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3D printing of buildings and building components as the future of sustainable construction?

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Abstract

The paper presents the state-of-the-art concerning the current achievements in the field of 3D printing of buildings and building components. The 3D printing technologies, comparing to traditional techniques of constructing the buildings, could be considered as environmental friendly derivative giving almost unlimited possibilities for geometric complexity realizations. Two kinds of technologies were described in this paper with pointing to Contour Crafting as a promising technique that may be able to revolutionize construction industry in near future. Numerous advantages of this technology, such as reduction of the costs and time, minimizing the pollution of environment and decrease of injuries and fatalities on construction sites could be cited. Despite many advantages and hopes, some concerns are summarized in the conclusions, as the technology still has many limitations. A brief description of few examples of pioneering usage of 3D printing in construction industry are presented (Canal House in Amsterdam, WinSun company and printing application for building carried out by Skanska company). Creating a model that will be appropriate for 3D printers is possible in many different modelling programs. One of the most popular formats for sharing such models is STL format. In the paper sample models crated in Autodesk Inventor are shown, but also other tools suitable for preparing models for 3D printing are briefly discussed.

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Keywords: 3D printing; concrete; contour crafting; building materials; sustainable construction

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1. Introduction

The first 3D printer was invented in 1984 and over the last decades, 3D printing has become one of the fastest growing technologies. At the beginning it was very complicated and what is more, expensive technology. Over the years, 3D printing started to be present in everyday life and printers became commonly used in all kinds of industry fields. A lot of achievements have been made in medicine, automotive or aerospace industry. Thanks to the open source systems, prototyping of new product, and innovative applications of 3D printing in various fields are available for everyone.

Improvement of the printing material and 3D technology became to be the goal for many companies all over the world from all industry sectors. In 2014, real revolution in construction industry has started, as the first house was printed starting a new chapter in building technology.

The questions asked in this document are: is 3D printing technology effective enough to go out of laboratory settings and be embraced by building industry? To which extent 3D printing can replace traditional construction technologies? What are the application areas where this technology is to be applied first?

2. 3D printing technology and materials

The idea of 3D printing was born already in 1983, when Charles W. Hull came up with an idea of hardening the tabletop coatings with the UV light [1]. This simple thought has lead him to invention of stereolithography, first technology of 3D printing. Stereolitography was the first technology of rapid prototyping which means fast, precise and repeatable production of elements usually with computer support. First step in creating the technology was invention of additions to the synthetic resins that after lightening of the resins, were causing start of the polymerisation process. Stereolitography is a technology that can build objects with a high precision and extremely complicated geometry and that's the reason why it is used in many fields like for example: medicine, automotive and plane industry, and even art and design. Similar technique for 3D printing is selective laser sintering (SLS) in which laser is used to melt a particles of powder together to create an object. Materials used in SLS technology usually have high strength and flexibility. The most popular ones are nylon or polystyrene. Fused deposition modeling FDM is a technology that was invented in 1988 by S. Scott Crump [2]. Ductile materials which are hardening itself during cooling process, are extruded through double headed nozzle. Both, modelling and supportive materials are being deposited according to the cross-section layers, generated from digital model supporting the printer. The nozzle contains resistive heaters that keep the filament in appropriate melting point, which allows it to flow easily through the nozzle, in case to form the layers. Like in the other technologies, after creating one layer, a platform is being lowered and next layer is created. This process is repeated until the whole object is completed. Materials usually used in FDM technology are called filaments and are used in printers as a rolls of thermoplastic materials like ABS (*Acrylonitrile Butadiene Styrene)* or PLA (*Polylactic Acid*) – which is a completely different kind of thermoplastic. It's being made from corn starch or sugar cane and is biodegradable, so it is considered as greener and more sustainable than ABS. Over the past two decades, fused deposition modelling has become the most popular and widely used 3D printing method in the world. Wide range of materials were developed during the last decades presenting various properties and allowing to increase the range of applications and giving the prints the aspect of wood (*PLA with wood fibers*), metal (*PLA with bronze*), sandstone (*PLA with milled chalk*) [3].

3. Examples of 3D printing application in building industry

3.1. Canal House in Amsterdam

In 2014 Dutch designing company Dus Architects decided to build a house by printing its parts by a giant printer. In Europe, this is the first project that will be realized entirely by 3D printing technology. Project called 3D print Canal House takes place in Amsterdam and it is going to take at least three years. Architects from Dus Architects want to prove, that by printing components of the house directly on the site, they will be able to completely eliminate building waste and minimize costs of the transport. Mobility of the printer, is a considered as the main advantage as it may be transported all over the world, thanks to what, a cost of transport of the material and its