Smart Geotechnics for Smart Societies – Zhussupbekov, Sarsembayeva & Kaliakin (Eds)

Reinforcement of compressed reinforced concrete structures with composite materials

U.S. Kuralov
PhD student of Satbayev University, Almaty, Kazakhstan
Kazakh Scientific Research and Design Institute of Civil Engineering and Architecture, Almaty, Kazakhstan

Z.T. Nashraliev
PhD, Associate Professor, Satbayev University, Almaty, Kazakhstan

U.B. Altigenov
PhD student of L.N. Gumilyov Eurasian National University, Astana, Kazakhstan
Kazakh Scientific Research and Design Institute of Civil Engineering and Architecture, Almaty, Kazakhstan

B.N. Amanov
Master's student of Satbayev University, Almaty, Kazakhsatn
Kazakh Scientific Research and Design Institute of Civil Engineering and Architecture, Almaty, Kazakhstan

ABSTRACT: There are presented the results of an experimental study of the strength of compressed reinforced concrete elements with polymer-reinforced plastics FIBARM TAPE 530/300. Reinforcement of compressed reinforced concrete elements with cages made of fiber-reinforced plastics causes triaxial compression in concrete, in which the strength of the elements can increase several times. Gluing clips of unidirectional vertical grids led to an increase in the strength of the compressed elements of a circular cross-section.

Keywords: Amplification, Fiber reinforced plastic, Carbon fiber, Composite, Static loading, Deformation

1 INTRODUCTION

In the process of operation, buildings and structures change their purpose, undergo reconstruction and renovation, they increase the requirements for reliability and comfort, they are subject to physical wear and tear and damage. Under these conditions, the need to strengthen building structures is becoming increasingly important. A special place is given to the strengthening and restoration of buildings and structures in seismic areas of construction (Zhussupbekov et al., 2020, Tulebekova et al., 2022), in areas of natural disasters, and after accidents and terrorist attacks.

Most of the load-bearing structures of buildings and structures of our time are made of concrete and reinforced concrete, so the problems of developing methods for strengthening reinforced concrete structures are becoming increasingly relevant. Traditional methods (SNIP 1991) of reinforcing reinforced concrete structures are very laborious, require overburden, welded and concrete work, and require considerable time to ensure the required strength. New, modern methods of reinforcing reinforced concrete structures are focused on the use of composite fiber-reinforced plastic materials for reinforcing, which are characterized by high strength, corrosion resistance and durability.

An alternative to traditional methods of reinforcing reinforced concrete structures is the use of fiber-reinforced plastics (FRP) - polymers reinforced with fiber fibers (Bakis et al., 2002). Unlike traditional reinforcement methods using steel reinforcement, these methods have high reinforcement efficiency, and do not require overburden and welding, or concreting of reinforced elements, they are distinguished by durability, corrosion resistance, low labor intensity, and economic

DOI: 10.1201/9781003299127-376

feasibility. The following types of fibers are commonly used as FRP reinforcement: carbon (C), aramid (A), glass (G), polyester.

2 METHODOLOGY

The study of the operation of compressed elements reinforced with fiber-reinforced plastics was carried out on samples of concrete cylinders and prisms of various sizes, differing in the number of layers of reinforcement meshes.

Some of the samples were tested under the axial action of quasi-static compression on hydraulic presses IPS-200 and ALPHA 3-3000S. To do this, the samples were subjected to axial compression with a gradual increase in the magnitude of the longitudinal compressive force at a rate of 0.3 MPa/s, up to the destruction of the sample. The magnitude of the stage of load increase did not exceed 5–8% of the breaking load.

During static loading, the longitudinal and transverse deformations of the prototypes were measured using strain gauges with a base of 50 mm, glued to all side faces of the samples, and an automatic strain gauge AID-4M (Figure 1).

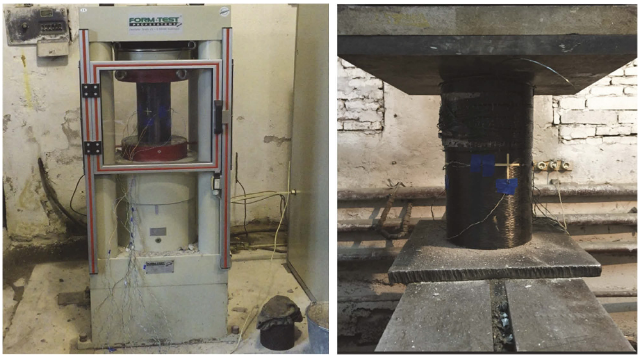

Figure 1. General view of the test of reinforced samples for axial compression on hydraulic presses ALPHA 3-3000S and IPS-200.

