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Experimental Research on Reinforcement Voltage Loss Caused by Creep of Autoclaved Aerated Concrete

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Abstract – The article presents the outcomes of experimental research on reinforcement voltage loss caused by creep of autoclaved aerated concrete for the preliminary stressed aerated members. It has been stated that the losses have linear dependence on the initial level of reduction in aerated concrete in the scope of 0.30 to 0.60 Rbn, and the possible losses are 22-30%. The residual stress in prestressed reinforcement is in the scope from 117 to 245 MPa, which is sufficient for providing operating cracking resistance of large size items made of autoclaved aerated concrete under the conditions of moisture exchange and carbonizing processes. The obtained results are crucial for the further method of evaluating voltage loss caused by creep and preparation of practical recommendations on designing large size prestressed cellular-concrete items.

Keywords – autoclaved aerated concrete; prestressed elements; concrete creep; voltage loss; cracking resistance; durability

I. Introduction

The extensive on-site investigation of the accommodation units with external wall panels made of autoclaved cellular concrete was carried out to assess their cracking resistance and durability during operation. The outcomes have shown that shrinkage cracks appear on the walls' surface from the impact of moisture exchange and carbonizing processes [1-7, 9].

The studies of E.S. Silayenkov [1] indicated that single cracks 0.2-0.3 mm wide (coming up to 0.5-0.7 mm) appear on wall panels made of cellular concrete during their operation from 5 to 6 months up to 1.5 years. These cracks divide the panels into certain segments and subsequently lead to the formation of a larger amount of narrower cracks (0.15-0.25 mm) concentrated inside the segments restricted by initial cracks. It was expected that the first cracks which appeared on the panels' outer surface are caused by drying out and the succeeding ones by the impact of the autoclaved cellular concrete carbonation.

Such dynamics of appearance and development of surface cracks is stipulated by the fact that calculated combined tensile shrinkage stresses which occur in the outer layers of a wall panel under the conditions of their concurrent behavior through-the-thickness (under a variety of working life starting from 6 months) can be equal to 0.5-1.4 MPa. These shrinkage stresses go 1.5-4 times beyond the limit of the tension breaking strength of cellular concrete used in building envelope, which inevitably leads to the crack growth and extension up to the inappropriate width [9].

II. Methods and Materials

Hardening cracking resistance and increasing durability of large size items made of cellular concrete is a multi-scale problem and it requires a complex solution both via working methods and constructive measures.

The working methods and the methods to manage operational deformability and cracking resistance of cellular concretes through the algorithms of constructing their optimal content characteristics and the structure of the powder phase and pore space on the basis of the complex of set parameters and compound technology factors of their regulation which provide high durability of cellular concretes developed by academic E.N. Chernyshov [5-6].

The research conducted in 1990s on the basis of Research institute of concrete and reinforced concrete (NIIZHB), Research institute of building constructions (TSNIISK), Ural PromstroyNIIproekt and Polytechnic University has shown that one of the constructive measures directed at cracking resistance hardening and increasing the durability of outer wall panels made of autoclaved cellular concretes is the application of stressed reinforcement [1].

Prestressing can have a significant influence on increasing the durability of cellular concrete constructions as it enables to eliminate technologic cracks formed at the stage of production and excludes the appearance of new cracks under operation conditions at moisture carbonizing grade influence [8, 10].

The influence of concrete creep and shrinkage in prestressed elements is rather high as these factors significantly alter the initial prestressing by limiting its impact and deteriorating the time of its operation.

The objective of this experimental research is to measure the actual value of voltage loss in reinforcement due to concrete creep in prestressed elements made of autoclaved aerated concrete with the concurrent test samples-twins (under the constant and reduced in time reduction pressure) whose initial level varied from 0.3 to 0.6 of prismatic strength. This information is crucial for the further processing on the basis of the existing creep theory of the engineering approaches to calculate the possible voltage losses in reinforcement when designing crack resistant large size items made of aerated concrete.

