THE STRENGTH OF REINFORCEMENT CONNECTION WITH CERAMSITE CONCRETE

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Annotation. *The article discusses the results of experimental research on the durability of A400 grade reinforcement connections with structural ceramsite concrete. Variations in the reinforcement diameter and the strength of the structural ceramsite concrete in the connection were considered as influential factors. The analysis and conclusions based on the results have been provided.*

Keywords: *Reinforcement, structural ceramsite concrete, testing, results, analysis, strength, connection.*

INTRODUCTION

The durability, load-bearing capacity, and reliability of a reinforced concrete structure during its operational lifespan are determined by the integrity of the reinforcement bars bonded with concrete. This indicator establishes the ability of a reinforced concrete structure, composed of two materials, to function as a cohesive and reliable system.

An inspection of operational reinforced concrete structures reveals that a significant portion of damage and defects occurs as a consequence of the deterioration of the bond between the reinforcement bars and the concrete. Such defects can potentially emerge during the construction of reinforced concrete structures and persist throughout their operational use.

Materials' Characteristics and Testing Methods

The method relied on increasing the volume of the primary expanding agent to identify the optimal compositions for structural ceramsite concrete [1], which means increasing its quantity beyond 0.85 m3. This method has a positive impact on the structure of ceramsite concrete, where it encourages a significant portion of the water in the concrete mix to be absorbed by the ceramsite particles, enhancing the density and strength of the contact zones. Additionally, it promotes better bonding between the contact zones and increases the strength of the cement-sand mixture.

The compositions of ceramsite concrete based on this method are listed in Table 1.

Table 1: Composition of Ceramsite Concrete

Ceramsite concrete class	Material consumption per 1 m^3						Water/cement ratio
	Portland cement, kg	Fine sand, kg	Ceramsite (L) fractions (mm)			Unit weight, kg/m^3	
			Sand 0-5	5-10	10-20		
B12.5	275	520	130	400	600	1500	0.65
B15	350	500	117	400	560	1635	0.57
B25	475	600	-	300	540	1710	0.52

Note: The consistency of ceramsite concrete mix complies with the standard cone of 2-4 cm.

Materials used for preparing ceramsite concrete mix include:

- Portland cement M400, with a 28-day strength of 41.5 MPa;
- Local ceramsite, bulk density ranging from 550 to 570 kg/m^3, and a compressive strength of 3.0 to 3.8 MPa when tested in a standard cylinder;
- Fine sand with a fineness modulus (Мкр) of 1.5 to 1.7 and a bulk density of 1400 kg/m^3;
- Water, obtained from the general water supply.

To assess the strength of ceramsite concrete, 15 cm cube specimens were prepared in metal molds. After demolding, they were stored under laboratory conditions (t=20±5 °C, W=70±5 %) until the testing day. Cubes of the same dimensions were also prepared with A400 grade reinforcement bars, intended for studying the bond strength between temporary reinforcement and structural ceramsite concrete. These specimens were also stored under laboratory conditions until the testing day.

The strength of ceramsite concrete was determined according to GOST 10180 – 2012 [2] by hydraulic pressing of samples at 28 and 60 days. Table 2 presents the average values of concrete strength (based on 3 samples).

Concrete Strength (Results of Quality Control Tests)

Table 2

Type of Concrete	Concrete Class	Strength, MPa	Age of Samples, Days	Density, kg/m^3
Ceramsite Concrete	B12.5	16.2	28	1450
		16.5	60	1440
	B15	21.5	28	1600
		22.0	60	1580
	B25	32.0	28	1680
		32.8	60	1650

According to the results presented in this table, the specified composition of concretes provides the expected results in terms of strength, and it is possible to prepare samples of the main studies from them. The laboratory conditions in which the samples were stored did not have a negative effect on the strength of the concrete, as no decrease in strength was observed in the 60-day-old samples.