3 RESULTS

JSC Kazakh Scientific Research Institute of Civil Engineering and Architecture conducted research on the behavior of reinforced concrete elements under static effects of compression, reinforced with layers of fiber-reinforced meshes FibArm Tape 530/300 (Modern Composite Materials of the Composite Holding Company), limiting transverse deformations of concrete and thereby creating triaxial compression of concrete.

Concrete cylinders of three sizes were used as prototypes: with a diameter of 100 mm and a height of 200 mm (K10), a diameter of 150 mm and a height of 300 mm (K15) and a diameter of 200 mm and a height of 400 mm (K20), made from one batch of concrete of natural hardening class B27.5. The prototypes were pasted over with layers of carbon unidirectional meshes (FibArm Tape 530/300), which had unidirectional fibers, a width of 300 mm, a surface density of 530 g/m2, a design thickness of 2.45 mm, with an elastic modulus Ef = 245 GPA and tensile strength fu =3.6 GPa.

Static tests of concrete cylinders were carried out under axial action of quasi-static compression on hydraulic presses IPS-200 and ALPHA 3-3000S. The samples were subjected to axial compression with a gradual increase in the magnitude of the longitudinal compressive force at a rate of 0.3 MPa/s, up to the destruction of the sample.

Tables 1-3 present data on the strength under static loading of concrete cylinders with a different number of reinforcement layers with FibArm Tape polymer meshes, the strength ratio of the series, ultimate longitudinal and transverse deformations.

Table 1. Static compressive strength of concrete cylinders with a section of 100x200 (dxh) mm.

Sample brand	Breaking force N. kN	Voltage, σ, MPa	Medium voltages σ_{mid}, MPa	Strength comparison	Deformations, 10^{-5} ε_{long}	ε_{cross}
K10-0-1	235	25.4	26.6	1.0	190	50
K10-0-2	210	22.9			205	32
K10-0-3	290	31.4			200	32
K10-1-1	702	75.9	79.9	3.0	700	660
K10-1-2	701	75.1			415	310
K10-1-3	797	88.7			810	530
K10-2-1	900	98.3	86.2	3.24	410	215
K10-2-2	700	77.9			260	150
K10-2-3	740	82.3			415	160
K10-3-1	1246	138.6	147.1	5.53	302	375
K10-3-2	1500	163.8			500	435
K10-3-3	1250	139.0			450	335

Table 2. Static compressive strength of concrete cylinders with a section of 150x300 (dxh) mm.

Sample brand	Breaking force N. kN	Voltage, σ, MPa	Medium voltages σ_{mid}, MPa	Strength comparison	Deformations, 10^{-5} ε_{long}	ε_{cross}
K15-0-1	510	28.1	25.1	1.0	128	66
K15-0-2	410	22,5			90	28
K15-0-3	444	24.8			133	22
K15-1-1	1200	69.8	65.9	2.62	310	330
K15-1-2	1000	58.1			320	194
K15-1-3	1249	69.9			300	270
K15-2-1	1450	83.4	94.1	3.75	650	440
K15-2-2	1797	100.4			350	380
K15-2-3	1899	108.9			310	300
K15-2-4	1500	83.8			340	356
K15-3-1	2299	130.1	131.1	5.22	300	436
K15-3-2	2400	135.2			320	425
K15-3-3	2200	127.9			340	330

Table 3. Static compressive strength of concrete cylinders with a section of 200x400 (dxh) mm.

Sample brand	Breaking force N. kN	Voltage, σ, MPa	Medium voltages σ_{mid}, MPa	Strength comparison	Deformations, 10^{-5} ε_{long}	ε_{cross}
K20-0-1	853,5	26.9	26.4	1.0	110	22
K20-0-2	814,2	25.6			98	23
K20-0-3	833,9	26.6			105	20
K20-1-1	1570	39.2	37.2	1.41	320	275
K20-1-2	1619	40.5			400	270
K20-1-3	1275	31.9			312	170
K20-2-1	2500	59.5	64.3	2.43	480	430
K20-2-2	2900	69.0			435	434
K20-3-1*	3001	71.4	69.0	2.61	391	284
K20-3-2*	2700	64.2			363	302
K20-3-3*	3000	71.4			489	474

The destruction of samples reinforced with FibArm Tape carbon fiber meshes occurred gradually (Khayutin et al., 2002). At first, a crack appeared, caused by the rupture of individual fibers, with an increase in the load, the crack increased and a section of the mesh broke and the concrete was brittle crushed in this zone, accompanied by a sharp sound.

