DOI: 10.37105/enex.2022.1.05

ENGINEERING EXPERT

RZECZOZNAWCA

# Analysis of 3D printing in the construction industry in terms of its pros and cons

**Anna STARCZYK – KOŁBYK** (*ORCID ID: 0000-0002-5448-7366*)

Military University of Technology, Faculty of Civil Engineering and Geodesy, ul. Kaliskiego 2, 00-908 Warsaw, Poland
Correspondence address: anna.starczyk@wat.edu.pl

Abstract: Results of an analysis of 3D printing in the construction industry over recent years are presented in this paper. The solutions in use were analysed in terms of the available printer types and examples of construction projects carried out with their help. The results of the analysis are presented with a focus on a summary of the pros and cons of using 3D printing in the construction industry.

Keywords: 3D technology, 3D printing in the construction industry, types of 3D printers, pros and cons of using 3D printing.



**Please, quote this article as follows:**

Starczyk-Kołbyk, A. Analysis of 3D printing in the construction industry in terms of its pros and cons, Engineering Expert, p. 41-50, No. 1, 2022, DOI: 10.37105/enex.2022.1.05

## 1. Introduction

Use of 3D printing in Poland and around the world over recent years have been analysed within the scope of this article. The research postulates formulated during the research concerned the potential for the developing 3D printing in the construction industry, i.e.: "The growth of 3D printing is a fact". In order to prove such a postulate, an analysis of the pros and cons of 3D printing use in the construction industry was carried out. Examples of the use of 3D printing during construction projects and its future outlooks were presented.

During the analysis, publicly available online literature sources were used. Photographs and photographic documentation also taken from publicly available websites have been included in this publication.

## 2. Process description

The 3D printing concept entails extruding a suitable blend and applying it layer by layer, fusing successive layers of material together based on a 3D computer model.

The prepared blend is placed in the device tank, from where it is transported to the printer head. The blend is then applied either onto a surface of an object or onto pre-printed layers.

For a long time, the size of the working volume of 3D printers and therefore the size of the printed objects was a major limitation of 3D printing.

In 2015, a huge (at the time) 3D printer with a working volume of 1 m × 1 m × 1 m was shown at a trade fair in Berlin. Obviously this was not big enough for the construction industry.

The introduction of robots with a 3D printing arm or the use of gantries has radically changed this situation (Dodziuk H., 2020), (Major M., Minda I., 2022).

**Fig. 1.** Apis Cor 3D printer (8.5 m x 1.6 m x 1.5 m) [Walasek M., 3d.edu.pl, 2021].

## 3. Solutions in use

There are three types of 3D printing hardware solutions:

1) Gantry 3D printers

They consist of a frame, three gantries and a print head. An entire building or sections thereof can be printed using such a printer.

**Fig. 2.** Vulcan 3D printer (11.5 feet high, 33 feet wide) [Walasek M., 3d.edu.co.uk, 2021].

2) Delta printer

Not limited by three-dimensional models and may be used to create more complex structures. The print head is suspended from arms attached to vertical guide rails.


**Fig. 3.** Big Delta printer, Crane Wasp [PlanRadar, 2022], [WASP].

3) Printers with mechanical arms.

These use either a robot or a network of robots, such as an industrial manipulator with an extruder, controlled by a computer.


**Fig. 4.** CyBe Construction CyBe RC 3Dp, CyBe R 3Dp printer [Walasek M., 3d.edu.pl, 2021].

## 4. Examples of completed projects

1) Head office: Russia
Type of structure: Low-rise buildings, however the company is working to develop equipment for high-rise construction
Geographical reach: Global
Printer: Apis Cor 3D (8.5 m x 1.6 m x 1.5 m)

