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Using 3d Printing in the Creation of Building Structures

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Abstract— *In modern times, innovative technologies have reached such a level that with the help of a 3D printer, it is possible to print not only construction but also other important functions. For example, such a direction as bioprinting allows you to reproduce organs and tissues of the human body. This happens by including actively reproducing cellular material that is capable of division in the print. Artificial intelligence and 3D technologies completely transform existing processes. This article discusses the methods of using 3D technologies in construction, which allow you to visualize three-dimensional structures for a better representation of them. The relevance of this study lies in the analysis of the application of 3D printing in the modern world, which is one of the most popular directions. In the final part of the study, the author concludes the advantages and disadvantages of using 3D technologies during construction work along with traditional methods.*

Keywords— *Innovative technologies, 3D technologies, modern methods in construction, 3D printing, building structures, three-dimensional images.*

I. Introduction

The integration of 3D printing in the construction sector heralds a transformative era in building practices, enhancing not only the efficiency and sustainability of construction projects but also the very nature of architectural design and engineering. The continuous expansion of the 3D printing market in construction, forecasted to grow at a compound annual growth rate (CAGR) of 101.9% from 2023 to 2030 (see Figure 1), underscores the significant potential of this technology to redefine traditional construction methodologies [7].

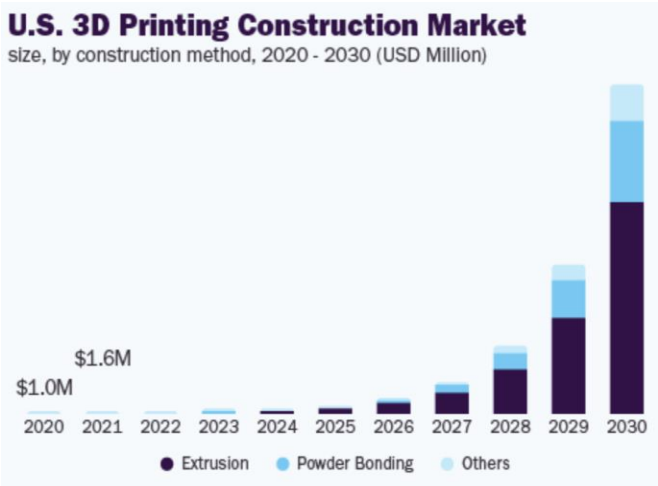

Figure 1: Growth rate of 3D printing [7]

One of the most compelling applications of 3D printing in construction is the use of concrete as a primary material. Dominating the market by revenue share, 3D concrete printing offers cost-effective solutions to traditional construction, significantly reducing the need for skilled labor and minimizing time on project executions. The capability to print complex, double-curved surfaces and intricate designs at a fraction of the cost compared to conventional methods is particularly noteworthy. Moreover, the environmental impact is considerably lessened through the optimized use of materials, thereby addressing some of the sustainability challenges faced by the construction industry today.

In the context of construction, metal 3D printing also shows promising growth, particularly in the creation of customized structural components like facade nodes and other architectural connections. This segment of the market is expected to see substantial expansion due to its precision and efficiency in producing complex structural elements [7].

Advances in technology will play an important role in the development of 3D printing in manufacturing. The development of sophisticated printers like the Vulcan and BOD2, which are capable of handling large-scale construction tasks, represents a significant leap forward. These printers enable the creation of sturdy, ergonomic homes and other structures with high precision and reduced material waste. The automation features integrated into these systems facilitate a streamlined, efficient printing process that can operate with minimal human intervention [8].

From a market perspective, the adoption of 3D printing technologies in the construction sector is increasingly driven by the demands for faster construction times, reduced labor costs, and lower environmental impact. As the technology continues to evolve, its integration into mainstream construction processes seems inevitable, with potential applications ranging from residential housing to infrastructural components like bridges and roadways [7,9].

