЕТОНА ПРИ СТАТИЧЕСКОМ И ДИНАМИЧЕСКОМ НАГРУЖЕНИИ.

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Аннотация. Приведены результаты и анализ экспериментальных данных по испытаниям образцов-призм из неавтоклавного ячеистого бетона при некратной нагрузке. По результатам испытаний составлены уравнения для неавтоклавных ячеистых бетонов, а также значения коэффициента динамического твердения и коэффициента условий эксплуатации $\mathbf{м_{кр}}$ с учетом роста долговечности неавтоклавных ячеистых бетонов. раскрытый.

Introduction. Improving the efficiency of capital construction implies the widespread use of modern scientific and technical achievements, building materials and products, resource-saving technologies that reduce the consumption of materials, fuel and energy resources for the production of construction products as well as for the construction of buildings and structures.

Non-autoclaved cell concretes have porous structure and low coefficient of thermal conductivity. These concretes are belong to the most effective building materials. The mass of panels made of such concretes is 45% less than the mass of the most effective expanded clay concrete panels, and their "in business" cost is 18% lower; energy intensity production of non-autoclave cell concrete is 60-70% less energy consumption production of expanded clay concrete and 50-60% of bricks, in addition, the production of non-autoclave cell concretes is somewhat simpler than autoclave ones, since the need to use metal-intensive funded steel autoclaves is eliminated and high pressure steam is not required.

Non-autoclaved cell concretes are intended for the manufacture of reinforced concrete external wall panels, small-sized blocks, wall panels for internal residential and public buildings, and thermal insulation products.

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, experimental studies of non-autoclaved cell concretes were carried out at the Scientific research, design and technological Institute of concrete and reinforced concrete with a non-multiply load.

Methods: Tests of prisms with a size of 10x10x30 cm at non-multiply dynamic loads were carried out under central compression on a specially designed power frame with a 100 kN hydraulic jack connected to a Losenhausen hydraulic pulsator. The hydraulic pulsator allows carrying out tests with a loading frequency of 300 cycles per minute. Since the high-frequency pulsating equipment did not allow the pulsating load to be applied immediately with the programmed voltage amplitude, during testing, the output of the voltage amplitude plays a great role, on which the accuracy of the obtained experimental data depends.

Dynamic durability of the material depends on the upper limit of the pulsating load $\mathbf{\acute{G}_{max}}$ and the coefficient of asymmetry of the cycle $\rho = \frac{\acute{G}_{\min}}{\acute{G}_{\max}}$.

When tested for non-multiply loading, ρ in all cases was 0.2. According to the results of static tests of twin cubes, the upper limit of the pulsating load was assigned and it was corrected using the revealed dependences "ρ_{dry} – R"; "ρ_{dry} -$E_\text{в}$" ; " $R_\text{в}$-$E_\text{в}$" (Fig. 2.2, 2.3, 2.4, 2.5). The maximal load of the cycle was (0.56÷1.1) Rв for the first series, and (0.73÷1.16) $R_\text{в}$ for the second series.

The loading of the testing samples during the tests was carried out in the following order: first, the prototype was loaded with a static load of 0.6 max, then the upper limit $\acute{G}_{max}$ increased, and the lower limit $\acute{G}_{min}$ was simultaneously lowered until they reached a predetermined value.

Results: When processing experimental data, the main task is to select an empirical formula that provides relationship between the relative fracture stress during pulsation and the number of load cycles by the time samples fracture. According to, the first stage in determining the presence and nature of dependence is a graphical representation of experimental data in semi-logarithmic coordinates. Analysis of experimental data and their statistical processing showed that the relationship between между $\frac{\acute{G}_{max.}}{R_B}$ and lgn is well described by the linear correlation equation:

$$\acute{G}_{max} = R_B(a - b\lg n) \qquad (1)$$

In order to determine the numerical value of coefficients "**a**" and "**b**" in the formula **(1)**, the following well-known (1) linear correlation equation was solved:

$$y = M_y + \eta\frac{\acute{G}_y}{\acute{G}_x} \cdot (X - M_x) \; (2)$$

where: $\mathbf{M_y}$ is arithmetic mean of value y = $\frac{\acute{G}_{max.}}{R_B}$;

