Eco-fiber concrete - an innovative material in tank construction

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Abstract. The history of the development of reinforced concrete is briefly outlined. Now the fourth stage of reinforced concrete development is underway and a new material is being born in it - "eco-concrete" - a domestic development of reinforced concrete, patented in 1992. "Eco-concrete" - ultra-high pressure concreting in a water-aerosol environment using inflatable formwork. The use of composite reinforcement (basalt fiber, polypropylene, glass fiber, metal fiber) in the "eco-concrete" technology gives rise to an almost new building material - "eco-fiber concrete", which has unique properties - high strength, durability, fire resistance, impact and fatigue strength, low-temperature strength, non-shrinkage, high crack resistance, reducing the cost and construction time. "Eco-fiber concrete" has great prospects in the construction of storage equipment of various shapes for the storage of explosive, toxic and low-temperature media.

Keywords. A brief history of reinforced concrete, "eco-fiber concrete" - ultra-high pressure concreting in a water-aerosol environment, concrete with composite reinforcement with fibers from

various materials (metal, basalt, plastic, propylene). Capacitive equipment - vertical cylindrical, spherical tanks. Stored products - explosive, toxic, liquid, gaseous.

According to historians of technology, the invention of reinforced concrete, in terms of its influence on the development of world civilization, can be put on a par with the discovery of electricity, the appearance of a car or aviation. The first inventors of reinforced concrete appeared in France (Lambo, 1850; Cunier, 1854; Monier, 1867 - 1880), in England (Wilkinson, 1854), and in the USA (Gnutt, 1855-1877).

And the history of reinforced concrete begins in 1848 with Jean Louis Lambo's boat made of a new material - a metal mesh made of interconnected wires and rods and covered with cement. Although Russian craftsmen back in 1802 used reinforced concrete in the coatings of the Tsarskoye Selo Palace. However, they did not consider it a new material and did not patent it.

In 1887 G. Weiss and M. Kenen proposed to place the reinforcement in the tensile zone of the structure. From that moment on, reinforced concrete became an independent new building material, which is the first stage in the development of reinforced concrete. At the same time, the method of calculating concrete structures by permissible stress, based on the laws of resistance of elastic materials, came into practice.

In 1917, E. Freyssinet proposed compaction of concrete by vibrocompression, and then, in 1928, prestressing of reinforced concrete elements. Although for the first time the idea of prestressing tensile elements was put forward and implemented in 1861 by the Russian artillery engineer A.V. Gadolin.

In the early 30s of the XX century A.F. Lawleyt, A.A. Gvozdev, E. Freisinet created a theory for calculating reinforced concrete based on destructive forces. This refers to the second stage in the development of reinforced concrete. And the method of calculation by limiting states that appeared in our country in the 50s (NS Streletsky, VM Keldysh, AA Gvozdev, etc.) marked the third stage in the development of reinforced concrete.

Doctor of Technical Sciences A.I. Zvezdov (President of the Reinforced Concrete Association, Deputy General Director for Research of the Research Center "Construction") formulated the concept of sustainable development of concrete and reinforced concrete.

1. Minimal consumption of irreplaceable natural resources. 1 ton of concrete takes 6-7 tons of natural resources, 1 ton of steel is almost 3 times more (~ 20 tons).
2. Durability. It is highly recyclable and reusable.
3. Compatibility with other materials.

Today, concrete is not produced in the world without all sorts of chemical additives. Modified concrete is more effective than conventional concrete, while modifiers of complex action are mainly used, which improve several properties and characteristics of concrete at once.

Usually 4 fractions are used, which are separately introduced into the concrete mixture. For this, it is necessary to have special equipment for the preparation, drying, fractionation, storage and supply of aggregates. Russian factories have one or, at best, two factions.

We currently have material with the following advantages and disadvantages.

The main advantages of reinforced concrete:

- fire resistance and incombustibility;
- strength and durability;
- corrosion, weather and frost resistance;
- resistance to seismic and dynamic influences;
- constructions of structures of any shape;
- minimum operating costs;
- hygiene, ability to protect against radioactive radiation;
- prevalence and availability of source materials;
- low production energy costs.

