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BONDING OF POLYMER COMPOSITE REINFORCEMENT WITH CEMENT CONCRETE

PhD, Umarov Shodiljon Abdugofurovich

Fergana Polytechnical Institute, 86 Fergana str., Fergana 150107, Uzbekistan

A R T I C L E I N F O.

Key words:
Polymer-composite reinforcement, steel reinforcement, adhesion strength with concrete, nature of tearing out of concrete.

Annotation

The results of experimental studies of the adhesion of cement concrete of various classes with polymer composite reinforcement (PCA) of fiberglass, having a different type of surface relief of the rods, formed by winding a thin bundle impregnated with a binder, or "sanding" on them, are presented. At the same time, samples of steel reinforcement of a periodic profile A400 and smooth A240 were tested for tearing out of concrete. The dominant role of the adhesion of cement concrete to the surface of the PCA epoxy coating and the insignificant role of spiral winding and "sanding" have been established.

In recent years, along with traditional steel reinforcement, polymer composite reinforcement (PCR) made of basalt, glass or carbon fibers and polymer binders based on epoxy and (less commonly) vinyl ester resins has attracted increasing attention in the construction market. Reinforcing bars are produced by the pultrusion method - drawing a roving impregnated with a liquid binder through a round die with simultaneous winding of the formed bar in a spiral with a thin bundle or coating with quartz sand.

The second method - needle trussing - is spinless, in which the formation of a round rod from impregnated strands of roving collected in a bundle is carried out by screw winding it with two of the same strands while continuously pulling the rod at a given speed. In terms of structure and properties, PCD belongs to fibrous highly oriented polymer composite materials (PCM), the high tensile strength of which is due to the strength of inorganic (silicate, carbon) parallel oriented fibers, firmly bound into a monolith by a polymer matrix. The high adhesion and “compliance” of the latter ensures their joint work under load, perceives shear stresses and, at the same time, imparts structural disadvantages characteristic only of organic polymers: low modulus of elasticity, creep under loading (due to forced elastic deformations of the binder), low long-term strength, high sensitivity mechanical properties to temperature and higher than concrete and steel, the coefficient of thermal expansion (compression), low heat resistance.

Due to its high tensile strength (more than 4 times the strength of steel) and chemical resistance (which does not require corrosion protection), PCD is actively introduced into the construction market of

Uzbekistan, however, the lack of a domestic regulatory framework and sufficient experience of real use in load-bearing concrete structures hinders its use. in the latter. The only mention of it is in the current standards in "Protection of concrete and reinforced concrete structures against corrosion" [1-22]; SNiP "Concrete and reinforced concrete structures" [2-32] allows the use of composite reinforcement. However, there are still no methods for calculating and designing concrete structures reinforced with PCA, which would take into account its low modulus of elasticity, heat resistance and long-term strength, due to the specific properties of the polymer binder. There is a need for extensive experimental studies of the mechanical behavior of both the reinforcement itself under long-term loading (evaluation of long-term strength, creep, stress relaxation) under normal operating conditions, as well as under elevated and cyclic temperature effects, and concrete structures reinforced with PCA. It is necessary to create a bank of experimental data for the calculation and design of structures and, obviously, it is necessary to start with an assessment of the adhesion of PCA with cement concrete, as the first condition for their joint work.

In addition, when reinforcing PCA concrete, one should take into account its pronounced structural anisotropy, and hence the different tensile, compressive, and shear strengths. The specified set of experimental studies from the adhesion of PCA to concrete to the strength, rigidity and crack resistance of structures reinforced with it is necessary not only for designers and designers. These data are also needed by PCD manufacturers themselves to improve its technology and optimize the surface profile, the diversity of which is explained, on the one hand, by the repetition of the periodic profile of steel reinforcement, on the other hand, by a different, relatively simple, technology for its formation (helical winding impregnated with thread or thin roving) , with the third - the desire to patent the technological nuances of profiling.

Below are the results of experimental studies aimed at determining the adhesion strength of various types of PCA (with different types of surface profiling) when pulled out of cement concrete of different strength classes.

Currently, to assess the adhesion of reinforcement to concrete, the method of pulling out rods from concrete cubes [3] or the beam method [4] is used, according to which special beams are tested for bending.

