Structurization of Composites When Using 3D-Additive Technologies in Construction

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Abstract. One of new and perspective lines of development in the field of construction technologies is the integration of additive production elements. The laboratory study of these issues revealed critical challenges that slightly slowed down the introduction of construction printing in daily construction practice. One of such problems is a big difference of structurization conditions of additive composites produced via traditional methods. The paper provides the analysis of factors exerting negative influence on structurization and considers the possibilities of solving such challenges.

Keywords: Construction printing · Mixing ratio · Structurization of composites · Composite binding agents · Mineral additives

1 Introduction

One of new and quite perspective development areas of construction technologies is the integration of additive production elements. The active development of construction printing launched a decade ago allowed creating some concepts demonstrating only a mere part of its potential and drawing public attention and investments to its development (De Schutter et al. 2018). However, it also caused some critical problems that slightly slowed down the introduction of construction printing in daily construction practice.

First of all, such problems include structural reinforcement. In the most cases traditional reinforcement methods (frames, rods, grids) do not correspond to the ideology of additive production, which implies that the construction robot installs the building structure without too much human involvement and use of various additional technical tools. Various methods of dispersed (Christ 2015) and textile reinforcement (Lesovik et al. 2017) may possibly solve the matter, and in the long-term perspective this problem may be solved by making the construction printer place or 'raise' the reinforcement according to the design project.

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Another problem, which is currently being tackled by scientists, is the production of efficient mixes for printing, which is considered controversial from the perspective of the traditional concrete technology and with regard to its sufficient properties. It is impossible to ensure competitiveness of construction additive technologies in relation to traditionally applied methods without the development of new principles of their creation that would integrate classic approaches and the latest achievements in construction materials science (Yi et al. 2017).

2 Methods and Approaches

The study used the traditional cement-sand mortar at the ratio of 1:4 at W/C = 0.45…0.5 as an extrusion printing mix. The following refer to special properties of mortar, which make its different from standard mixes:

- ability to easily pass through the extruder and a 20 × 20 mm nozzle without losing uniformity and sticking to walls;
- ability to hold its shape after extrusion and resist loading of at least 5 layers placed on top without intermediate curing.

The specified qualities were obtained due to combination of two Russian additives characterized by availability, low cost and good technological effectiveness. The used additives allow receiving various mixes for construction printing at the C:S ratio from 1:3 to 1:5 that preserve special properties within 25…30 min.

3 Results and Discussion

The printing with the developed mixes on a laboratory unit (Fig. 1) sets the task to obtain the flattest surface without post-processing.

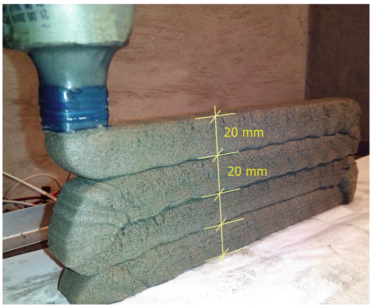

Fig. 1. Printing with developed mixes on a laboratory unit

Table 1 shows the strength properties of the mix during processing in various conditions. The preparation of a molding compound is critical since this stage ensures the formation of traditional and special properties.

According to our experience in the study of construction printing, it is more preferable for industrial facilities to ensure continuous supply of the mix into a small bin feeder installed on a forming device.

Table 1. Strength of mixes (MPa) depending on curing conditions

Composition	1 day	3 day	7 day	28 day
1:3 (in water)	3.7	8.2	12.6	17.9
1:3 (in insulation)	4.2	8.2	11.3	14.3
1:3 (in air)	4	6.9	8.1	8.5
1:4 (in water)	2.9	6.3	9.4	12.9
1:4 (in insulation)	3	6.8	10.5	15.2
1:4 (in air)	3	5.4	6.6	6.8

The stage when the mix passes through the extruder is followed by its additional mixing, decrease in viscosity, and utilization of some amount of air. Printing with slight premolding of lower layers with the newly placed ones ensures the formation of stronger contact between them compared to free mix outflow, but at the same time imposes increased requirements on the ability of a mix to keep its shape after extrusion (Secrieru et al. 2017).

The third stage is characterized by the largest duration and ensures the formation of final indicators of the additive structure.

The curing conditions of composites in the printed structure significantly (for the worse) differ from traditional methods of concrete works (Zharikov et al. 2018). The wall assemblies made via outline printing have small effective sectional area at their quite big surface area, which leads to their fast dehydration. Table 1 shows the influence of curing conditions on strength accumulation velocity.

It is less likely possible to create favorable conditions for structurization of composites due to external moistening, therefore it is possible to define solution to this problem: reduction of a binder's demand in water and the maximum increase in early strength during the period until the main amount of liquid has not evaporated yet.

As it was noted in some works (Chernysheva et al. 2013; Sumskoy et al. 2018; Lesovik et al. 2014; Kuprina et al. 2014; Elistratkin et al. 2018), a good solution in such cases may be the replacement of portland cement with composite binding agents that contain mineral additives with developed microporosity (zeolites, utilization products of some ceramic construction materials). Such products are able to create some moisture stock, which maintains hydration for some time needed for the material to become strong.

4 Conclusions

Alongside with various processing technologies, quite often complicating the design of a construction printer, the essential positive effect may be achieved by using composite binding agents with required properties: required rheology, ability to quickly gain strength during solidification in the conditions of fast dehydration, reduced or zero shrinkage. Such measures will provide for a simpler solution to the task of creating favorable conditions for composite structurization in construction printing thus establishing a self-sufficient system not too much dependent on external factors.

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