საქართველოს მეცნიერებათა ეროვნული აკადემიის მოამბე, ტ. 12, №2, 2018
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# Study of the Strength and Deformability of Compressed Concrete according to Creep Adsorption Theory

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**ABSTRACT. According to the results of the study of the effect of the compressed deformation of the concrete creep from the position of the creep adsorption theory of solids, it can be concluded that at compression of creep deformation with the stress concentration decreasing water wedging action decreases as well, which ultimately leads to substantial increase of the concrete strength. In the areas of stress concentration in concrete, reversible microcracks in the region of elastic deformation are more actively revealed, which causes the creation of uncompensated surfaces and surface energy in concrete. The free migrating water in concrete as surfactant acts as additional stress, of the wedging action in reversible microcracks and, hence, there will be a greater adsorption of water effect. As a result, the strength is greatly reduced. To increase the strength it is necessary to limit the process, restrict it by reinforcement, friction or other means. It is the main physical essence of this effect by new approach.** *© 2018 Bull. Georg. Natl. Acad. Sci.*

**Key words:** strength, deformability, endurance limit, reversible microcracks, wedging action of water

Numerous experimental and theoretical studies show that compressed deformation of the concrete creep caused by reinforcement, friction, etc., increases the ultimate tensile and ultimate strength of concrete, and the greater the degree of compression, in particular, the larger the reinforcement and the more dispersed it is distributed [1-3]. At first, it was explained by the fact that concrete as a roughly heterogeneous material contains many different defects, at the edges of which concentration of stresses takes places, which greatly reduces its strength and extensibility. In order to increase the strength of concrete, it is necessary to eliminate or at least reduce the effect of stress concentration, which can be achieved by compressing the tension of the concrete creep [4].

Any destruction in concrete occurs when it reaches the actual strength limit R and the ultimate elastic deformation $\varepsilon$lim. In this case, the work equal to the area 0Nn is performed (Fig. 1). When the loading speed changes, its strength also changes. Experiments on dry, air-dry and water-saturated concrete show that the additional stress is caused by the wedging action of water or, sorption load. It is noted that "for calcium hydrosilicates and materials on portland cement, the sorption load at all values, including the maximum, acts like mechanical one." Therefore, the destruction of concrete in time comes with the total work of the external force, expressed by the area of the trapezium Obb'n, and the additional work from the wedging action of water equal to the area of the triangle BB'N, which in sum is equal to the area of the triangle 0Nn (Figs. 1, 2).

According to the results of the study of the effect of the compressed deformation of concrete creep from the position of the creep adsorption theory of solids, it can be concluded that, in the case of a creep compressed deformation, the wedging action of water decreases simultaneously with decrease in the stress concentration, which ultimately leads to substantial increase in the strength of the concrete. After all, in the areas, where stresses are concentrated in concrete, reversible microcracks (in the region of elastic deformation) are more intensively disclosed and, consequently, there will be a greater adsorption effect of water, i.e. greater wedging effect of moisture. As a result, strength is greatly reduced. To increase the strength it is necessary to limit, to restrict this process. This is the physical essence of this effect from new approach.

## Experiments and methodology

To assess the effect of the compression of deformation of ultimate tension on limiting characteristics of concrete, 48 concrete prisms 10x10x30 cm were made and tested. Concrete was prepared on the washed dry gravel (5-20 mm) and sand sieved through 5 mm sieve from the quarry of the Kvirila River. Slag Portland cement of the Rustavi cement plant M400 with consumption, kg of materials per 1 m3: cement - 320; gravel - 1120; sand - 650; water - 180 (2 330 kg / m3) was used as a binder. Mobility according to the Stroi-TsNIIL cone is 3 cm; the duration of vibration is 20 sec.

Two days after producing the samples, they were dismantled and placed in a sensitive facility under normal temperature and humidity conditions (with a relative humidity of 70%, temperature 20°C). After two and a half months, one-half of the samples were put into the water, while the remaining half were kept in air-dry environment. At three months of age, the concrete prisms were tested in axial compression at a pressure H-50. It should be pointed out that 12 samples from each series were tested without friction, while the remaining twelve - with friction. The friction between faces of the prism and supports was smoothed by attaching paraffin to the faces of the prism.