Determination of the mechanical properties of reinforcements was carried out by stretching their samples according to the requirements of GOST 12004-81. Such tests were carried out on GRM-1 hydraulic machines in the Turin investment engineering laboratory. In the experiments, local reinforcement rods meeting the current standard were used.

Results and their analysis

The connection of reinforcement with concrete ensures that they resist displacement together. This resistance depends on many factors, confirmed by the results of the conducted studies. Among these factors, the type of concrete is also important. In particular, the issues of connection with reinforcement for structural ceramsite concrete have not yet been sufficiently studied. Any research conducted in this direction is evaluated by its relevance, because the use of structural ceramsite concrete in pre-strengthened reinforced concrete structures has its own effect. Their use in the conditions of our republic increases the earthquake resistance of buildings and structures.

The conducted tests are based on the pressing of the reinforcing rod located in the center of the ceramsite concrete cubes.

During these tests, as a result of the increase in tension, the contact bonds between the reinforcement and ceramsite concrete begin to break, microcracks are formed, and the reinforcement is pushed out of the sample due to the rapid development of transverse stretching deformations.

Due to the relatively small number of connections of the reinforcement, the reinforcement compresses the samples of B12.5 class ceramsite concrete without breaking. It was observed that the reinforced concrete samples with strength class B15 were broken into two pieces, and when the class was B25, the sample was broken into three pieces. Of course, the nature of such a failure depends on the tensile strength of ceramsite concrete and its limit tensile deformations. The failure begins with the breaking of the thin bonds between the reinforcement and the concrete, because they cannot withstand the critical stresses that have arisen. After that, the movement of the reinforcement to the lower side accelerates, and finally, the formation of longitudinal cracks on the surface of the sample was observed.

Based on the obtained test results, the test stresses were calculated as the ratio of the ultimate stress in the reinforcement to the surface of the anchored reinforcement.

The test results for the studies are presented in Table 3.

Table 3

Ceramsite concrete class	Strength of ceramsite concrete on the test day, MPa	Statistical distribution parameters	Diameter of the reinforcement, mm	
			12	18
B12,5	17,2	τ_{bs}	6,1	5,5
	18,0	S_m	6,7	3,65
	15,5	ν	6,1	7,2
Average value	16,9		-	-
B15	21,6	τ_{bs}	7,5	6,4
	22,6	S_m	3,06	6,45
	21,8	ν	4,85	7,3
Average value	22,0		-	-
B25	34,6	τ_{bs}	9,9	8,8
	33,4	S_m	3,6	4,62
	32,8	ν	8,4	4,95
Average value	33,6		-	-

Note. τ_{bs} – arithmetic mean value of bond strength, MPa; S_m – mean squared deviation; ν – coefficient of variation, %

According to the research results presented in Table 3, it can be said that the connection surfaces between the reinforcing rod and ceramsite concrete have high strength and their joint operation is reliable. The peculiarity of the structure of construction ceramsite concrete and its deformations are responsible for the occurrence of such a process.

As confirmation of this, the following obtained results can be cited [3]. It has been established that the initial modulus of elasticity of structural ceramsite concrete and its limiting compressive deformations depend not only on concrete strength, but also on the properties of the porous filler used and the specific gravity of the cement + sand mixture in the concrete mixture.

According to the results of researches [4,5], the limit elongation value of ceramsite concrete is equal to $20 \div 30 \times 10^5$, which shows that this indicator is approximately twice as much as that of heavy concrete. When the consumption of porous filler in the composition of such concretes is in the range of $0{,}86 \div 0{,}96\ {}^{m^3}/_{m^3}$, their tensile strength and ultimate elongation increases and increases the degree of crack formation according to O.Ya.Berg [6].

