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RELIABILITY OF PRINTERS 3DCP DURING CONTINUOUS WORK

NIEZAWODNOŚĆ DRUKAREK 3DCP W TRAKCIE CIĄGŁEJ PRACY

Summary: *The paper presents the studies on the reliability of printer Rebuild v3 during the implementation of the order of the Institute of Construction Technology. The object of the study was printing out of three miniature houses for fire tests and evaluation of burning ability of printouts made from the concrete. All the houses were printed during one session, lasting for 27h. Apart from the process of producing the objects, it was also possible to check the reliability and behaviour of the printer in so long and non-interrupted process.*

Keywords: *printer 3DPC, printer Rebuild v3, construction, reliability test*

Streszczenie: *Artykuł przedstawia badania niezawodności drukarki REbuild v3 w trakcie realizacji zlecenia dla Instytutu Techniki Budowlanej. Przedmiotem badania było wydrukowanie trzech miniaturowych domków do testów ogniowych i oceny palności wydruków z betonu. Wszystkie domki zostały wydrukowane podczas jednej sesji trwającej 27 godzin. Poza samym procesem wykonania obiektów, udało się sprawdzić niezawodność i zachowanie drukarki w tak długim i nieprzerywanym procesie.*

Słowa kluczowe: *drukarka 3DCP, drukarka REbuild v3, budownictwo, badanie niezawodności*

Introduction

At present, construction is the greatest sector of the industry which has not been automated. It is connected with many negative social consequences such as the highest mortality rate as compared to all remaining branches of the economy [1] and also, the economic effects among which the deficit of qualified physical workers is the most significant phenomenon [2, 3 4]. Therefore, it is estimated that value of 3DCP market will be very quickly increasing [5, 6]. Print 3 D may be employed in the target site as well as in the manufacturing hall for performance of ready-to-install prefabricates.

The aim of the work

IThe reliability tests were conducted during the implementation of the work, ordered by the Institute of Construction Technology. The purpose was to print three miniature houses for fire tests and evaluation of burning ability of printouts made from concrete. The mentioned houses had the external dimensions equal to 2.4 m x 3.4 m x 2.2 m (illustration with the dimension is given below). Each of them was placed on a separate, prefabricated plate made from reinforced concrete with the dimensions 2.5 m x 3.5 m x 0.2 m and weight of 4 tons each. All the houses were printed during one session lasting for 27 hours. Apart from the process of printing the objects, it was also possible to check the reliability and behaviour of the printer during such long and non-interrupted process. For printing, the printer Rebuild v3 was used.

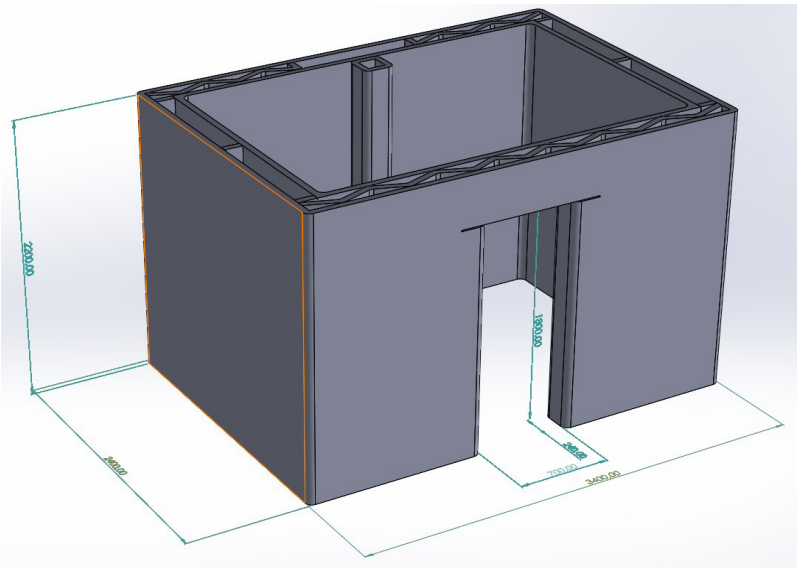

Fig. 1. Dimensions of the object: 2.4m x 3.4 m x 2.2 m

Fig. 2. Printer Rebuild v3. Real view from the first building site of this type in Poland, with the application of concrete in 3D printing