Disadvantages:

- large dead weight of the structure;
- high sound and thermal conductivity;
- the complexity of alterations and reinforcements;
- long-term holding of the structure in the formwork (28 days) until the concrete acquires the required strength;
- the appearance of shrinkage and force cracks.

Complete or partial elimination of these drawbacks is carried out through the use of concretes on porous aggregates, special processing (steaming, evacuation, etc.), prestressing. Thus, reinforced concrete - the youngest of building materials (wood, stone, metal), continues to develop, fighting its shortcomings and multiplying its advantages.

The next stage in the development of reinforced concrete, in our opinion, is the emergence of the patented innovative technology "eco-concrete" - concreting under ultra-high pressure in a water-aerosol environment using inflatable formwork developed by CJSC NPPSO "GrantStroy" and design solutions of "Spetsstroyproekt" LLC [1, 2].

Consider the application of this virtually new material in tank construction - the most material-intensive area of construction.

All of the listed advantages of "eco-concrete" very successfully meet the requirements for the construction of tanks for the storage of explosive, toxic, with a higher specific gravity, higher or lower storage temperature. Such requirements are imposed by such products as oil, oil products, acids, alkalis, liquefied gases.

The technology of concreting under ultrahigh pressure in 2007 was recognized as a world discovery of a scientific idea and a domestic copyright certificate [3] and a US patent [4] "On the force inertial compaction of particles of continuous media" were issued. The basic principles of this technology are aimed at achieving a high density concrete structure with increased physical and mechanical properties and increased isotropy of properties.

When creating the "eco-concrete" technology in 1992, CJSC NPPSO "GrantStroy" invented a fundamentally new mechanized complex for the preparation of concrete mixture in a hermetically sealed chamber high-speed concrete mixer (fig. 1, 2), providing transportation under high pressure 1.4 MPa at a speed 120-200 m/s and concreting in a water-aerosol environment in a hermetically sealed system (fig. 3), which absolutely excludes dust release and rebounds in order to achieve ecological cleanliness of the environment.

The ultra-high density of concrete and reinforced concrete structures is achieved by compaction and displacement of water and air from the concrete mixture to the peripheral surface of the concreting. It provides the strength of a homogeneous single-layer concrete mix at an early stage of concreting up to 40%.

The use of "eco-fiber concrete" with composite reinforcement in the "eco-concrete" technology has an advantage over traditional reinforced concrete due to its higher physical and mechanical properties:

- significant reduction in the cost and construction time;
- an increase in the productivity of concrete works and concreting by 10 times;
- tensile and shear strength - 4 times higher than conventional reinforced concrete;
- flexural and compressive strength - 20% higher;
- high resistance to cracking;
- impact and fatigue strength - 3-5 times higher;
- strength at destruction from water hammer - 3-5 times higher;
- modulus of elasticity - 20% higher;
- increased fire resistance;
- frost resistance - minus 120°C
- the work of destruction is 3-5 times higher;
- equality of indications of thermal expansion of composite reinforcement and fiber-reinforced concrete;
- elimination of shrinkage of the concrete mixture;
- increased surface resistance to abrasion and its higher resistance to weathering and weathering;
- construction in hard-to-reach places and confined conditions;

- 25 years of experience in extreme conditions shows a high degree of water tightness and resistance to cavitation and abrasion.

All of the listed qualities of "eco-concrete", with varying fibers having different properties (heat resistance, alkali and corrosion resistance) (tab. 1), can expand the field of application of this actually new material "eco-fiber concrete" by using it for the construction of vertical tanks for storage of oil, petroleum products, chemically active substances (including ground-based), ball tanks for storing products under pressure, as well as isothermal tanks for storing low-temperature liquefied gases. These qualities include the following properties: increased strength, leading to a decrease in weight (the main disadvantage of reinforced concrete) of the structure; due to the lack of moisture and air in the body of concrete, the reasons for the occurrence of shrinkage disappear; a quick set of the required strength significantly reduces construction; the minimum construction area makes it possible to carry out work in cramped, inaccessible and remote areas. The increased impact strength will be in demand in the protective walls of oil terminals, as well as in the outer shells of vertical isothermal tanks of complete containment of the combined design. Significant reduction in the magnitude of stress concentrators at the joints of the wall with the bottom and with the coating due to the "eco-fiber concrete" application method.