$\mathbf{M_x}$ s arithmetic mean of value X = ;

η is correlation coefficient ;

$\acute{G}_y$, $\acute{G}_x$ is the standard deviation of the values, respectively, y and x. Table 1 gives the results of statistical calculations showing the reliability of dependence (1), and Figure 1 (correlation lines 2) gives the relative dynamic strength of non-autoclaved foam ash concrete (a) and gas ash concrete (b).

Test results of non-autoclave cell concrete at non-multiply loads (Table 1).

Table 1 shows that for all series the ratio of the correlation coefficient to its average error is more than 3, therefore, according to the literature on the technique of statistical calculations, the correlation coefficients can be considered reliable and the relationship between $\frac{\acute{G}_{max.}}{R_B}$ and lgn proven.

Table 1

Set of samples (on Table II.1 II.2 and II.3)	ρ, kg/m^3	R_B, MPa	Coefficient		Correlation coefficient η	Correlation coefficient error $\pm m_\eta$	$\frac{\eta}{m}$	Number of samples tested		
			“a”	“b”				At static load		At multiply load
								10x10x x10	10x10x x30	10x10x x30
II	1008	2,25	1,066	0,088	- 0,813	0,11	7,39	30	6	30
III	951	5,012	1,057	0,040	- 0,710	0,12	5,83	42	6	42

Figure 2 (correlation line 2) shows the relative dynamic durability of non-autoclaved gas-ash concrete in dependence from lgn, taking into account the data obtained at single and low-cycle dynamic loads. From these, it is possible to write the following correlation equations for non-autoclave foam-ash concrete

