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3D PRINTERS IN BUILDING CONSTRUCTIONS – FUTURE IN BUILDING INDUSTRY

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Abstract: *The article deals with the history of 3D printing and its use in the buildings and civil construction at all. The author of the article will try to clarify the current status of the issue and the level of use. And will also include current systems and applications especially from abroad within EU countries and the possibility of future use with regard to the development of material base used not only limited to Earth.*

Keywords: Building production, materials, technology, 3D printing, building systems

1 INTRODUCTION

It Digitization and computing have been deeply affected architecture in the past decades. Projects taking advantage of these new technologies are often criticized for their frivolous or indulgent nature. On the other hand, there has been an emergence of work that exemplifies the most optimistic of this so called "Third Industrial Revolution" – an architecture that appropriates new technology and computation for the collective good of our cities and people (Oh, 2016).

2 FROM CAD TO 3D PRINT

Computer-aided design (CAD) is the use of computer systems to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing (Horák, 2016).

CAD is an important industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more. Because of its enormous economic importance, CAD has been a major driving force for research in computational geometry, computer graphics (both hardware and software), and discrete differential geometry. CAD is just another example of the pervasive effect computers were beginning to have on industry. Current computer-aided design software packages range from 2D vector-based drafting systems to 3D solid and surface modelers. Modern CAD packages can also frequently allow rotations in three dimensions, allowing viewing of a designed object from any desired angle, even from the inside looking out.

Not only CAD systems are prerequisites for 3D printing. 3D printing is complex area, which needs to have strong IT support. CAD systems can be divided into general CAD systems (2D or 3D - surface and volume) and specialized. In the area of construction and architecture are especially: AEC (Architecture-Engineering-Construction), BIM (Building Information Model), CAAD (Computer-aided architectural design). BIM technology when designing is increasingly used (Venkrbec, 2016). The designer who decides to switch from designing in general CAD system for the use of BIM systems will initially deal with plotting elements, e.g. the walls. Suddenly faced with the decision whether to draw the wall as usual, i.e. the compositional dimensions, which does not show plaster. Or individual layers to include layers of walls to allow more accurate reporting of the bill of quantities, which, using existing principle of drawing, cannot achieve. For basic CAD systems it is based on the principle of graphical representation of elements by drawing a substitution tags where it was not necessary to address this issue. Walls were represented by only two lines, without any relationship and were placed at a distance corresponding modular dimensions.

When creating the design documentation in BIM, it leads to the involvement of other parameters (price, quality, other properties...), so that the model can be used for further processing. It must be therefore carefully consider the purpose for which this documentation is determined, and then adjust the level of detail of the model. If we compare the way of working in CAD systems, it is as the use of electronic drawing board. When using BIM you can create a complex model that you can use later in life-cycle of the building.

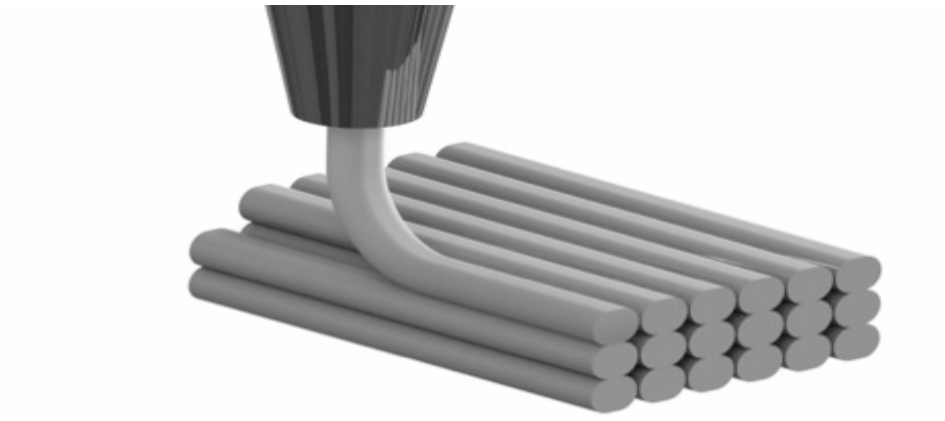
One output of using BIM system can be possibility to print building or its part using 3D printer. Such 3D print can be various depending on "printing" material.

3 PRINCIPLES OF 3D PRINTING IN BUILDING INDUSTRY

We define 3D printing or additive manufacturing as a process of making three dimensional solid objects from a digital file or digital

source in general. The creation of a 3D printed object is achieved using additive processes. In an additive process an object is created by laying down successive layers of material until the entire object is created. Each of these layers can be seen as a thinly sliced horizontal cross-section of the eventual object.
Not all 3D printers use the same technology. There are several ways to print and all those available are additive, differing mainly in the way layers are built to create the final object. Some methods use melting or softening material to produce the layers. Selective laser sintering (SLS) and fused deposition modeling (FDM) are the most common technologies using this way of printing. To be more precise: since 2010, the American Society for Testing and Materials (ASTM) group "ASTM F42 – Additive Manufacturing", developed a set of standards that classify the Additive Manufacturing processes into 7 categories according to Standard Terminology for Additive Manufacturing Technologies. These seven processes are: Vat Photopolymerisation, Material Jetting, Binder Jetting, Material Extrusion, Powder Bed Fusion, Sheet Lamination, and Directed Energy Deposition. In building industry the most used is Material Extrusion, see example Figure 1.

Fig. 1 An FDM print head laying down printing material



FDM method could be considered as an analogy to building based on Superadobe technology (Kovářová, 2012). Wall, which is built by layering of bags, which are filled with mixture of soil and straw. Bags are connected by barbed wire which is also reinforcement for the wall. This barbed wire is freely laid between bags. The walls being constructed with these bags is 50 cm thick. Openings for windows and doors are prepared during the building process. Instead of windows temporary wooden fillings are placed into openings. These wooden frames are later substituted for windows and doors. See figure 2.