We determined the adhesion strength of reinforcing bars with concrete in accordance with [3] according to the formula:

$$\tau = \frac{F}{C_b\, l} \quad (1)$$

Where τ is the average cohesive stress, F - is the tensile load, C_b - is the equivalent circumference of the PCD rod, l - is the length of the embedment.

Tests for pull-out from concrete cylinders of PCA samples with a nominal diameter of 6 mm according to specifications of various manufacturers (five samples of each type (Table 1). Ribbed profiles differed in single or double-start helical winding impregnated with a tow of glass or basalt fibers. "sanded" rods (No. 5), the rough surface of which is formed by grains of quartz sand "embedded" into the surface of the rod during molding (similar to abrasive paper).

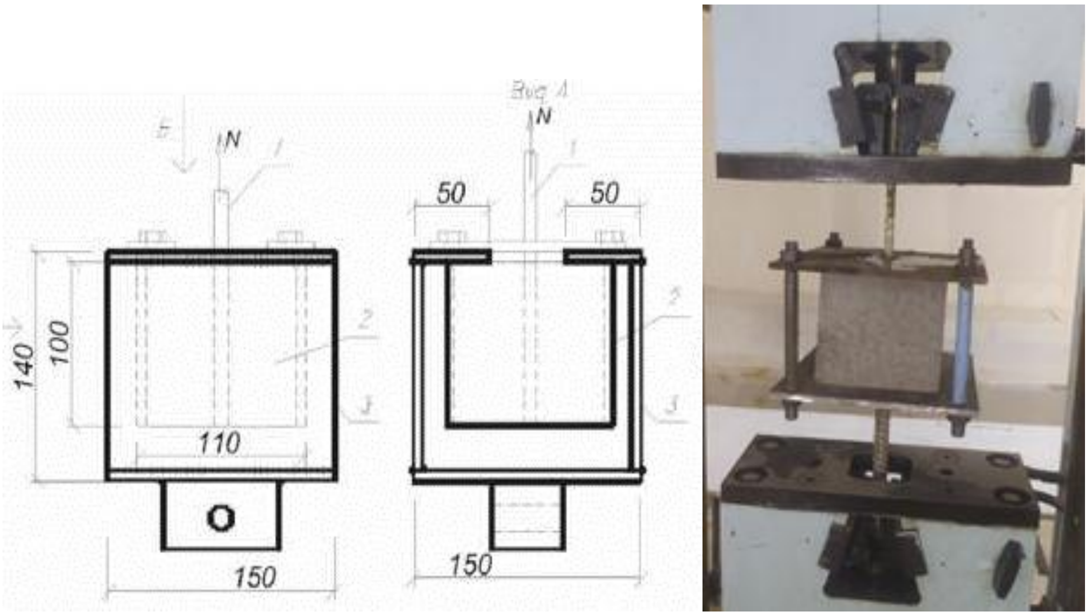
In addition, to assess the role of surface profiling (roughness), samples were tested after preliminary removal of the winding and sand from the surface of the PCD rods.

For comparison, hot-rolled steel reinforcement 8 mm according to GOST 5781-82 [5] was tested for pull-out: periodic profile of class A-400, smooth class A-240 and the same, coated with an epoxy binder.

For each series of tests, concrete mixtures of class B12.5 were produced; B22.5; B35; B40. The molding of each series of samples was carried out in polyethylene molds-cylinders, 100 mm high.

Reinforcing bars were installed vertically along the axis into the molds along with the laying of the concrete mixture and its subsequent vibrocompaction. Control tests of concrete strength were carried out in accordance with GOST 10180-90 [6-44].

Mechanical loading was carried out at a speed of movement of the jaws of the tensile testing machine of 20 mm/min. The cylinder with the sample was captured using a steel clip fixed on the traverse of the tensile testing machine (Fig. 1), the other end of the PCD rod was captured by the jaws of the tensile testing machine through copper spacers.