4 DISCUSSION

Analysis of the data shows that the strengthening of the samples by wrapping (pasting) with FibArm Tape 530/300 material led to a significant increase in the strength of the compressed samples, while the strengthening value almost linearly depended on the number of mesh layers. So, single-layer meshes caused an increase in strength by an average of 200% for samples (K10 series), by 162% for samples (K15 series), by 41% for samples (K20 series), two-layer meshes led to an increase in strength by 224% for samples (K10 series), by 275% for samples (K15 series), by 143% for samples (K20 series), and three-layer meshes - by 453% for samples (K10 series), by 422% for samples (K15 series), by 161% for samples (K20 series).

The presence of cages made of FibArm Tape meshes leads to a significant increase in the longitudinal deformations of concrete, which reach 4‰, as well as an increase in the transverse deformations of concrete, which can increase almost 10 times, reaching a value of 0.3-0.4%. In addition, there is an increase in the initial modulus of elasticity, which increased by 30%, 52% and 61% with one, two and three layers of reinforcement meshes.

In general, the effect of reinforcement with FibArm Tape meshes for 200x400 (bxh) mm samples is much less than for 100x200 mm and 150x300 (bxh) mm samples.

5 CONCLUSION

The destruction of concrete samples reinforced with carbon fibers of the FibArm Tape series occurs gradually under axial compression. First, a crack appears, caused by the rupture of individual fibers. With an increase in the load, the crack increases and then there is a brittle crushing of the concrete in the area of the mesh rupture, accompanied by a sharp sound. The more layers of reinforcement, the earlier the process of breaking the fibers of the grids begins.

Strengthening concrete samples by wrapping (pasting) FRP under axial compression led to a significant increase in the strength of the elements, while with an increase in the cross-sectional dimensions of the sample and the number of layers of reinforcement grids, the efficiency of using FRP decreases. So, for samples with dimensions of 100×200 (b×h) mm and 150×300 (b×h) mm, single-layer meshes caused an increase in strength on average by 200% and 162%, respectively, two-layer meshes led to an increase in strength by 224% and 275%. % and three-layer mesh increased strength by 443% and 422%. At the same time, for larger specimens (200×400 (b×h) mm), the corresponding increase in strength was much smaller.

The presence of meshes leads to a significant increase in the longitudinal deformations of concrete, however, with an increase in the number of layers of meshes, the intensity of strain growth decreases and, with three layers of meshes, the deformations of concrete differ little from the deformations of specimens with two layers of meshes. The ultimate compressibility of concrete is about 0.3%. The presence of meshes also causes an increase in transverse deformations of concrete. They increase from 30-40×10-5 to 300-400×10-5 relative units, i.e. in magnitude approach the limiting value of longitudinal deformations.

Increasing the cross-sectional dimensions of the compressed members reduces the effect of increasing the strength of the compressed members. An increase in the cross sections of compressed specimens from 100 × 200 (b×h) mm and 150 × 300 (b×h) mm to 200 × 400 (b×h) mm led to a decrease in relative strength by almost a factor of two.

REFERENCES

1. Zhussupbekov A., Tulebekova A., Jumabayev A., Zhumadilov I, 2020. Assessment of soils deformability under vertical load. International Journal of Geomate, 18 (70). pp. 221–228.
2. Tulebekova A.S., Jumabayev A.A., Aldungarova A., Zhankina A. 2022. The use of geosynthetics for strengthening the soil base: a laboratory experiment to develop practical skills of postgraduate students. World Transactions on Engineering and Technology Education, 20 (4), pp. 286–291.
3. SNiP 2. 03.01-84* 1991. Concrete and reinforced concrete structures. State Construction of the USSR, 1991

4. Bakis C.E., Bank L.C., Brown V.L., Cosenza E., Davalos J.F., Lesko J.J., Machida A., Rizkalla S.H., Triantifillou T.C. 2002. Fiber-Reinforced Polymer Composites for Construction-State-of-the-Art Review. Journal of Composites in Construction, 2002, V.6, No 2, pp. 73–87.
5. Khayutin Yu.G., Chernyavsky V.L., Axelrod E.Z. 2002. The use of carbon fiber to strengthen building structures//Concrete and reinforced concrete. - No. 6. - 2002. - p. 17-20; No. 1. - 2003. - p. 25–29.