The long-time testing was posed on 18 prestressed aerated elements isolated from drying out and having the following size: 120x150x1200 mm, with the holes along the mechanical center and on three samples-twins (not subjected to prestress) with the same parameters to control thermal deformations. Prestressing was made by one pivot with the diameter equal to 12 mm and made from steel of class A600(A-IV) with the elastic module Es=1.9*105 MPa and an ultimate tensile stress R sn=590 MPa.

The reinforcement stretching force was transmitted to concrete through steel plates, a dynamometer and the threaded socket which assisted in choosing the isolation joint preventing the reinforcement elongation at tension. The intensity of stress posed on reinforcement was controlled according to the scale of a dial test indicator with the division value equal to 0.001 mm set on a purpose made dynamometer adjusted on a plant press. The collet closing mechanism of NIIZHB type was applied at one of the butt ends of prestressed aerated elements used for grasping the reinforcement.

The research was carried out on autoclaved aerated concrete with the density equal to 600 kg/m^3 with the prism strength Rbn=3.2 MPa and the elastic module Eb = 2100 MPa. The initial levels of concrete reduction in prestressed elements were equal to 0.30, 0.45 and 0.60 Rbn, which complied with the initially controlled values of prestress in reinforcement rods equal to 175 MPa and 350 MPa.

Figure 1 presents an overall view of the test prestressed elements with the appliances and measurement units for tensioning in reinforcement and controlling the corresponding tensions in it as well as for measuring long-term deformations in concrete. The voltage losses in reinforcement and concrete creep in prestressed elements at each level of reduction were determined based on the results of testing six samples-twins.

The long-time testing of 18 prismoidal specimen with the size 100x100x400 mm (6 specimen for each level of reduction) was conducted with the objective to study the creep deformations of the given aerated concrete at the same levels of reduction in concrete but with the constant pressure load. Three unloaded specimen (patterns for eliminating deformations caused by room temperature fluctuation) were also studied along with the loaded prisms.

Fig. 1. Overall view of prestressed elements made of aerated concrete during long-term testing on framework meters.

Performance and design characteristics of autoclaved cellular concretes for the condition of an average stated concrete moisture equal to 10% by mass are used under the conditions of static calculations of the elements of cellular-concrete constructions. Therefore, we conducted the research with the objective to determine voltage losses in reinforcement caused by concrete creep on the prestressed elements and prismoidal specimen which were waterproofed with adhesive foil and paraffin wax under the same degree of concrete moisture.

To maintain the experimental integrity the impact of reinforcement creep on voltage loss was eliminated by means of its preliminary stretching up to the pressure equal to 0.9 from the design strength.

The deformations of aerated concrete creep in prestressed elements (Figure 1) were measured with the dial test indicators graduated in 0.01 mm and dead installed along two opposite facets on the base of 350 mm. the deformations of prismoidal specimen applied in the experiment were measured with regards to simple creep on the base of 200 mm (Figure 2).

Fig. 2. Cassette-spring instalements for studying creep in aerated concrete prismoidal specimen

Figure 3 demonstrates the curves of relative strains of aerated concrete creep. The curves were constructed on the basis of average indicators of the affined element and prismoidal specimen groups under the different levels of pressure in concrete.