System analysis was chosen as the method of conducting this study, as it allows us to consider the phenomenon under study both in its full structure and to study its elements. In some aspects of the issue of the relevance of 3D technology application in the printing of building structures, a comparative analysis of some parameters was applied, which covers both the advantages and disadvantages of each factor. Supplementing the paper with a review of existing sources on the topic allows for adding opinions recognized in the scientific community on the subject, which also support or refute the arguments presented in the study. Only up-to-date works that include

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relevant information verified by practical experience were included in the paper.

Application of BIM technologies

Babaeva V.M. in her paper "Digital Technologies in Construction" notes the positive changes after modernization in construction works: "Since its first appearance, BIM has significantly improved the work. It allows you to get a digital representation of the building in 3D format, not on traditional drawings. This program is shaping the future of the construction industry. It uses old data and projections to improve designs and plan the entire process in the most efficient way possible." This example demonstrates the benefits of incorporating 3D technology into the construction process because the depiction on traditional drawings can be different from reality and does not take into account possible errors that can be eliminated with a volumetric representation of the layout [1].

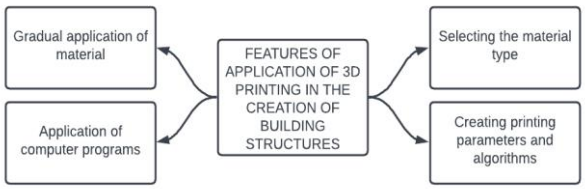

Figure 2: Features of 3D printing application in the creation of building structures

Development of 3D printing in construction

The 3D printing technology itself consists of the constant overlapping of layers on each other, during this process, textures are tightly bound together according to a given parameter, which determines the resulting product. With this technology, you can print a variety of geometric objects, characterized by a variety of details and have a complex shape. Usually, the preparation of the model for 3D printing is done through its development in the traditional format, which involves calculating the necessary dimensions, and planning materials for the future product. Then all the data is moved to specialized computer programs, such as 3DMax, where a volumetric body is made for subsequent printing.

When developing a construction product, it is important to choose a suitable durable material, the properties of which will be able to withstand any weather conditions, and have heat-conductive characteristics. The preparation of the product for printing is characterized by a special process, in which it is not only necessary to calculate in advance all the dimensions and select the type of material.

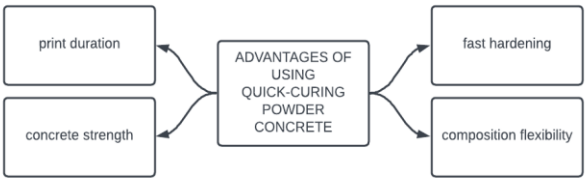

Figure 3: Advantages of using quick-setting powder concrete

Also a necessary condition is the preparation of the equipment itself, which consists of selecting the physical characteristics of the future object: selecting the desired layer thickness, and printing duration. Once the printing is completed, the product is tested for strength and compliance with pre-defined parameters: this is an important stage, as the strength of building structures will determine the success of the project as a whole.

Advantages and limitations of 3D technologies

Samandasyuk G.V., Slesarev I.A., Kozhen M.S. in their study "Adaptive Technologies in Construction" note the printing of the product from fast hardening concrete: "In terms of preparation of concrete (mortar) mixture in construction 3D printers there are two main approaches:
- Preparing the fine concrete mix outside of the 3D printer by pumping the mix into the printer's print head;
- preparing the mixture directly in the 3D printer and then extruding (extruding) it."

This example demonstrates the ease of use in printing products made of this material due to its structure, which is characterized by special strength, reliability and rapid solidification. The latter property is particularly relevant in the construction of apartment buildings, where deadlines must be strictly adhered to. This is also due to the fact that some people enter into shared construction and buy real estate at the design stage, thereby reducing the cost burden of the construction company at the beginning.

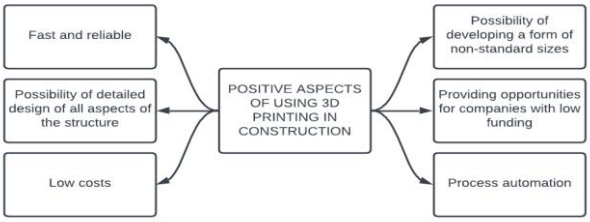

Figure 4: positive aspects of using 3D printing in construction

Therefore, when using 3D technology in the work, many companies choose in favor of this type of concrete, due not only to its low cost and quick setting but also the flexibility of the composition, which lends itself to the creation of products of complex geometric shapes. When working with this material, it is also possible to adjust the thickness of the layer when overlaying, which allows for the production of particularly thin parts [2].