Fig. 2 Superadobe technology

In the building construction is used in two directions movable nozzle because the table (unlike applications in other industries) is fixed. As material is used concrete based mixture. Print speed/construction depends on the planar size, the layer thickness and consistency of the mixture, since it does not use shuttering. Compared with the traditional construction of reinforced concrete we can see an analogy - you can print directly on site (reinforced concrete), or assemble a pre-printed components (prefabricated concrete). Pre-printed parts can be produced directly on the site (site-cast units), or in central factories. See examples figure 3 and figure 4. Both types of print outs are the result of computer-aided design, mostly based on BIM system.

When printing directly on the construction site, the building creates printing consecutive layers can be seen here technological analogy to “classical” construction based on bricks. In contrast, when using pre-printed components leads to their assembly into the finished work. Components can be assembled by stacking, or may be used in part shaped "sections" of the object. See in Figure 4. Both options can of course be combined. The actual construction should use all possibilities of BIM, e.g. simultaneous incorporation of piping and cabling, which increases the efficiency and reduces the price demands of finishing work on the subject.

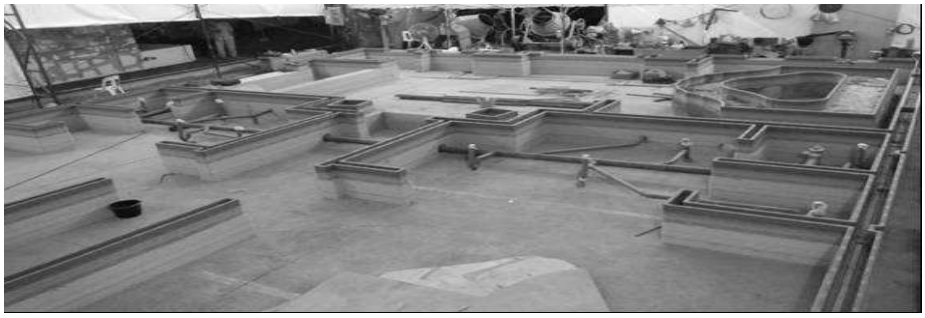


Fig. 3 Plumbing and other hardware installed into the 3D printed house

Fig. 4 Building based on pre-printed parts

4 FUTURE OF 3D PRINTING IN BUILDING INDUSTRY

3D printers gradually penetrate into all industries. This is true also for the area of construction. Using a 3D printer is an increase in productivity, reduce waste due to improved accuracy of production, even if the diversity of requirements - 3D printing easing requirements on modular coordination.

Netherlands within the EU supports the most advanced 3D technology. Let the occasion of the EU Presidency to propose a mobile pavilion Building Europe for meetings with politicians’ entrance facade from the studio DUS Architects. Attractive shape concept enabled 3D printed parts made from fully recyclable plastic, see Figure 5.

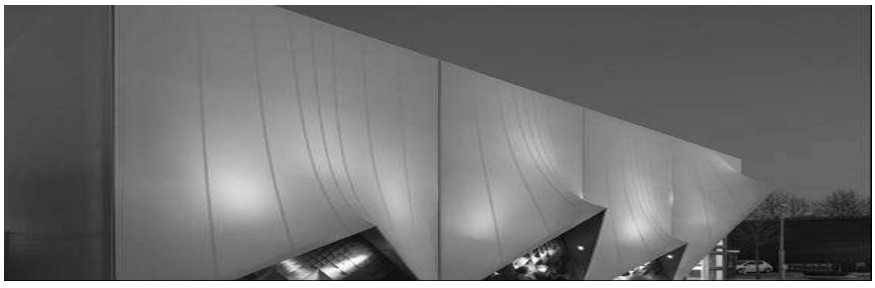


Fig. 5 Building based on pre-printed parts

In comparison with the "classical" methods of construction using 3D printing is another alternative in technology. Outputs of 3D printing show improved mechanical and thermal properties compared to the current monolithic and prefabricated structures. Another highly positive benefit is less impact on the environment due to reduction in waste and a lower environmental demands during the construction process. Of course we should mention the disadvantages of this method of construction. The main disadvantage is current material base paste for printing. The technology is relatively new, materials are subject

to research and development. Another disadvantage of printing on the construction site is relatively complicated installing of very large printer on site to achieve the required accuracy of printing, thus resulting accuracy of the works.

It could be use metal as “printing” material as well. Printing an intricate, ornate metal bridge for a special location is the ultimate test for robots and software, engineers, craftsmen and designers. The bridge by designer Joris Laarman will be ready in 2017. The design process using new Autodesk software is a research itself, synchronized with the technical development and taking into account the location. The project is a collaboration between MX3D, software giant Autodesk, construction company Heijmans and many others.

Fig. 6 Bridge over the water in the center of Amsterdam

3D printing is not limited only to Earth. Setting up a lunar base could be made much simpler by using a 3D printer to build it from local materials. Foster + Partners devised a weight-bearing ‘catenary’ dome design with a cellular structured wall to shield against micrometeoroids and space radiation, incorporating a pressurized inflatable to shelter astronauts. 3D printing offers a potential means of facilitating lunar settlement with reduced logistics from Earth. The new possibilities this work opens up can then be considered by international space agencies as part of the current development of a common exploration strategy. The UK’s Monolite supplied the D-Shape printer, with a mobile printing array of nozzles on a 6 m frame to spray a binding solution onto a sand-like building material. First, here is needed to mix the simulated lunar material with magnesium oxide. Then for structural ‘ink’ is applied a binding salt which converts material to a stone-like solid (ESA, 2013).

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