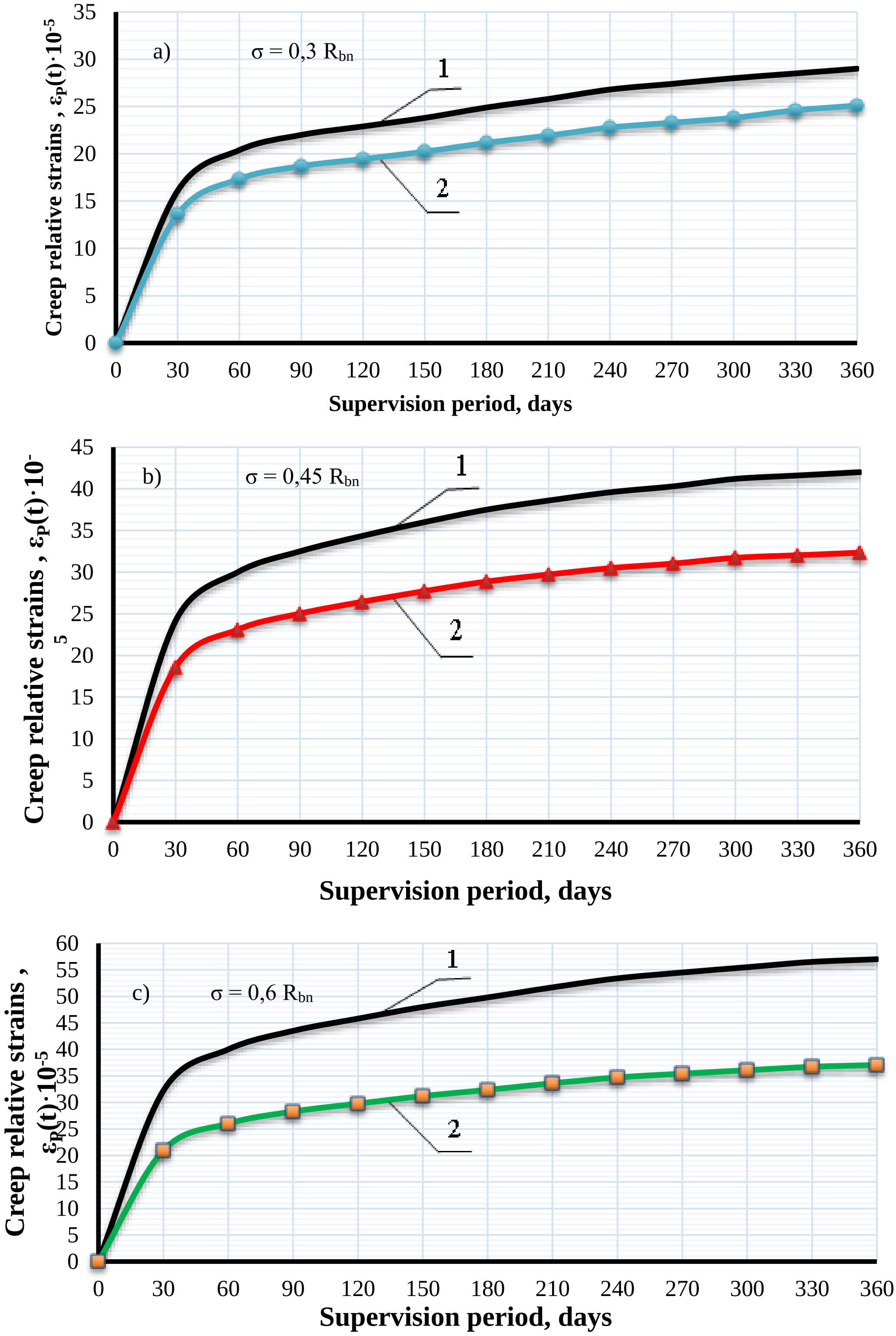

Fig. 3. Aerated concrete creep in prestressed elements and prismoidal specimen: a, b, c are the initial levels of concrete reduction 0.3; 0.45; 0.6R_{bn} correspondingly; 1 is prismoidal specimen creep; 2 is prestressed elements creep

As we can see from Figure 3 the process of aerated concrete creep in prestressed elements under fluctuating stress in reinforcement is qualitatively similar to the corresponding processes of concrete creep in prismoidal specimen under long-term exposure of constant stresses. However, the speed and degree of concrete long-term deformation decrease by means of decreased stress period in prestressed reinforcement. Aerated concrete creep deformation in the studied prestressed elements under the levels of concrete reduction 0.30, 0.45 and 0.60 R_{bn} were correspondingly 85, 77 and 65% from the concrete deformation on prisms under the constant compression stresses by the 360th day of supervision.

