Application of Modeling Processes and 3D Print on Casting Molds for Concrete Furniture

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Abstract. The paper describes the practical use of modeling processes and 3D printing for the production of furniture, decorative and other objects. Using 3D modeling and printing on a 3D printer, it is possible to create a mold and subsequent product with a much more complex shape than would be possible with hand-made formwork or mold, or at least much simpler. Demonstration of applicability of these molds was carried out by an experimental method when the molds were poured out by cement or concrete from the fine aggregate. The forms themselves were formed from PLA filament. Experiments have shown the usability of such molds for complex concrete elements. These forms can be reused. Damage to the molds occurred during handling or cleaning, i.e. rough handling. During the filling itself and the process of cement hydration, they were not damaged. For a longer mold life, it is necessary to print in a larger percentage of filling, which, however, makes the mold more expensive. The durability of molds and better formwork is obtained by using formwork oil.

1. Introduction

The aim of the article is to verify the practical use of modeling processes and 3D printing for the production of furniture, furniture, decorative and other elements. The paper will verify whether it is possible, using 3D modeling and subsequent printing on a 3D printer, to create molds for casting from concrete or cement. Such castings could have much more complex shapes than conventional formwork. In addition, the use of PC modeling and subsequent printing can be simpler and less laborious than molding by hand or other methods.

Nowadays some companies are engaged in the production of concrete decorative elements, advertising products and the like [1].

2. Preparation of forms for printing

For modeling of forms is based on knowledge of general modeling of objects, which is used in building construction. In this case, the Inventor modeling software from Autodesk [2] was used, but any software that allows you to create three-dimensional models with exact dimensions can be used and the object can be exported in a .stl file.

When modeling a mold for casting concrete objects it is necessary to have knowledge of 3D printing and casting of concrete into classical molds. The modeling is preceded by the layout - reconnaissance [3] - of the mold on the parts so that their size corresponds to the printable three-

dimensional area of the 3D printer used, and also the mold fulfills its purpose so that it can be opened after casting to remove the desired object and reuse. Figure 1 shows the form in the software and the final printed form.

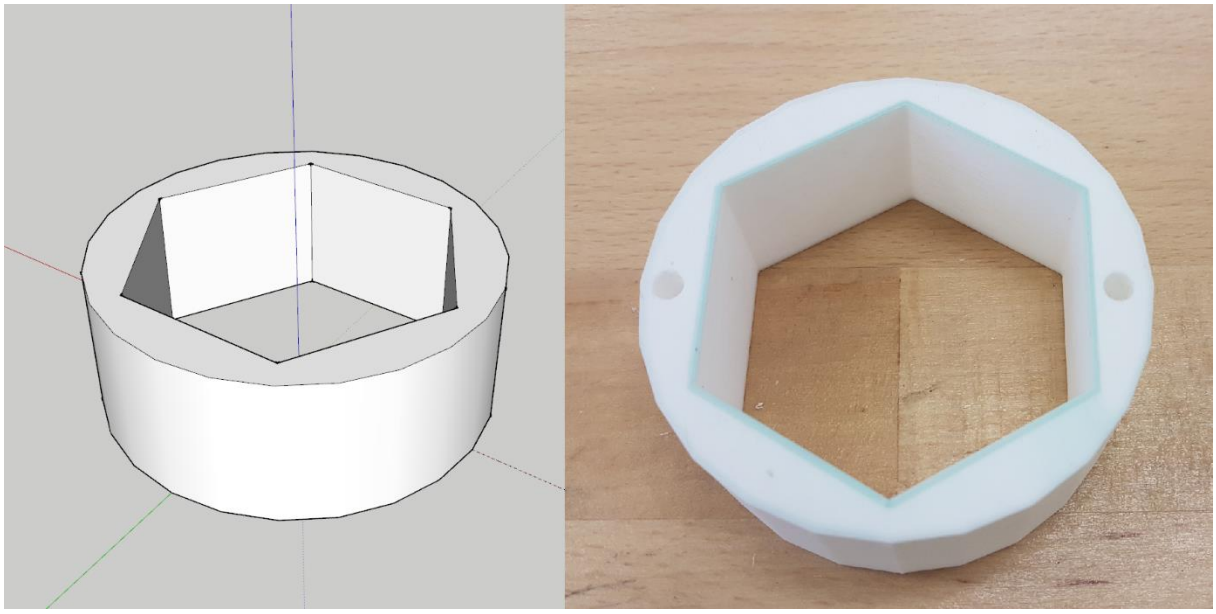

Figure 1. Form modeling in 3D software, final embossed form.