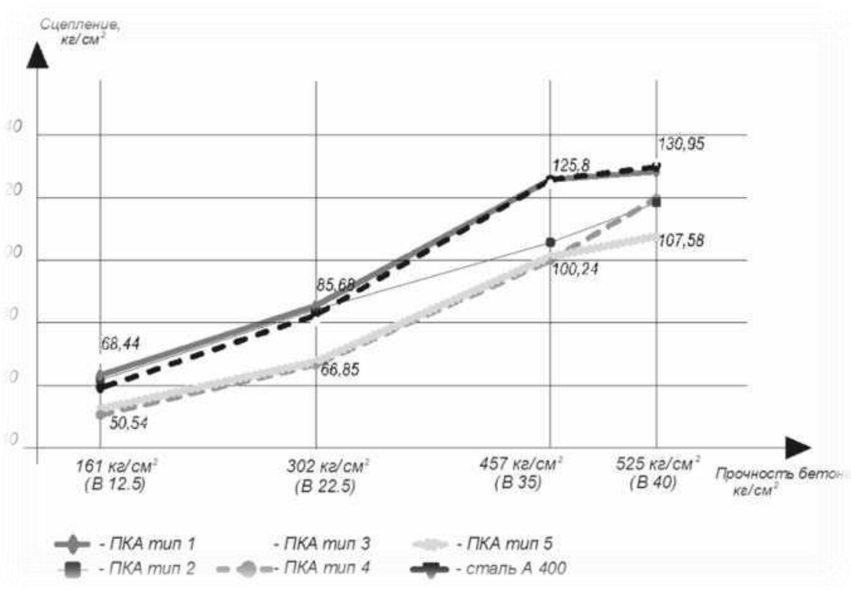


Rice. 1. Scheme of capturing the test sample

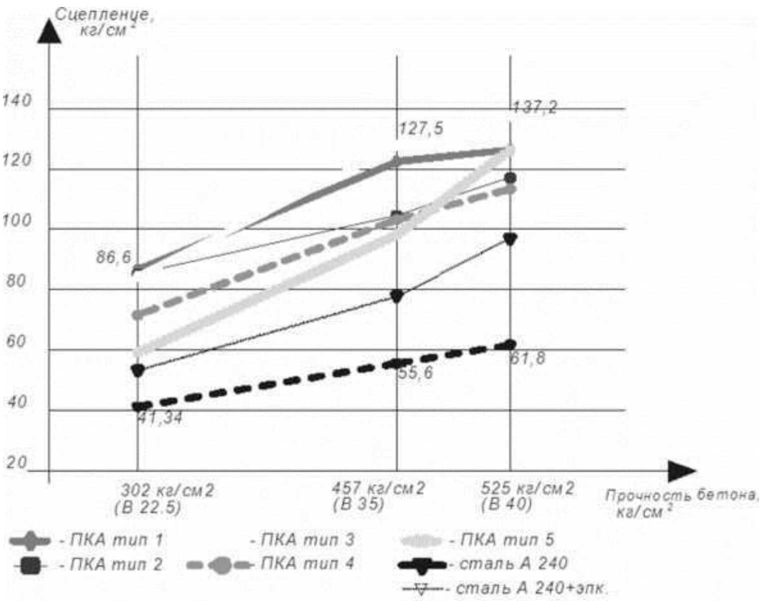
The average values of the adhesion after processing the results for each batch of five samples are given in table. 2, in figures 2, 3.

Adhesion value (t, kgf/cm2) of reinforcing bars with concrete of various classes

Concrete class	**Type of fittings according to the table. 1.**							
	1(ASP-8)	2(ASP -8)	3(ASP -8)	4(ASP -8)	5(ABP -8)	6(A 400)	7(A 240)	8(A240+ ep)
B12.5	63,3	61,6	68,4	50,5	52,4	59,1		
B22.5	85,7	84,5	80,7	66,9	67,8	82,8		
B22.5*	86,6	85,25	84,3	71,7	59,2		41,3	53,3
B 35	125,8	105,71	124,4	100,2	101,2	125,7		
B35*	122,4	104,6	127,5	103,2	98,1		55,6	77,8
B40	128,3	118,4	130,9	119,7	107,6	129,8		
B40*	126,3	117,1	137,2	113,4	126,3		61,8	96,8



RICE. 2. Adhesion strength of various types of PCA and steel with concrete of various strengths.