We would like to point out the prospects of using "eco-fiber concrete" in the outer shells of isothermal tanks at temperatures up to -104°C (ethylene) even without metal cladding of the inner surfaces. At the same time, the shell thickness can be reduced by 2 times, as well as in spherical tanks, especially in large volumes (>3000 m^3). The use of inflatable formwork in combination with the property of "eco-fiber concrete" to quickly gain 40% strength within a short time increases its advantages in the construction of structures of complex shapes (fig. 4).

"Eco-concrete" technology is widely used and has successfully proven its unique capabilities in the construction of buildings and structures of the most complex shapes and structures for various purposes. They have been tested by time and natural disasters. Unfortunately, these unique construction and operational capabilities have not yet found their application in the construction of storage tanks for oil, oil products, toxic products, and liquefied gases, although all the prerequisites for this exist. It is necessary to carry out in-depth comprehensive laboratory tests, select the optimal concrete mixtures, chemical additives and plasticizers, the material and shape of the fiber, the density of reinforcement, and build prototypes of storage facilities of various configurations and designs.

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Comparative characteristics of different fibers Table №1

Indicator	Basalt fiber	Polypropylene fiber	Fiberglass fiber	Steel (metal) fiber
Material	Basalt	Polypropylene	Fiberglass	Carbon steel wire
Structure				
Tensile strength, MPa	3500	150 – 600	1500 – 3500	600 – 1500
Fiber diameter	13 – 17 µm	10 – 25 µm	13 – 15 µm	0.5 – 1.2 µm
Fiber length	3.2 – 15.7 mm	6 – 18 mm	4.5 – 18 mm	30 – 50 mm
Elastic modulus GPa	Not less than 75	35	75	190
Elongation coefficient,%	3.2	20 – 150	4.5	3 – 4
Melting point, °C	1450	160	860	1550
Resistance to alkalis and corrosion	High	High	Alkali resistant fiber only	Low
Density, g/cm^3	2.60	0.91	2.60	7.80

Fig. 1, 2 – Mechanized complexes in the "eco-concrete" system

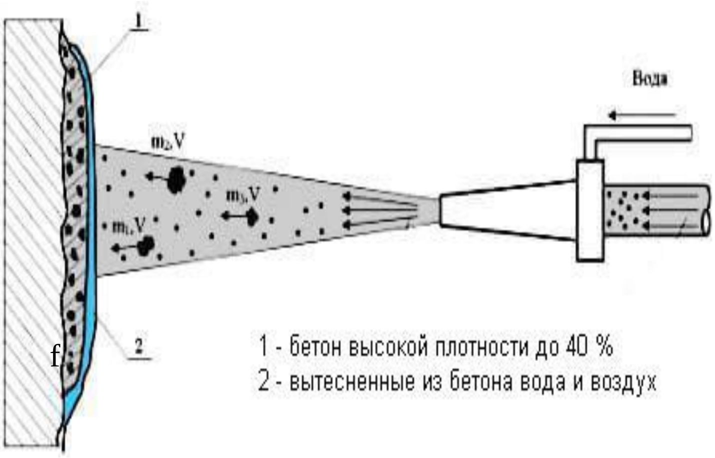

Fig. 3 – Concreting technology "eco-concrete"

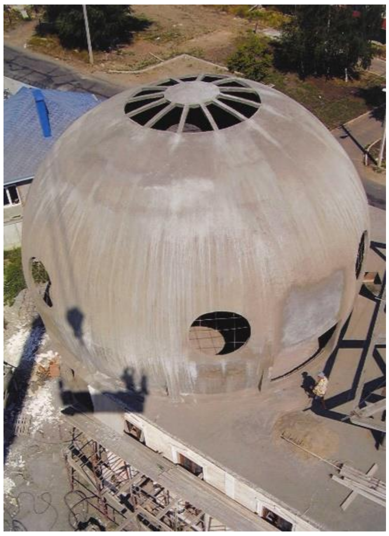

Fig. 4 – Civilian structure