**Fig. 5.** Structure made using an Apis Cor printer [Walasek M., 3d.edu.pl, 2021].

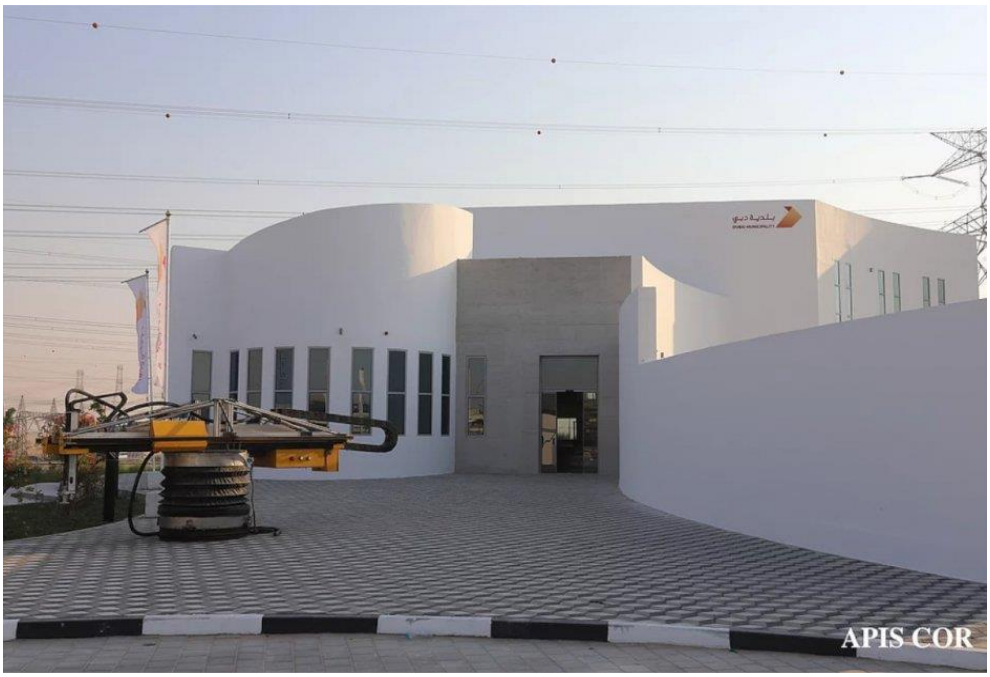


**Fig. 6.** A two-storey office building in Dubai, United Arab Emirates [dezeen, 2019].

2) Head office: Texas (USA)
Structure type: Low-rise buildings
Geographical reach: Global
Printer: Vulcan 3D (11.5 feet high, 33 feet wide)

**Fig. 7.** Construction of a residential estate in Mexico comprising 50 houses built using an Icon Vulcan printer [Walasek M., 3d.edu.pl, 2021].

3) Head office: France
Structure type: Low-rise buildings
Geographical reach: Global
Printer: XtreeE Large 6-axis robotic arm

**Fig. 8.** Structure made using an XtreeE printer [Walasek M., 3d.edu.pl, 2021].

4) Head office: China
Type of structure: Low- and high-rise buildings
Geographical reach: Global
Printer: Winsun (Yingchuang Building Technique) 3D, 492 feet long

**Fig. 9.** 3D printed houses by WinSun in China [PlanRadar, 2022].

**Fig. 10.** Office of the Future in the United Arab Emirates [PlanRadar, 2022].

5) Head office: California (USA)
Structure type: Low-rise modular buildings
Geographical reach: Global
Printer: Mighty Buildings, non-standard

**Fig. 11.** Structure made using a Mighty Buildings printer [Walasek M., 3d.edu.pl, 2021].

6) Head office: Italy
Type of structure: Low-rise buildings, however the company is working on expanding its portfolio
Geographical reach: Primarily Italy
Printers: Big Delta, Crane Wasp
This Italian company (WASP) coined one of the most interesting initiatives in the field of low-cost green buildings in the guise of the TECLA estate design.