3. 3D printing of forms

Fused Deposition Modeling was used for 3D mold printing. The process of this 3D printing technology is that the thermoplastic filament is extruded through a small nozzle into fine layers that accumulate on each other to form the object. The printer heats the plastic to a molten state and pushes it (or extrudes) through a small nozzle - much like a hot glue gun, molten adhesive flows out when the trigger is pressed. The computer controls the movement of the 3D printer (based on your 3D model) and tells it to selectively deposit the molten plastic in the shape of the first layer of your object, which solidifies almost immediately as it cools. Then the next layer is extruded onto the first layer and so on. As layers build on each other - a small layer after a small layer - the physical object begins to form. [4]

The Prusa MK2 3D printer was used with the following settings:

Material:	PLA
Step:	0,2 mm
Nozzle:	0,4 mm
Perimeter:	2
Temperature:	210 °C
Filling:	20 %

For larger parts, a 0.3 mm step was used to reduce 3D printing time. A 20 % filler is sufficient for concrete molds as the mix pressure is not high enough to require a higher filler percentage. For the same reason, filament from PLA could be used.

4. Production of concrete castings

The printed form was either fixed to the base plate as shown in Figure 2 or other cases it was directly assembled from multiple pieces printed on a 3D printer. The most important thing has always been

that the finished concrete product can be easily removed. At the same time, the form was undamaged and could be used further.

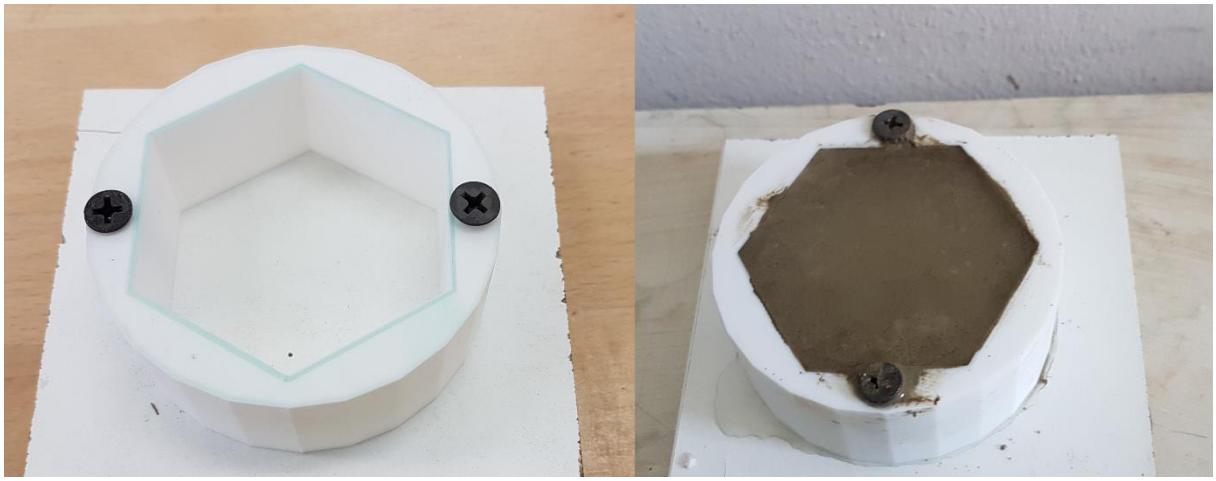

Figure 2. Casting of concrete into molds.

The concrete mix consisted of Portland cement mix CEM II/B-M (S-V-LL) of strength class 32.5 R according to ČSN EN 197-1 [5]. It also consists of aggregates with a 0-2 mm fraction. The aggregate grain size curve is shown in Figure 3. The mixing water was supplied with a water coefficient of 0.4 to 0.5, depending on the complexity of the mold. The more complex the form, the higher the water coefficient was used or the plasticizer was used.