$$\frac{G_{max}}{R_B}1.066 - 0.88 = lgn \qquad (3);$$

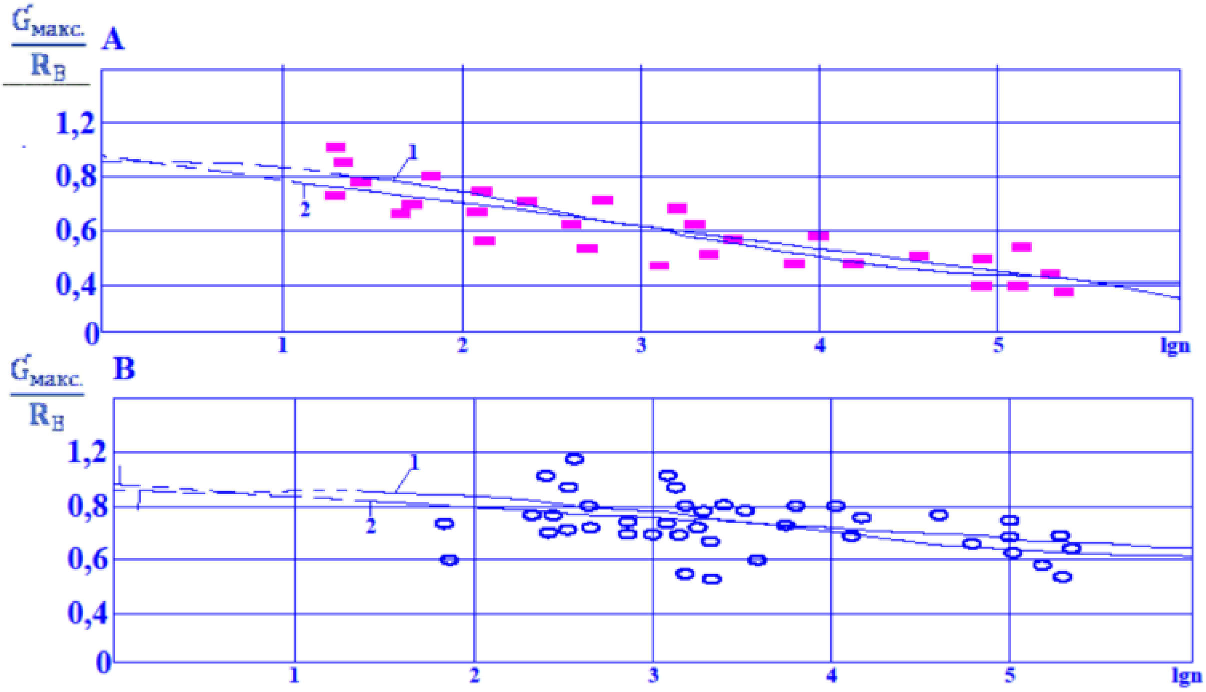

Fig. 1. Relative dynamic durability of non-autoclave foam-ash concrete “a” and gas-ash concrete “b” as a function of lgn at a non-multiply load.

1 – curve according to the formula of S.V. Polyakov (2 and 3);

2 – correlation line by empirical dependence (3 and 4)

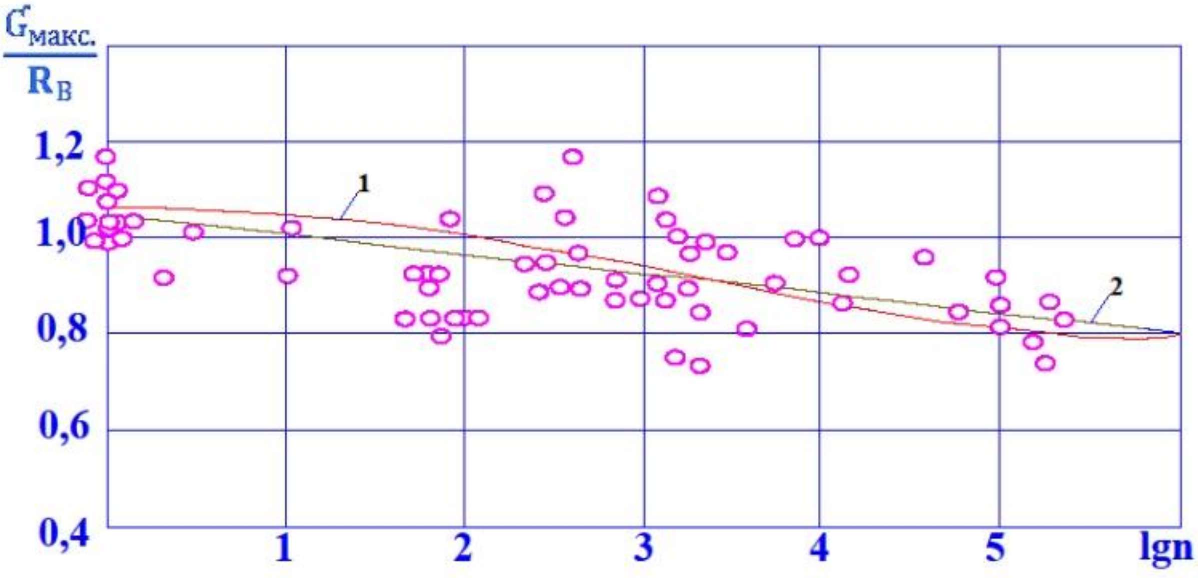

Fig. 2. Relative dynamic strength of non-autoclaved gas-ash concrete (III series) depending on lgn.

1 – curve by S.V. Polyakov's formula (8);

2 – correlation line according to empirical dependence (5).

3 – for non-autoclaved gas-ash concrete without taking into account the experimental data obtained under single and low-cycle dynamic loads:

$$\frac{G_{max}}{R_B} = 1.057 - 0.04\,lgn \quad (4)$$

4 – taking into account the data obtained at single and low-cycle loads:

$$\frac{G_{max}}{R_B} = 1.063 - 0.046\,lgn \quad (5)$$

In the studies carried out, the minimum number of cycles at fracture was equal for series II 19, III series 70, and the maximum for II series 235500, III series 230200.