Another advantage of using 3D technologies is the relative speed, which allows to production of ideas with the desired (more flexible) parameters on the flow directly, compared to the factory. In case of mismatch of the part in practice, you can change the parameters in the 3D printer, and many times faster to get under your request, as when manufacturing in factories will have to change the entire batch, which will be more costly in money and time. Not many companies currently trust digital technologies, due to the fact that they are relatively new. However, they allow to thoroughly calculate all the characteristics, which minimizes the risks of error. The use of 3D technologies is especially relevant for start-up companies with limited funding. The most costly aspect of using 3D

technologies is the purchase of the equipment itself due to its high cost [4].

In modern times, construction companies are also actively discussing the issue of quality management in order to improve the competitiveness of the enterprise. An effective solution in improving the business processes of the company will be the use of 3D technologies, due to the environmental friendliness of production. In turn, factories usually use fuel, which emits a large amount of carbon dioxide during production into the atmosphere, and with 3D printing there is no harmful waste.

However, despite all the advantages of using 3D technologies, they also have some imperfections in the system. Since at this stage such printing methods are only at the stage of active development and gradual implementation, the functionality of printers is limited to certain shapes and sizes. Full-scale large parts are quite labor-intensive to reproduce. Therefore, in construction, only part of the structures are printed, and most of the parts are made by mechanical standard method. Also for some companies the purchase of a 3D printer can be a difficult aspect, as the equipment is particularly expensive both to purchase and to maintain. The company will also need to hire additional employees who specialize in the implementation of digital technology. However, it is not uncommon for construction companies to participate in tenders that involve attracting investors to the project and further sponsoring it along the way. The purchase of such equipment can be carried out during participation in a tender for the construction of a complex object, the details of which are characterized by special intricate shapes, the development of which can be due to the use of 3D technology.

Also, the disadvantage of the development of three-dimensional objects today is the lack of a single instruction for manufacturing a part of any complexity, since this direction is at the stage of studying and improving processes [5]. Not without reason, many companies choose in favor of traditional methods, proven by time, due to the fact that they have shown their durability and reliability. In turn, 3D technologies require additional research for widespread introduction and development of various methods of printing products.

The use of 3D technology differs from traditional methods of manufacturing parts in the complexity of execution, because over the course of industrialization, uniform rules have developed that regulate the production process. Because 3D technology has only become widespread in recent years, the requirements for the production of parts using this method have not yet had time to develop. An additional advantage of using traditional methods is the adaptability of the construction industry to this method, due to the standards developed over the years of manufacturing parts.

The development and active introduction of innovations, which include 3D technologies, in all sectors of social life is not without reason: such inventions modernize many existing processes, automating them, and reduce human labor costs for routine operations, and allow them to perform them much faster. It is likely that 3D technology will not be able to completely replace traditional construction methods of making parts, and both methods will be used simultaneously, capitalizing on each to benefit the construction process [6]. In addition, 3D printing can be used in cases where economy-class housing development is required in a short time, such as during the development of Far Eastern lands. The high speed of development of the region can attract people to live and carry out professional activities there under favorable conditions.

II. Conclusion

As a result of this study, it was found that the prospect of 3D technology has a great advantage in modernizing construction processes. With this innovative technology, many companies have the opportunity to produce parts from inexpensive materials in a short period of time, without the need for additional labor. Also, another undeniable advantage of 3D printing is the ability to manufacture parts of complex geometric shapes, the thickness of the layers of which can be calculated in detail before manufacturing. The introduction of such technology allows you to set the necessary parameters for each part of the project, including the necessary speed of solidification. This property is especially useful when the project has a tight deadline. The most common materials for manufacturing 3D parts are concrete and cement, due to the curing speed, strength, and flexibility of the material. The latter property is used in designing a part of non-standard shapes and sizes.

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