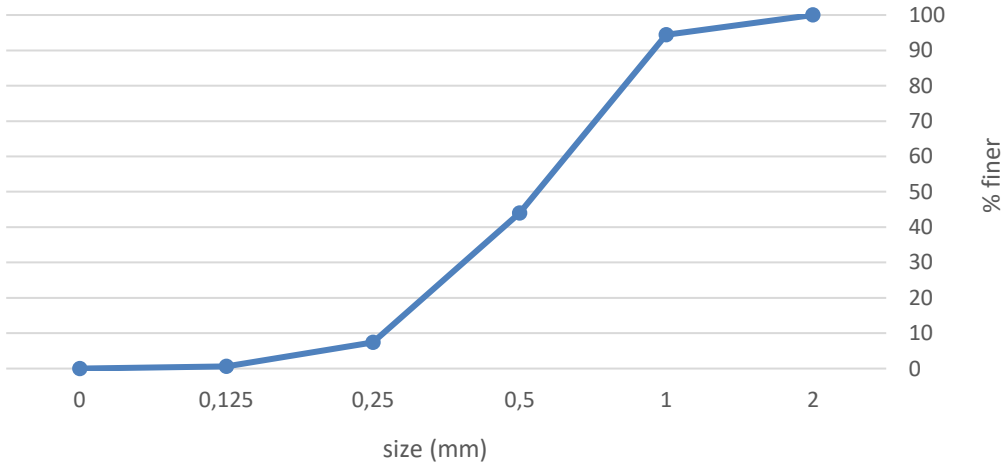

Figure 3. Grain Size Analysis of Aggregates.

The first hexagonal mold (Figure 2) was used to determine the correct ratio of binder (cement) and aggregate (silica sand). Visually the best result was 1:1, cement to sand (weight ratio). The test products are shown in Figure 4. In this figure, the final mixture is indicated by 1. The number 0 denotes the cement paste, ie without the use of aggregates.

The mold was filled by pouring the concrete mixture into the mold, printed on a 3D printer. The molds were wiped off with formwork oil. Furthermore, the sample was shaken by an impact on the table or by shaking on a vibrating table. The blend mold was covered with a plastic bag for 24 hours to prevent the blend from drying out. Then, the sample was removed from the mold and immersed in

water for 24 hours to avoid cracks. According to the usual procedure, the sample should be aged under water for 28 days, but in this case, it was not necessary to measure the strength after 28 days.

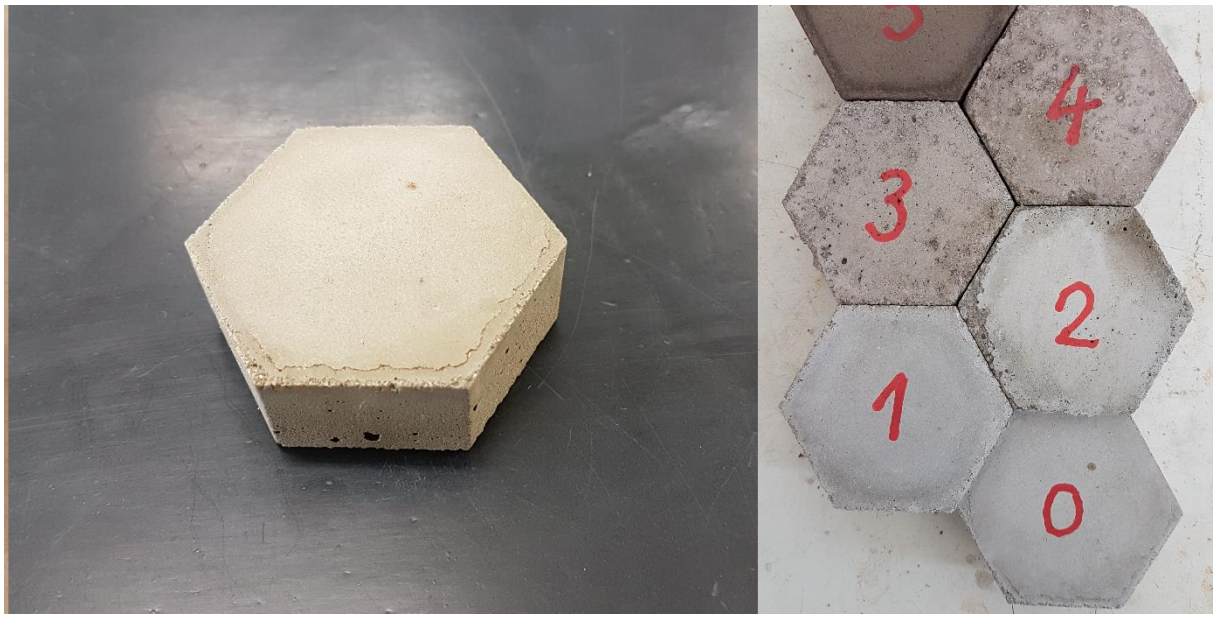

Figure 4. Final castings.