It is known that one of the factors determining the strength of connection of reinforcement with concrete is the adhesive ability of cement gel, that is, its consumption in concrete. The analysis of the results of experimental studies on this issue shows that the strength of the connection of the steel reinforcement with a diameter of 12 mm to ceramsite concrete can be calculated using the following model:

$$\tau_{bs} = 1{,}3 \cdot K_a \cdot r_0 \cdot \sqrt{R_b(t_0)}\text{, MPa}$$

where:

r_0 – specific gravity of the cement + sand mixture in the concrete mixture;

$R(t_0)$ – strength of ceramsite concrete under loading moment, MPa;

K_a – coefficient that takes into account the effect of the shape of the surface of the reinforcement;

$K_a = 1{,}0$ – for a smooth surface reinforcement;

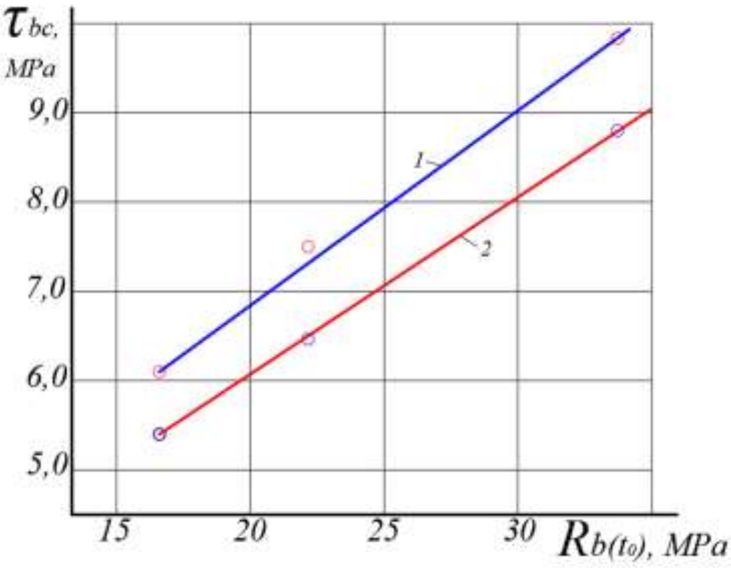
$K_a = 1{,}9$ – for a periodic surface reinforcement;

$1{,}9$ – coefficient depending on the properties of the porous filler.

This model should be higher than $R_b(t_0) \geq R_{b,28}$ and belongs to the class of ceramsite concrete compressive strength from B12.5 to B25.

The correlation of the obtained results is presented in this figure. For the reinforcement diameter of 12 mm, the calculated values of its bond strength with ceramsite concrete according to the formula (3) have a reciprocal ratio of the experimental values in Table 3 equal to 0.93, that is, the difference between them is 7% on average.

It was found that the average value of the ratio of the strength of the reinforcement when the diameter of the reinforcement is 18 mm to the strength of the connection at the diameter of the reinforcement is 0.9, that is, it is less than 10% on average.



The connection strength of reinforcing rods with ceramsite concrete depends on its class:

1 - Reinforcement with a diameter of 12 mm

2 - Reinforcement with a diameter of 18 mm

CONCLUSION

Based on the results of the conducted experimental and theoretical research, the following conclusions can be drawn:

- The connection strength of structural ceramsite concrete with reinforcement depends on its class (A400) as well as the diameter of the reinforcement. Variations in the test results were not significantly high, with a coefficient of variation below 7.3%. This indicates the consistent performance of ceramsite concrete for the tested parameters.
- The increase in the diameter of the reinforcement from 12 mm to 18 mm resulted in an average decrease of 12% in the connection strength. This reduction can be attributed to the larger diameter of the reinforcement.
- As the class of ceramsite concrete increased from B12.5 to B25, the connection strength for anchorage increased by up to 60%. This suggests that higher-class ceramsite concrete is more suitable for anchoring purposes.

It should be noted that the anchorage strength of reinforcement with ceramsite concrete remains largely consistent, but the specific values depend on the class of concrete and the diameter of the reinforcement.

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