According to the experimental results the voltage losses in reinforcement were determined by the formula:

$$\sigma_{sp}(t) = \sigma_{01} - \sigma_{02}(t), \quad (1)$$

where $\sigma_{sp}(t)$ are the losses of prestressing in reinforcement under the concrete reduction t; σ_{01} is the stress in reinforcement under the concrete reduction; $\sigma_{02}(t)$ is the stress in reinforcement at the time t in view of the concrete creep current losses:

$$\sigma_{02}(t) = \frac{\sigma_{01} - \varepsilon_s(t)E_s}{1-\mu_H n_t}, \quad (2)$$

where $\varepsilon_s(t)$ is reinforcement deformation due to concrete creep;

$$\mu_H = \frac{F_s}{F_b + nF_s}; \quad n_t = \frac{E_s}{E_b(t)}$$

(F_s and F_b are the areas of reinforcement cross-section and concrete correspondingly; E_s, E_b (t) are the elastic modules of reinforcement and concrete. Herewith, the value of the initial elastic module is set being constant in time.

Simultaneously, prestress losses in reinforcement due to aerated concrete creep were controlled according to dial test indicator scale with 0.001 mm division value set on a purpose made and adjusted dynamometer (Figure 1). It is worth noting that the losses calculated according to the formulas (1) and (2) were different from the values recorded by means of the dynamometer in scope of 5 to 10% depending on the level of pre-stretching in reinforcement.

As we can see from Figure 4 the losses of prestressing in reinforcement have linear dependence on the initial level of reduction in aerated concrete in the scope of 0.30 to 0.45 Rbn. However, when reaching the level corresponding to 0.60 Rbn especially at the moments close to supervising the losses, they grow negligibly. Thus, some nonlinear dependence occurs in this case within the testing timeframe of 30-45 days. Thereafter, the stress degree drops in the concrete due to the great decrease of stress in the prestressed reinforcement with the level reduction equal to 0.60 R_{bn}, which unquestionably leads to turning nonlinear dependence into linear one. The analysis of the obtained results enables to recommend the 0.45 – 0.60R_{bn} level of preliminary reduction in concrete for the prestressed elements made of aerated concrete as the maximum one. This level corresponds to the border of linear creep for autoclaved cellular concretes.

The losses of preliminary stress in reinforcement linked with fast flown creep deformations under the conditions of transmitting the force to aerated concrete elements of the autoclave curing were so small that they can be neglected.

Figure 5 presents the dependences of time-edge stress on the time of various initial levels of reduction in concrete in order to enhance the understanding of the developmental character and the degree of press drop in reinforcement on the aerated concrete creep in prestressed elements.

The empirical evidences suggest that the processes of stress relaxation in prestressed reinforcement run with approximately equal speed without regard to the length of supervision and the value of the initial stress level in it and in concrete.

Herewith, the values of relative prestress losses (in reinforcement) occurring during the equal time periods differ from each other in the scope of 4 to 8%.

On the basis of the experimental research we can state that the possible losses in reinforcement for prestressed elements made of autoclaved aerated concrete are from 22 to 30% due to its creep. The mentioned losses occur during 360 days under the initial reduction level in concrete equal to 0.3 to 0.6 Rbn. Herewith, the absolute values of residual stress in the prestressed reinforcement were equal to 117, 164 and 245 MPa, which provides the following levels of reduction in concrete: 0.74, 1.03 and 1.54 MPa correspondingly. These levels are sufficient for neutralizing the tensile and shrinkage stresses in the uppermost layers of wall panels made of aerated concrete.

III. Conclusion

1. The losses of prestressing in reinforcement caused by concrete creep in the elements made of cellular concretes have linear dependence on the initial level of reduction in concrete up to 0.60 Rbn, and the possible volume of their losses makes 22-30% out of their initial value.
2. The residual stresses in reinforcement provide the appropriate reduction level in concrete. This level is sufficient for closing possible technologic cracks up as well as for eliminating new cracks in panels made of aerated concrete under the conditions of moisture exchange and carbonizing processes during exploitation.
3. In future it is necessary to devise engineering approaches for determining the stress losses in reinforcement caused by concrete creep with the objective to prepare the recommendations concerning design and production of large size prestressed elements made of aerated concrete.