Longitudinal deformations were measured with resistance sensors with the base 50 mm attached to two opposite faces of a prism. The sensors were isolated from the impact of water by applying to them a thin layer of rubber cement 88. The sensor readings were registered with two dielectric testing equipments for fixing deformations on each sensor separately with price pressure 10-5.

The sequence of experiments performed was similar. First, the ultimate strength was determined on three samples for each series at the rate of loading of 15.0 MPa/s and its corresponding stress–strain. For samples with compressed deformation intended for air-dry keeping, the ultimate tensile strength amounted to R=27.5, ultimate strain $\varepsilon=122\text{x}10^{-5}$, and modulus of elasticity $E=25\text{x}10^{2}$. For water-saturated samples with compressed deformation R=27.0; ε=125x10-5; E=25x106. For air-dry concrete prisms without friction R=22; ε=98x10-5; E=2500, and for water-saturated prisms without friction R=21; ε=98x10-5; E=2500.

Then ultimate strength and its corresponding stress–strain were determined in a general way, i.e. at the loading rate of 0.2 MPa/s. A chart tension-deformation was plotted. As a result of the test of three prism samples, the ultimate strength and ultimate strain of air-dry compressed concrete amounted to R=23.8; ε=17.0x10-5; for water-saturated compressed concrete R=13.2 MPa;

ε=175x10-5; for air-dry uncompressed concrete R=20 MPa; ε=102x10-5 and for water-saturated uncompressed concrete R=13,2 MPa, ε=100x105.

The results of the test are set out in Figs. 1 and 2.

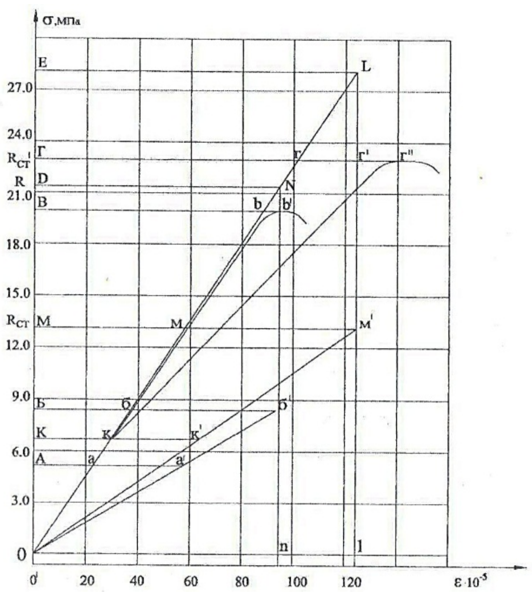

**Fig. 1.** Graphs σ-εfor air-dry, uncompressed Ob' and compressed Oг" concretes:
OL – ultimate strength of compressed concrete at momentary application of force; OΓ – strength of compressed concrete at a loading speed of 0.2 (MPa); Nn – vertical line of indices of limiting characteristics of free concrete; LI – vertical line of indicating the order of occurrence of microcracks in the compressed concrete; OM – ultimate strength of compressed concrete; Бб – ultimate strength of uncompressed concrete

Based on the analysis of the diagrams in the Figs. 1 and 2, it can be concluded:

Initial modulus of concrete elasticity obtained during instant application of force for all cases examined (dry, air-dry, water-saturated concretes with friction or without) turned out to be constant.

The ultimate strength and its corresponding ultimate compressibility for air-dry and water-saturated compressed concrete do not differ greatly from each other, and the speed of load application has little impact on the strength.

Ultimate strength of air-dry uncompressed concrete is greater than that of water-saturated uncompressed one. The slower is the load applied, the more is its value. Nevertheless, both have equal ultimate strength. OM is a fatigue limit of compressed concrete, and mm' - its corresponding creep deformation that intersects the vertical Nn line at the specified point.