5. Results and discussions, Conclusions

Experiments have shown the usability of such molds for complex concrete elements. These forms can be reused. Damage to the molds occurred during handling or cleaning, ie rough handling. During the filling itself and the process of cement hydration, they were not damaged.

For a longer mold life, it is necessary to print in a larger percentage of filling, which, however, increases the cost of mold production. The durability of molds and better form removal is obtained by using formwork oil.

A problem in the production of concrete products and decoration by this method is the limitation of the size of the printed form by a 3D printer. Each printer has certain limits in terms of print area and print height. There are two methods to solve these problems. The first method is to assemble a mold from multiple parts printed on a 3D printer and then join them together, for example gluing, screwing and the like. This method is also suitable for easier removal of the product. Thorough gluing of the individual parts does not result in visible joints on the concrete product, but it may be more difficult to remove the formwork. If parts of the mold are screwed together, they can be stripped off well, but again they are visible on the concrete product (as shown in Figure 5). Another method of eliminating the problem of mold size limitation is by mold shifting. However, this method is only suitable for some products where the mold can be moved in one direction. The manufacturing process according to this method means: 1. casting the first part into the mold; If necessary, continue from step 2. For better connection of the individual parts, the product must be still moist or need to be supplemented with wires connecting the two parts.

An example of the application of mold casting from a 3D printer is shown in Figure 5. There was created a set of decorations with ashtray, candlesticks and coaster.

Because of the formwork, it is preferable to use silicone molds. Silicone molds, however, do not retain large concrete weight for larger products. Creating a silicone mold is more difficult or less

available than using 3D printing. A suitable option would be to use a combination of silicone and 3D printing.

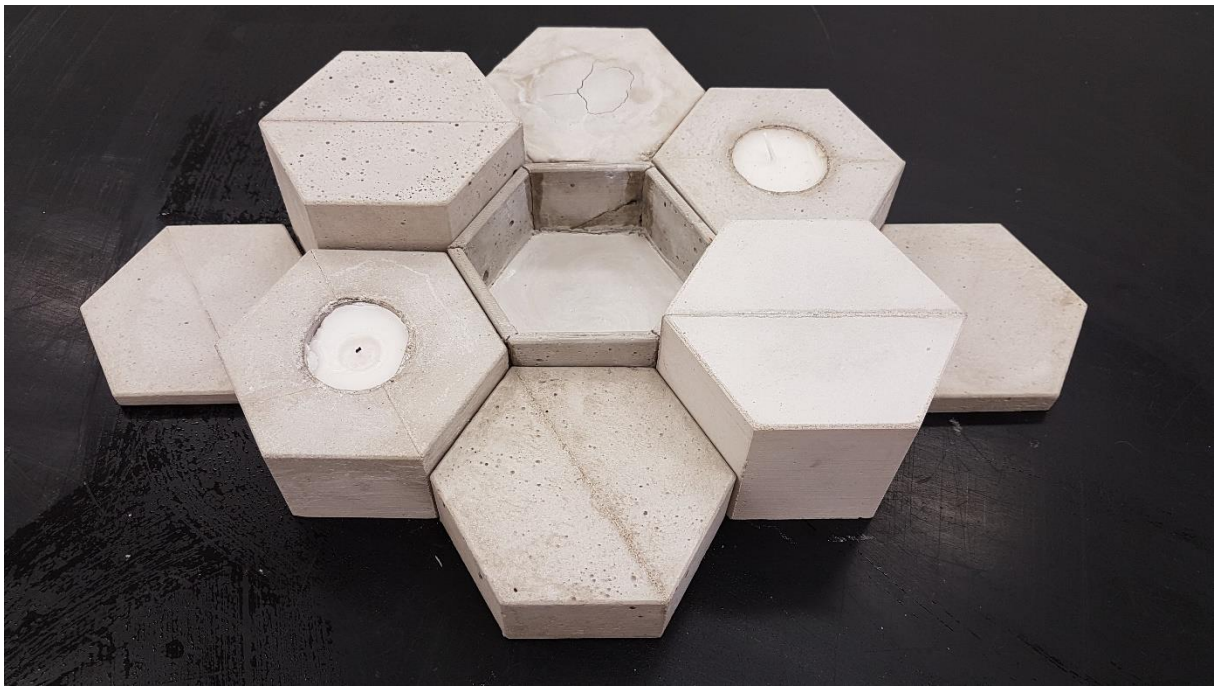

Figure 5. Example of application of mold casting from 3D printer.

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