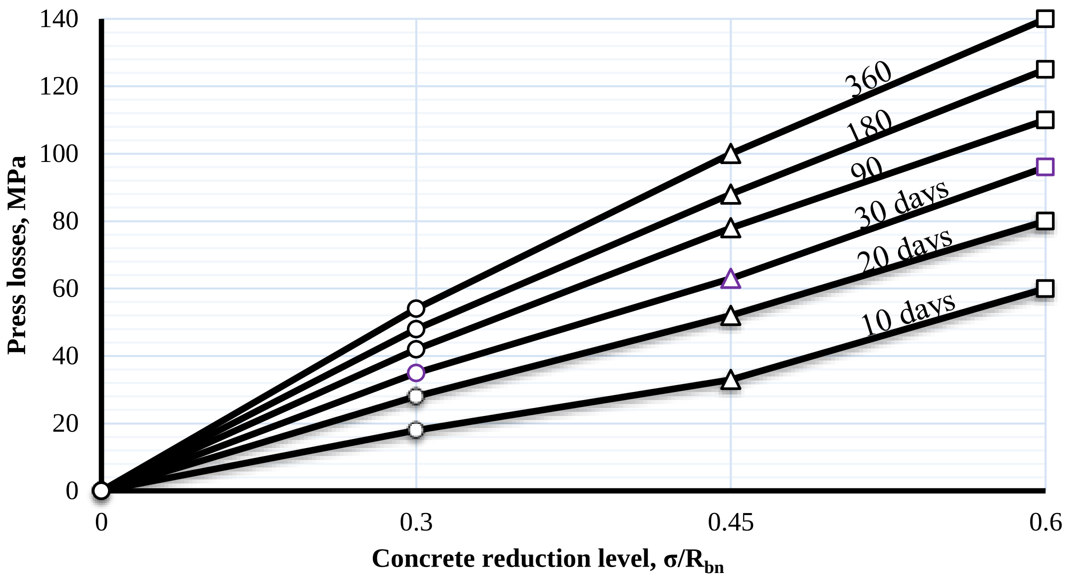

Fig. 4. Dependence of stress losses in reinforcement on the initial concrete reduction level during the equal periods of supervision

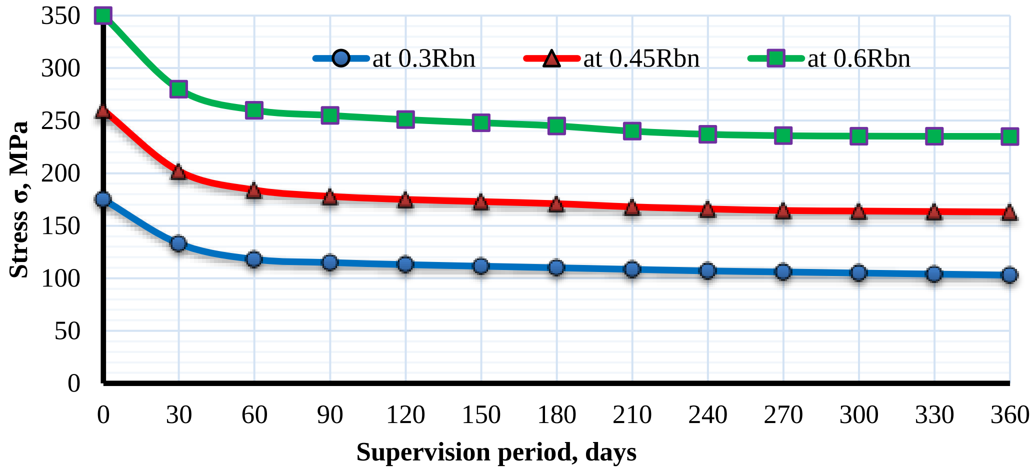

Fig. 5. Curves of stress relaxation in reinforcement under different levels of reduction of prestressed elements made of aerated concrete.

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