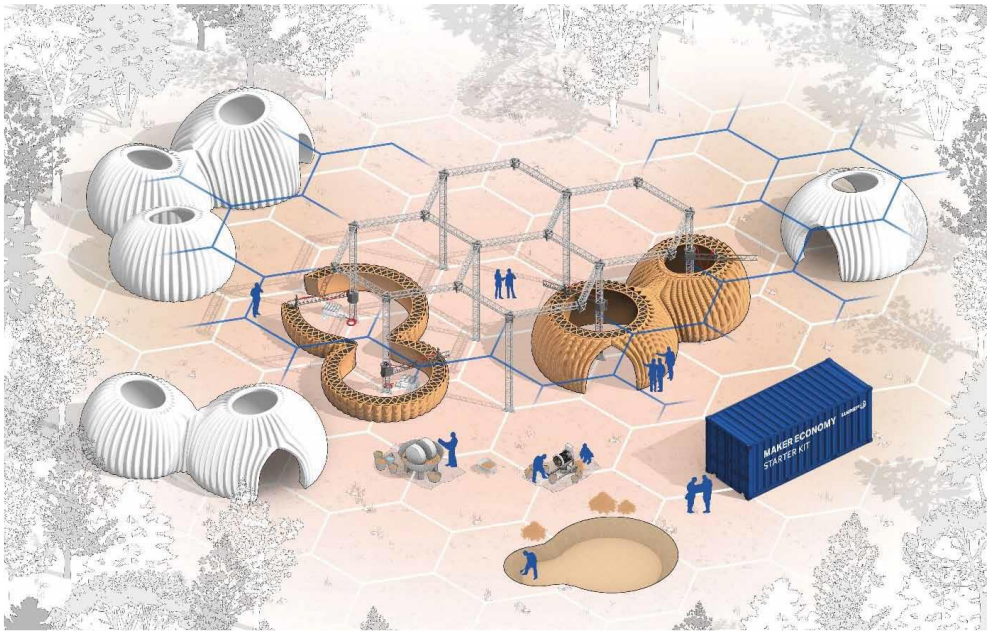


**Fig. 12.** WASP's TECLA estate design [Dodziuk H., 2020], [WASP].

## 5. Analysis results

**Table 1.** A comparison of the pros and cons of using 3D printing in the construction industry [Walasek M., Maciążek M., 3d.edu.pl, 2021], [PlanRadar, 2022].

| | Pros | Reason | Cons | Reason |
|---|---|---|---|---|
| 1. | Zero waste construction process | The construction industry generates almost a third of all waste in the UK. According to estimates, the construction industry will generate 2.2 billion tonnes of waste worldwide by 2025. Demolitions as well as construction sites are responsible for a significant amount of it. Too much material is often ordered, which resulting in unnecessary costs and excess waste. 3D printing has the potential to practically eliminate waste. A 3D printer only uses as much material as is needed to print a given item. This can deliver huge savings. | Research and development costs | Most construction companies operate on low profit margins. An investment enabling large scale use of 3D printers would require a huge financial outlay. |
| 2. | Savings in terms of time and money | Just as artificial intelligence in the construction industry, a 3D printer can operate 24/7. This can lead to a faster delivery of construction projects and reduced costs associated with unskilled manual work. Furthermore, 3D printing does not require temporary structures, such as scaffolding or formwork, commonly used in traditional construction. | Difficulty with integrating other components | 3D printers excel at working on bespoke projects. However, if we are dealing with a building that uses a lot of different utilities or components that are not very suitable for 3D printing, the use of a 3D printer will pose more of a problem than using traditional techniques. |
| 3. | Ability to pursue unusual designs | One of the most attractive features of 3D printers is the ability to work on complex and unusual designs, even those which will only be "one-offs". 3D printers operate by layering the material, so they can be programmed to make more complex shapes that would be much more difficult to construct using traditional techniques. | Shortage of skilled labour | With the current labour shortage in the construction industry, 3D printing would require even more specialised skills, further exasperating the current situation. |
| 4. | Minimised risk of human error and improved safety | Construction workers face one of the highest accident risk rates. Through greater automation and programmability of the construction process, 3D printing is likely to reduce the probability of serious and fatal accidents in the workplace. Robot-assisted construction requires standardised, accurate and complete digital building data. 3D printing is more precise and effi- | Quality control at the construction site | Weather is capable of slowing down traditional construction, and this can be even worse for 3D printing. Environmental factors can turn a commercial construction industry application of 3D printing into a failure. Furthermore quality control of such a construction project may be a difficult |