Discussion: Analysis of experimental data shows that with an increase in durability of non-autoclave cell concretes, their relative durability proportionally increases (Fig. 1). Similar results were obtained in. In order to compare the experimental and theoretical data for non-autoclave cell concretes with non-multiply load with the experimental data obtained by different authors for other types of concretes, Fig. 3 shows the relative dynamic strength of concretes depending on lgn. The nature of the correlation straight lines in Figure 3 shows that at the same frequency of rotation and the coefficient of asymmetry of the cycle ρ, the change in the relative durability of non-autoclave cell concretes, depending on the number of cycles ***n***, exceeds the values for autoclaved gas silicate based on dune sands, autoclave belite cement gas concrete, autoclaved gas silicate based on loess, heavy cement concrete, and closer to expanded clay concrete, dense silicate concrete and autoclaved gas concrete on a mixed binder based on dune sand.

To solve problems related to seismic resistance, the left side of the graph is important, which is limited by the values of n = 300÷500 cycles and in, from which it follows that area of loading up to 100 cycles of repetition of the load can be taken as the criteria for assessing the strength of a material with a non-multiply loads.

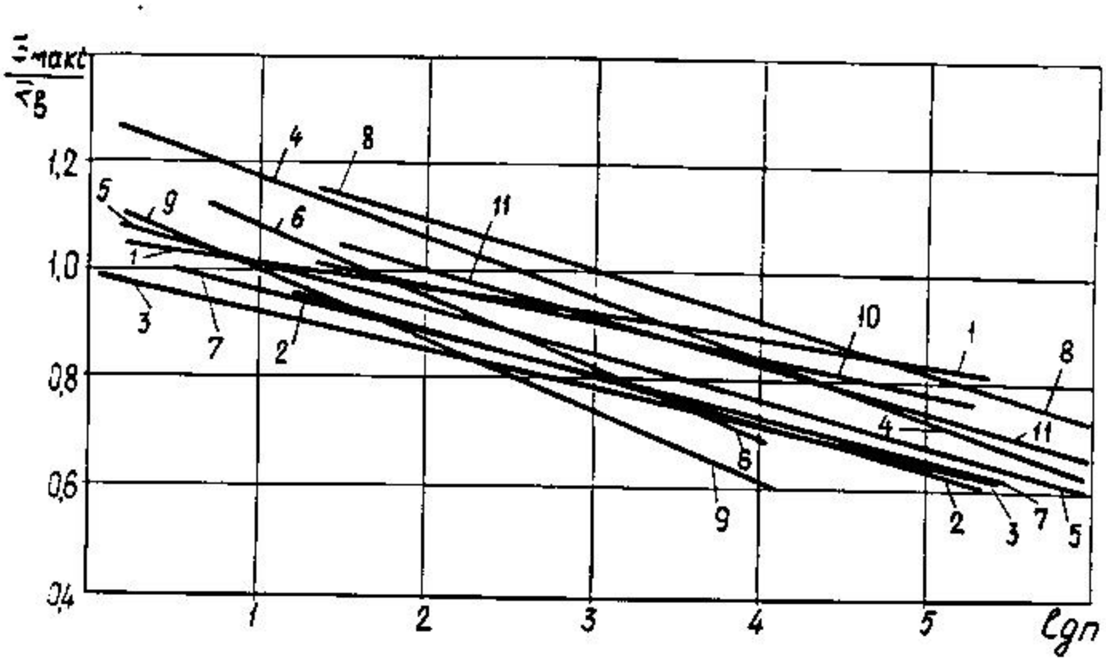

Fig. 3. Relative dynamic durability of concretes depending on lgn according to data of various authors.

1 - non-autoclaved gas concrete (III series); 2 - non-autoclaved foam-ash concrete (II series); 3 - autoclave gas silicate based on dune sands (4); 4 - expanded-clay concrete (6); 5 - dense silicate concrete (7); 6 - heavy cement concrete (5); 7 - autoclave gas silicate based on loess (4); 8 - autoclaved gas concrete (cement) based on quartz sand (2); 9 - autoclaved belite cement gas concrete (5); 10 - autoclave gas silicate based on quartz sand (9); 11 - autoclaved gas concrete on a mixed binder based on dune sands (2).

