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TYPES OF REINFORCEMENT OF CONCRETE STRUCTURES WITH 3D PRINTING TECHNOLOGY

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During the rapid development of 3D printing technologies, research and improvement of materials and equipment, quite insufficient attention was paid to the strengthening elements of concrete structures. Due to the unimproved system of building elements reinforcement made by a 3D printer, they often have low bearing capacity for bending and stretching, and cannot replace reinforced concrete elements made in the traditional way. As a result, buildings are not high-rise and have no long spans, which restricts architects and engineers to implement their most daring ideas. Also, one of the main advantages of 3D printing is lost − full automation of construction processes, since in most cases reinforcement elements have to be laid manually.

Thus, in order to have a positive impact on the sustainability of the construction industry, 3D printing technology must be able to cover a wider range of production of structural elements, including more complex structures. The development of reinforcement strategies compatible with extrusion printing of concrete allows producing safe and reliable concrete structures of non-standard forms [2]. At the same time, these strategies must be able to provide sufficient reinforcement to meet all structural integrity requirements related to load-bearing capacity, as well as in-service behavior.

Nowadays, several approaches to reinforcing structures using 3D printing technology have been proposed. Reinforcing rods are the most common way to reinforce extruded structures. For this, both traditional steel reinforcement and composite reinforcement are used. But when using this method, there is a high probability that the extruder will collide with the armature. One of the options for solving this problem is to lay concrete from different sides of the reinforcing frame with the help of several nozzles.

Also, reinforcing bars can be added after the printing process, either outside or inside the printed element. When using the last approach, the void in the formation must be filled with cement mortar for reinforcement. However, the use of conventional reinforcing bars is associated with two main problems: rigid bars limit geometric flexibility, and increased porosity at the interface of layers

can accelerate the corrosion of the reinforcing bar, which reduces the durability of the structure [3].

But the use of prestressed rods can provide geometric flexibility of the structure. The armature is similarly installed in the void created during printing, which, after its stress, is filled with cement mortar.

The next approach to reinforcing extruded structures is the addition of fiber to concrete. Metal, polypropylene, fiberglass or basalt fiber is usually used, which is mixed with concrete and laid together [1]. However, with this method, the length of the fibers is limited due to the small size of the holes of the pumps for feeding the mixture to the extruder, and the small size of the nozzle of the extruder itself. Based on this, only short flexible fibers can be used, which are usually more expensive and structurally less efficient. In addition, the dispersion and disorientation of fibers in the matrix causes great uncertainty at the stage of designing and calculating structures.

To address these limitations, there is an approach to reinforcement where the fibers can be placed separately from the concrete. Immediately after each concrete layer, the robot layer adds fibers in the desired orientation and in the desired quantity on top of the existing layer. As soon as the nozzle is turned to print the next layer, the fibers are coated with concrete. This process makes it possible to no longer limit the length of fibers by the technological limitations of a specific matrix. In addition, this process allows the fibers to be aligned in the direction of the resulting tensile stresses and to adjust the fiber dosage according to structural requirements [4].

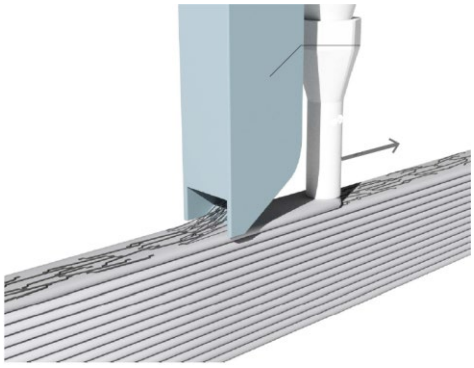

Fig. 1. Reinforcement of the structure with fiberglass with separate laying of fiber and concrete

The greatest potential has an approach to reinforcing printed structures in which a thin reinforcing cable is added during printing, which is easily bent and adapted to almost any printing trajectory. Studies using high strength smooth steel wire or impregnated carbon filaments show promising structural properties in printing [5].

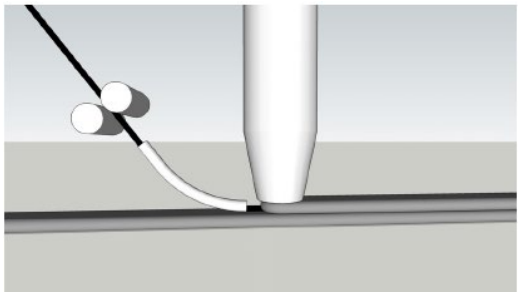

Fig. 2. Reinforcement of structures with thin reinforcing wire

Thus, the study of various types of reinforcement of structures made by 3D printing technology is of great importance for improving the quality and safety of structures. In addition, it is important to develop new reinforcement methods and optimize existing ones to achieve better results and improve the performance of 3D printing technology as a whole.

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