RICE. Fig. 3. Adhesion strength of PCA samples without coiling and sanding with concrete of various strengths.

The following character of destruction is established when reinforcing bars are pulled out of concrete:

- the pull-out of reinforcing bars of all types (except type No. 8) from concrete of all classes occurs along the concrete layer bordering with reinforcement, that is, it is of a cohesive nature and therefore is limited by the shear strength of concrete, which increases with an increase in its class. From the nature of the destruction of concrete during the pull-out of reinforcing bars, it follows that the adhesion of concrete to the surface of the PCA and steel is higher than the cohesive strength of concrete in the boundary zone;
- pull-out of PCA rods with a screw winding glued onto a cylindrical rod (No. 1-4) occurs as a result of its shear separation (cut) from the "body" of the rod when testing concrete samples of class B22.5 and higher, and the destruction occurs in 2 stages: first at the maximum pull-out load, the deformation displacement of the rod occurs with delamination of the lower turns of the winding, which occurs due to the insufficient strength of their gluing with the PCD rod. The number of

simultaneously delaminated turns for different types of PCA is different, but their number increases with increasing concrete strength. At the second stage, at a load of 40-50% of the maximum, a “smooth” pulling out of the rod from the concrete cylinder occurs;

- the pull-out of PCD rods with previously removed winding occurs evenly (at a constant speed) after reaching the maximum load determined for each sample. In this case, the pull-out force differs little from that in rods with a screw winding;
- pull-out of PCA rods with coiling (No. 1-4) from low-strength concrete of class B12.5 occurs evenly without coiling breakdown when a certain load is reached;
- in the course of research, it was found that samples No. 2 (with a partially "embedded" winding into the rod) are pulled out of the concrete sample without destruction of the winding and its delamination from the rod. In terms of the nature of the destruction of concrete during tearing, PKA No. 2 is close to steel reinforcement of a periodic profile;
- from a comparison of the pull-out forces of PCA No. 1,3,4, it follows that a decrease in the winding pitch and an increase in its angle to the axis of the rod reduces the pull-out force from concrete of all classes, because adhesion of cement stone to the "epoxy surface" of the rod is higher than the shear strength of the coil;
- when sanded samples are pulled out of concrete (type No. 5), destruction occurs in the contact zone: both along the concrete and along the layer of coarse sand on the surface of the PCA, due to the cut of its large grains. The pull-out force of the rods after the removal of the sand dressing exceeds the initial ones for the initial samples of PC A No. 5;
- as a result of testing samples of smooth reinforcement A-240 coated with epoxy binder (type No. 8), it was found that the values of its adhesion to concrete exceed the values of adhesion of steel reinforcement (type No. 7) when pulled out of samples of a similar class of concrete by 20-30% . This fact indicates the priority role of the adhesion of concrete to the surface of the epoxy polymer. The lower adhesion values for samples No. 8, compared with PCA samples, are due to partial delamination of the epoxy coating from the surface of the steel rod in the process of tearing out of concrete.

Conclusions:

1. Adhesion of PCA to concrete is ensured by the adhesion of the cement stone with an epoxy coating, and not by the mechanical engagement of the turns in the concrete matrix, in contrast to profiled metal reinforcement. The device of a helical (periodic) PCA profile by gluing a bundle of basalt and glass fibers impregnated with a binder is impractical, since this winding is cut off from the surface of the rod when pulled out, and the adhesion of concrete to the epoxy coating exceeds the cohesive strength of concrete and is sufficient for PCA anchoring in it [6-26].
2. When analyzing the test results, it was found that it is more expedient to profile the PCD rod itself (similar to type No. 2) by “compressing” it with a thin bundle with a step of 4-6 of the rod diameter. This increases the specific area of contact with concrete, improves the conditions for joint operation of PCA with concrete under load, which will make it possible to better realize the strength properties of PCA when working in a supporting structure. [36-44].
3. To fully realize the strength properties of PCA, it is advisable to use it in high-strength concretes of class B30 and higher. Since the nature of the destruction of concrete during the pull-out of PCA is similar to that for steel reinforcement with a periodic profile, this allows using the methods used to calculate the anchoring of steel reinforcement with a periodic profile when calculating the anchoring values.

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