In order to assessing the dynamic durability of non-autoclave gas concretes with non-multiply load, the following dependence, proposed by S.V. Polyakov was used.

$$\frac{\acute{G}_{max.}}{R_B}=\frac{\acute{G}_B}{R_B}+\left(\frac{R}{R_B}-\frac{\acute{G}_B}{R_B}\right)*e^{-(\alpha*lgn)^m}\ \text{or}\ \acute{G}_{max}=\acute{G}_B+(R-\acute{G}_B)\,e^{-(\alpha*lgn)^m}\quad(6)$$

where $\acute{G}_{max}$ is stress at sample fracture corresponding to load repetition cycles with an asymmetry coefficient ρ and frequency ω;

$\acute{G}_B$ is absolute endurance limit at the same ρ and ω;

R is ultimate resistance at single loading at a speed corresponding to the frequency of cyclic loading;

α and m are empirical coefficients.

Because of processing the experimental data, the following parameters included in dependence (3) were determined: for foam-ash concrete (II series) , σ_B = 0.513;

R = 1.066; α= 0.295; m = 2 ; and for gas-ash concrete (III series), σ_B= 0.706 ;

R = 1.1; α = 0.225; m = 2.

Taking into account the above, the dependence of Polyakov S.V. (8) has the following form for non-autoclaved foam-ash concrete (Figure 6, a)

$$\frac{\sigma_{\text{макс}}}{R_B} = 0,513 + 0,553\, e^{-(\alpha * lgn)^m} \qquad (7)$$

for non-autoclaved gas-ash concrete (Figure 1, b and Fig. 2).

$$\frac{\sigma_{max}}{R_B} = 0.706 + 0.394\, e^{-(0,225 * lgn)^2} \quad (8)$$

It should be noted that the values of ultimate durability at a single dynamic loading, ***R***, determined by extrapolation, differ little from the experimental data. This is confirmed by the experiments carried out on non-autoclave gas-ash concrete (Fig. 1,b and 2) (straight line 2). Therefore, from equations (3 and 4), it can be assumed that the durability corresponding to a single dynamic loading exceeds the prismatic durability $\mathbf{R_в}$ by 6.6% and 5.7%, respectively.

Analysis of the nature of the straight line and the curve (Figures 1a and 2), obtained responsibly according to dependencies (6), shows that, in our opinion, the curvilinear dependence (4.7) is more acceptable for assessing the relative strength of non-autoclaved cell concrete, since the curves are better coincide with the experimental data over the entire range of loading numbers ***n***. The nature of the destruction of non-autoclave cell concrete at a non-multiply load is given in Fig. 4. The destruction of the prototypes occurred with a sound effect immediately after the appearance of cracks on their surface.

Hereby, the relative dynamic durability of non-autoclaved gas-ash concrete over the entire range of loading numbers ***n*** exceeds the corresponding values for non-autoclaved foam-ash concrete. In general, the studies carried out have shown that the behavior of non-autoclave cell concretes does not fundamentally differ from autoclave ones. When using non-autoclave gas-ash concrete and foam-ash concrete in the structures of buildings raised in seismic regions, and calculating structures, the value of the coefficient of operating conditions $\mathbf{m_{kr}}$, taking into account the growth of their durability and time can be taken for non-autoclave gas-ash concrete $\mathbf{m_{kr}}$ = 1.1, and for non-autoclave foam-ash concrete: $\mathbf{m_{kr}}$= I

Conclusion:

1. It has been established that the value of coefficient of dynamic hardening of non-autoclave gas-ash concrete is equal to $\mathbf{K_d}$ = 1.1.