| | | | | |
|---|---|---|---|---|
| | | cient, and corrections related to human error or conflicting information are extremely rare. | | task, requiring constant human supervision. |
| 5. | Reduced energy consumption | 3D printing in the construction industry promotes the use of locally available, natural materials. This may contribute to a reduction in energy consumption within the scope of transport, the construction or production process by using and installing mostly local materials whilst using less energy. Local materials often perform better in the local climate, delivering savings on building insulation, which is associated with a reduction of production costs. | Lack of rules and regulations | Recently 3D printing was seen in headlines, but it has not yet made enough of an impact on the construction industry. Transferring some tasks on a building site from humans to printers can complicate accountability issues. Until the right rules and regulations are in place, 3D printing will not be the most favoured form of construction by engineers who bear responsibility for that which will be printed. In the absence of legal regulations, 3D printing is too new and uncertain form of erecting structures for the moment. |
| 6. | Opening new markets | 3D printers enable construction companies to enter new markets that were previously inaccessible to them. For newly established companies, a 3D printer can constitute a competitive advantage. Furthermore, 3D printing is a great way to raise the profile of a construction company among those interested in reducing the impact of traditional construction on our planet. | | |
| 7. | 3D printing shortens the supply chain and the entire design process | Due to the fact that 3D printing is done in-house, several time-consuming steps of a traditional design process can be eliminated: architects, engineers, subcontractors, clients and enforcement bodies are no longer so necessary. | | |
| 8. | Laying pipes and wiring systems becomes simpler and more efficient | In traditional construction practices, insulation and the connection of heating systems, running water or electricity are associated with labour-intensive on-site work. Some of these functions can be performed by a 3D printing process. Printing hollow walls requires fewer resources, improves insulation and can allow the use of 3D printed hot and cold water pipes. | | |

| | | |
|---|---|---|
| 9. | Improved logistical processes | Many components suffer damage in transit, and this can be avoided by printing them on-site. Components are additionally reinforced to withstand the potential hazards of transport, which generates more costs and such measures are not necessarily required when 3D printing on-site. |
| 10. | Popularisation of bespoke designs | In traditional construction, building a house with the help of an architect is simply too expensive for many people. 3D concrete printing makes the shape irrelevant: it does not affect the cost. This means that, in the future, more people will be able to afford to buy a 'bespoke' house that is precisely tailored to their needs. |

## 6. Conclusions

Our analysis unambiguously points to the promising future of 3D printing in the construction industry. Relevant regulations and legislation have to be put in place to expand the use of 3D printing in construction projects.

Today, most countries around the world are using and developing 3D printing technology. Dubai has introduced a nationwide policy for such applications and pursuant to their strategy every new building in Dubai is to be 25% 3D printed by as early as 2025. Similar nationwide strategies have been introduced in the US (America Makes) and the UK (Innovate UK).

## Literature


- Dodziuk H. (2020). *Druk 3D w budownictwie*; Napędy i sterowanie No. 12, December 2020
- Major M., Minda I. (2022). *Zastosowanie technologii druku przestrzennegow budownictwie*; Zeszyty Naukowe Politechniki Częstochowskiej; Budownictwo 22; DOI: 10.17512/znb.2016.1.23
- Walasek M. (2021). *Domy drukowane w 3D – 8 powodów, świadczących o tym, że są przełomowym rozwiązaniem w budownictwie*; 3d.edu.pl; 2021
- Maciążek M. (2021). *10 najważniejszych zalet druku 3D w 2021 roku*; 3d.edu.pl; 2021
- PlanRadar (2022). *Jakie są korzyści druku 3D w budownictwie?;* PlanRadar; 2022
- Walasek M. (2021). *7 Największych firm budujących domy drukowane w 3D*; 3d.edu.pl; 2021
- dezeen; (2019). *World's largest 3D-printed building completes in Dubai;* 2019; ttps://www.dezeen.com/2019/12/22/apis-cor-worlds-largest-3d-printed-building-dubai