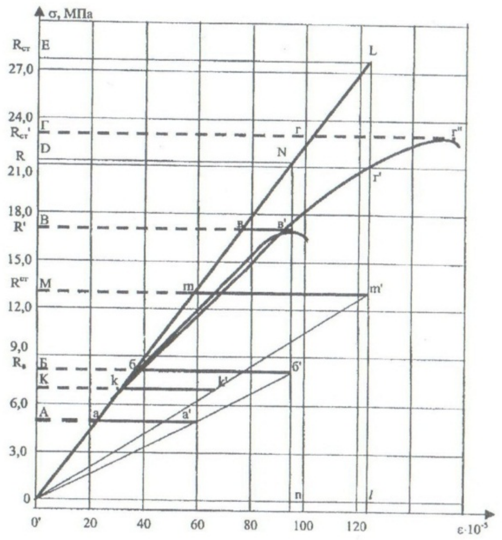

**Fig. 2.** Graphs σ-ε for water-saturated uncompressed Ob' and compressed Oг" concretes:
OL – ultimate strength of compressed concrete at momentary application of force; OΓ – strength of compressed concrete at a loading speed of 0.2 (MPa); Nn – vertical line of indices of limiting characteristics of free concrete; LI – vertical line of indicating the order of occurrence of microcracks in the compressed concrete; OM – ultimate strength of compressed concrete; Бб – ultimate strength of uncompressed concrete

In the absence of friction, the points of the graphs σε are located on vertical Nn line and simultaneously they are endpoints of ultimate strain. OБ - it is fatigue strength of compressed concrete, and bb' – its corresponding creep deformation that intersect vertical Ll line at the specified point.

In the presence of friction, vertical Nn line goes right to Ll, while the breaking points will be located to the right and above Γ". The points of intersection of these graphs will be the endpoints of ultimate strain and they will be located on the new vertical Ll line, to the right and above mm'. The specified elastic deformations are the limit for microcrack formation of compressed concrete or area for their elastic deformation. In this case, concrete is still in steady state, although irreversible microcracks have already appeared and developed in it what is clearly seen in the graph OΓ".

*სამშენებლო მექანიკა*

# ბეტონის შეზღუდული გაჭიმვის დეფორმაციის გავლენის შესწავლა მის სიმტკიცესა და დეფორმაციაზე ცოცვადობის ადსორბციული თეორიის მიხედვით

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მყარი ტანის ადსორბციული თეორიის პოზიციიდან ბეტონის გაჭიმვის დეფორმაციის შეზღუდვის ეფექტის გათვალისწინებით ჩატარებული ექსპერიმენტების დროს მიღებული შედეგების თანახმად შეიძლება დავასკვნათ, რომ გაჭიმვის დეფორმაციის შეზღუდვა ძაბვების კონცენტრაციის შემცირებასთან ერთად ზღუდავს და ამცირებს წყლის გამხლეჩ მოქმედებასაც, რაც საბოლოო ჯამში მნიშვნელოვნად ზრდის ბეტონის სიმტკიცეს. ეს მოვლენა შესაძლებელია ასე აიხსნას: ბეტონის ძაბვის კონცენტრაციის ადგილებში ინტენსიურად იხსნება შექცევადი მიკრობზარები, რაც იწვევს ბეტონში არაკომპენსირებადი ზედაპირების შექმნას და ზედაპირული ენერგიის წარმოქმნას. ბეტონში არსებული თავისუფლად მიგრირებადი წყალი, როგორც ზედაპირულად აქტიური ნივთიერება მოქმედებს, როგორც დამატებითი ძალა, რომელიც გამოიხატება წყლის გამხლეჩი მოქმედებით შექცევად მიკრობზარებში, რის შედეგადაც მნიშვნელოვნად მცირდება მისი სიმტკიცე. სიმტკიცის გაზრდისათვის კი აუცილებელია ამ პროცესის შეჩერება, შეზღუდვა არმირებით, ხახუნით ან სხვა საშუალებებით. სწორედ ამაში გამოიხატება აღნიშნული ეფექტის ფიზიკური არსი ახალი პოზიციებიდან.

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