2. To assess the low-cycle dynamic durability in the range of loading numbers 1 < ***n*** <100 cycles, the following dependence can be used:

$$\sigma_{max} = R_B\,(\alpha - lgn)$$

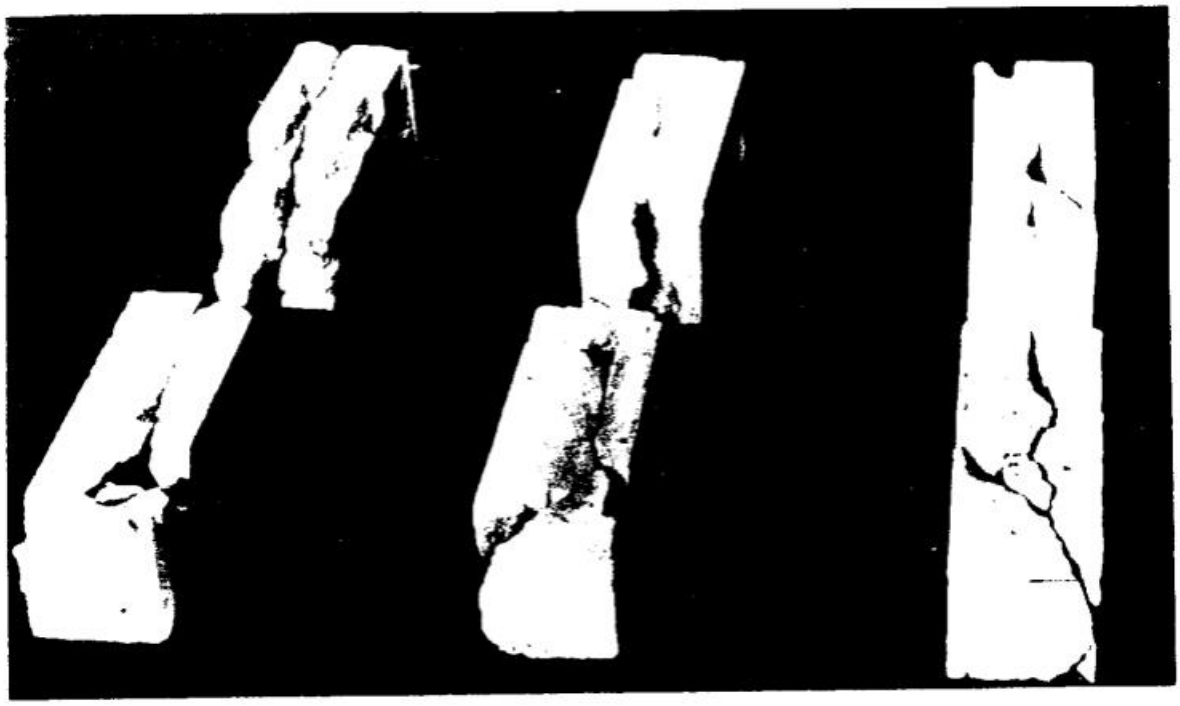

Fig. 3. Nature of the destruction of samples at non-multiply load.

3. Change in the relative durability of gas-ash concrete under low-cycle dynamic loading, depending on the number of load cycles, is close to established value for heavy concrete.

4. The new test methodology at non-multiply loads have been developed and reliably tested.

The value of the speed (***t*** = 0.05-0.06 sec) of loading the prototypes under single dynamic loads corresponds to those speeds that arise under seismic influences, and the time for outputting the stress amplitude with non-multiply dynamic loads is maximally reduced, i.e. from 100 to 30-50 cycles.

5. It was revealed that with increase in durability of non-autoclave cell concretes, their relative dynamic durability increases too.

6. Dependence (4.7) is more acceptable for most reliable assessment of relative durability of non-autoclave cell concrete at non-multiply load.

7. Non-autoclaved cell concrete can be used in seismic regions of the country.

8. Experimentally and theoretically have been established that the coefficient of nodal work $m_{кг}$ for non-autoclaved gas-ash concrete should be taken 1.1, and for non-autoclaved foam-ash concrete should be taken 1.

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