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METHODS FOR TESTING FORMULATIONS FOR A CONSTRUCTION 3D PRINTER

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The article describes the application of 3D printing in construction. The main factors hindering the widespread development of these technologies are noted. The main technological characteristics of the mixture affecting the possibility of using it in a construction 3D printer are given. Possible ways of achieving the required parameters for the mixture are given.

3D printing is developing at a rapid pace and every year new areas are mastering it and construction is no exception [1]. For several decades, there have been construction 3D printers that differ in their dimensions, printing technology or place of application (fig. 1).

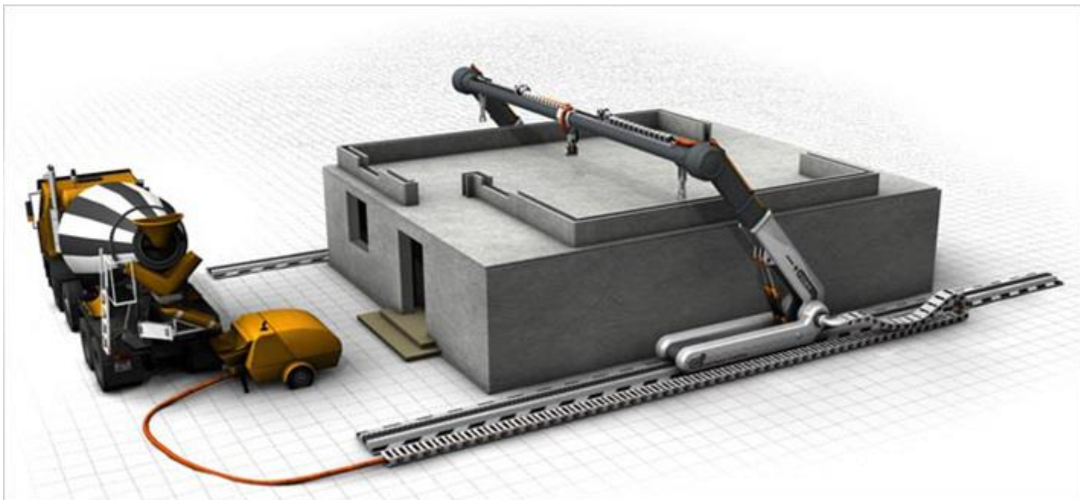

Fig. 1. – Construction 3D printer

However, if the creation of construction printers is not very difficult, and their designs are constantly being improved, then there are constraints. One problem is insufficient quantity of print mix. There are various formulations to suit different printer designs, however, they all include local materials or waste. Based on this, the purchase of such a mixture and its transportation becomes high in cost and makes the construction process using a 3D printer financially unreasonable.

Based on this, for the successful use of printers, it is required to develop a composition based on local materials and production waste, which will not only remove the cost of purchasing foreign material, but also contribute to reducing the cost of construction. In this regard, the question arises, what properties should a solution for a construction 3D printer correspond to.

In the publication, the authors note that the main technological characteristics of concrete mixes for 3D printing are: mobility, extrudability, shape stability, setting time and shrinkage [2].

The mobility index should ensure that the slurry will be easily pumped through the conveying system and will easily pass through the extruder. Fine mineral additives can fill voids and lubricate the mortar. Research has shown that crushed ash increases mobility, but adding too much of it increases friction between particles and increases viscosity, which has the opposite effect.

Extrudability indicates the ability of a solution to be continuously delivered through pipes and through a printer nozzle. Achieving good extrudability is possible when using round aggregates, as well as with a significant volume of cement to fill the voids. It was found that the optimal ratio of fine aggregate to cement is 1.28, and that of fine aggregate to sand is 2.0.

Shape stability refers to the ability of a printed material to maintain its shape after printing under its own weight and pressure from the top layers. The high rate is achieved due to the high content of sand and fine aggregates. It is noted that the viscosity modifier can provide a set of more than half the strength for 28 days, already one day after printing. Also, the test results showed that the addition of 0.05% lithium hydroxide can shorten the curing start time to 9 minutes.

To ensure a continuous printing process, it is required that the material has a significant setting time, while the onset of hardening should not increase. Studies have shown that the setting time increases when replacing 30% of the cement with blast furnace slag. The main additives that affect the setting time are accelerators and hardening retarders. It is noted that alkaline accelerators are more effective than alkali-free ones. It is described that the introduction of alkali-free accelerators from 2% to 7% by weight of cement reduces the setting time of the cement post from 360 to 150 minutes.

Shrinkage is one of the main characteristics, since the dimensional accuracy of the layer and shape stability depend on it. Concrete material for 3D printing requires a significant water content to provide the required mobility and extrudability. As a result, shrinkage deformations occur during hydration. It should be noted that structures created using 3D printing always have a larger surface area than structures cast in formwork, which also leads to evaporation of free water and deformations. Shrinkage control is carried out by introducing mineral additives. The data obtained show that replacing cement with 80% ash leads to a decrease in slump by 66.7%. Using 5% and 15% silica reduced sediment by 29% and 35%, respectively.

D. Soltan and co-author also call the extrudability, print window, compressive strength and strength between layers the main parameters of a solution for a construction 3D printer [3]. The authors note that such indicators as extrudability, extensibility and interlayer bonding depend on workability, and manufacturability can be equated with flowability.

The relationship between extrudability and extensibility is inversely opposite. Thus, by increasing the rate of extrudability, the possibility of building up layers is reduced and vice versa. This complicates the task of finding the optimal balance for the solution.

Another criterion for evaluating a mixture for 3D printing is the adhesion of layers of concrete mixture. The authors of [4] note that the bond strength between layers depends on many parameters, which include: viscosity, setting time, contact area between layers. It has been found that a rectangular nozzle gives a larger contact area than a circular one, hence the adhesion between the layers is better.

Thus, summing up, it can be noted that there are the main technological characteristics affecting the quality of sweep, these are: mobility, extrudability, shape stability, setting time and shrinkage. The balance between some indicators is quite difficult to maintain, which requires the addition of various modifiers affecting specific characteristics to sweep away. If all the required criteria are met, it can be argued that the resulting mixture will be suitable for printing on a construction 3D printer.

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