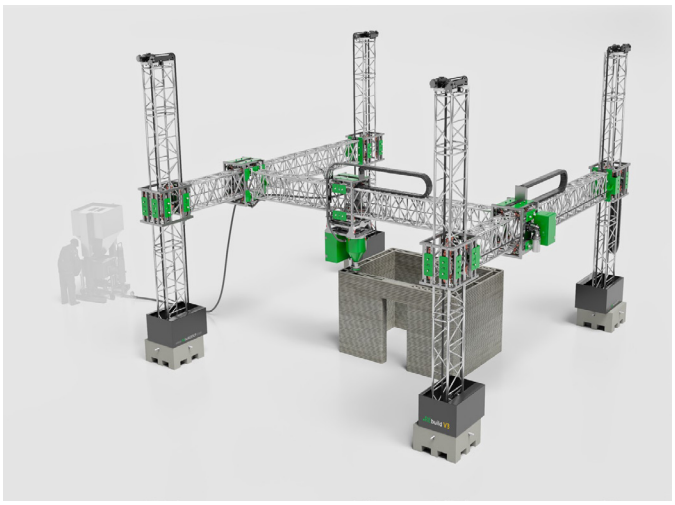

Fig. 3. Computer model of printer

Fig. 4. Printing of houses (reinforcement and thermocouples are visible)

During printing, thermocouples were inserted between the selected layers for temperature measurements. In total, 40 thermocouples were inserted into each house.

The layer of 25 mm high and a path of 50 mm wide with elliptic shape were used. Printing was conducted with the use of round nozzle with 40-mm diameter. The total printout consisted of 88 layers and the weight of the printed out concrete mixture was equal to 18 tonnes. It gives the output of 670 kg of concrete mixture per hour. The value of expenditure in the case of printouts is a componential of two factors – expense of extruder and shape of the printed path. The expense of the extruder used during printing amounts to maximum 6t/h , the printing however consisted of many short segments (inside the walls) what forced often breaks and slowing down of the printer, what, in turn de-

Fig. 5. Final effects

Fig. 6. Transport of the houses

creased the mean output of the mixture. The concrete mixture was prepared especially for the needs of 3D printing by ATLAS company. The discussed houses had a door opening, the printed reinforced lintel and wall pillar; they did not have a roof. The walls had the thickness of 240 mm and, depending on the site they consisted only of outline or outline with filling in a shape of Z letter. The filling is aimed at the increase of the strength of the printing, and the empty space was filled with the different types of thermal insulation. The walls were reinforced manually with the rods with 6 mm diameter, bent in U letter shape and laid each 5 layers.

After completion of the process, the buildings were wetted with water and then, tightly covered with foil in order to minimize the risk of cracking of the printout. In the case of the mixture intended for 3D printing, the key operation consisted in ensuring the appropriate care of the concrete after completion of the process due to a high inclination of the material to generate the cracks (a high contraction during binding).

The successive stage included transport of the objects to the target site where they would be subjected to fire tests. For loading and unloading, the hangs screwed into the fundamentals were employed.

Conclusions

The printers for the concrete were able to work without a failure during the whole process which lasted finally for 27 h. It is evidence that the technology of print 3DCP is ready for a wide use in construction and prefabrication processes.

During such a long process of printing connected with the constant binding of the concrete in the performance systems, it might be expected to meet the problems connected with the clogging of pumping hoses, mixing elements and material dispensers. Any decline in output of the extruder or pump feeding the material to buffer tank was not observed. There was detected only one problem connected with the removal of the tank of concrete extruder from the mixing device. It was solved by the change of geometry of the buffer mixer.

Fig. 7. Composite reinforcement in the concrete sample

The currently employed material gives the possibility of rising the construction at the rate of 0.3 m/h (experimentally determined). It is a parameter connected with the geometry of the element as well as with the speed of binding of the mixture. The discussed buildings could be ready during 10 h. The shape and structure of the walls were not prepared in this case to 3 DCP technologies, therefore they require optimization. All types of short and complicated paths have a very negative impact on the mean expense of the process; due to this reason, the process becomes prolonged.

Transport of the printed objects goes in the same way as that one of other prefabricated concrete elements. Limitation includes the dimensions and weight of the final product what should be considered in the stage of design of the construction. In the case of necessity, it should be produced in the pieces; another solution may be transport of machine and the building site and performance of the printing "on-site". It has certain advantages such as the possibility of printing of the objects in one process, on the total working area which may be even 15 x 13 x 5 m in the case of REbuild v3. Also, transport of the decomposed machine is simpler (due to utilization of aluminium lattice (grate) the weight of the construction is less than 2.5 t). On the other hand, the drawback includes the dependence on the weather conditions whereas during printing in the manufacturing hall, the mentioned conditions are constant and are, as a rule, favourable for the process of the care of the concrete.

Plans for the further development

The successive step includes production and testing of automatically reinforced constructions, with the utilization of the system for automatic placing of reinforced elements (developed in Rebuild), as being described in the patent application PCT/EP2019/069290) and comparison of the obtained resistance (strength) data and reliability of the process.

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