# ANALYSIS OF EXISTING TYPES OF CONSTRUCTION 3D-PRINTERS AND METHODS USED FOR THE CONSTRUCTION OF BUILDINGS USING ADDITIVE TECHNOLOGIES.

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**Annotation.** 3D-printing has significant advantages over other types of construction and opens up unprecedented opportunities. However, existing types of printers and construction methods have both advantages and disadvantages. This article discusses various technologies used in 3D-printing, their advantages and disadvantages. A brief description of the principle of operation and design features of 3D-printers is given. The main problems of the complexity of introducing 3D-printing to the construction market are identified. The directions of development and improvement of this technology are considered.

**Keywords**: 3D-technologies, 3D-printing, 3D-construction, layer-by-layer extrusion, 3D-printer, 3D-printing mix

**Introduction**

3D-printing in construction is a pool of technologies based on the use of 3D printing in the construction of houses, residential buildings or administrative buildings and their construction components. Other names are used to refer to them: construction 3D-printing, additive manufacturing for construction, and so on. What is 3D-printing? In fact, this is a layer-by-layer creation of material objects based on a computer-designed digital 3D-model (CAD). A feature of this type of production is the possibility of using a variety of materials, but for construction, of course, cement is especially important. This is possible due to the properties of the mixture for additive production – it includes gelling additives that increase the density and thickness relative to regular cement, so the mixture can be self-supporting.

Already on the basis of the above: we understand that 3D-printing in construction opens up significant prospects for a complete change in everyday architecture and mossy representation of geometric forms. However, the main advantage of 3D-printing, which is impossible not to mention, lies in the technological plane - and this is the possibility of robotic construction of structures for a predetermined project directly on the construction site. Hence the economic benefit – no need to spend money on production facilities and storehouse, transport and installation.

But in addition to the financial component, an important point is to reduce the building time, which will allow in the near future to completely solve the global, acute problem of providing cheap and fast-built housing to low-income people. In addition, rapid building is irreplaceable when rebuilding territories after earthquakes, fires, floods, and other natural disasters or devastating military actions.

But the speed of construction is not all. The advantages of 3D-printing include less resource-intensive construction (25-30 % lower consumption of building materials and human labor during building), and less environmental damage to the planet and to man as such, which in modern realities is increasingly coming to the first place when making decisions. In the case of using additive technologies in the building of waste, pollution and noise becomes 45-55 % less than when using traditional methods of construction of buildings.

It is clear that the prospects for 3D-printing are very, very great. But in order for them to become truly revolutionary, a comprehensive approach to capital building is required, including design and construction, building thermal insulation, BIM model, construction materials, 3D-printing, noise isolation, and so on.

Immediately after the invention of 3D-printing, the main focus of companies using it was on saving materials, but now it becomes obvious that there are other benefits. And this is a breakthrough in the cosmic increase in labor productivity (just think about the numbers: an average of five (!) times) by solving the issue of insufficient qualified labor by automating the process. Isn't this the solution that the construction industry is waiting for all over the world?

Advantages of 3D printing over other construction methods

Let's combine the already listed advantages of additive technologies over other methods of construction of buildings and indicate the main ones:

- The cost of building individual buildings (for specific projects, individual orders) will no longer be inflated and will be equal to the cost of a typical building.
- 3D-printing removes limitations from the imagination of designers and architects who design buildings, as it provides opportunities that are not available in the construction of our usual methods.
- Only 3D-building (and no other) can be used to build houses on other planets, preparing the ground for future colonizers, removing even the planetary limitation from humanity.
- The building process becomes cleaner, reduces or completely disappears construction waste, which corresponds to the vector adopted in most progressive countries, on a conscious and humane attitude to nature and ecology.
- The speed of construction soars up to the skies. Just numbers to illustrate this point: a building of 100 square meters can be printed in 48 hours. Two days – and here is a ready house.
- Minimizing human intervention in the construction process not only allows you to build in places that are inaccessible to people, but also in normal

areas eliminates the human factor and reduces the probability of mistake.

- Due to the almost complete automation of the construction process, no more than four people will be required for the construction of a single building – this is more than enough for a single 3D-printer to work around the clock.
- Despite the popular belief that the printer can only print bare solid walls, communication channels such as electrical wiring, various pipes, ventilation holes for air circulation and other things will be printed in the walls at once – you only need to make this at the design stage in a computer 3D-model. As we can see, 3D-printing, as an additive technology used in construction, has at least eight advantages over other types of construction. However, existing construction 3D-printers certainly differ in their designs and methods of building walls. We will analyze the advantages and disadvantages of each type of printer design and the features of the printing methods associated with them.

Types of existing printer designs and their features

- At the moment there are five types:
- Four-support construction 3D-printer,
- Two-support construction 3D-printer,
- Portal construction 3D-printer,
- Construction 3D-printer with hand manipulator,
- Circular construction 3D-printer based on the type of tower crane.

**Four-support construction 3D-printer.**

**Principle of operation**. A digital model of the future construction is being developed, and the construction mixture is applied in layers according to the developed model. The print head is limited in movement and moves only along three axes. There are advanced printer models in which the head not only prints the wall in several layers, but also makes it smoother. For such printer models, additional drives are being developed, including those that provide the resulting complex unit with the ability to rotate around the Z axis.

**Advantages:**

- Suitable for printing small structures of the same type.

**Disadvantages:**

- To install such a structure, it is necessary to align the site before installing the equipment to ensure the correct architecture of the future building.
- The size of the printed building is limited by the size of the 3D-printer.
- It is not possible to switch to multi-floor construction due to the limited design.

**Existing prototypes:**

COBOD BOD2-111
Working area 1900 x 2100 x 1500 mm
Print speed 12 m/min
Price: from $200.000


**2. Two-support construction 3D-printer.**

**Principle of operation**. Above, we have listed the disadvantages and limitations of the four-support design. To avoid them or level them out, a construction 3D-printer with two supports was developed. Of course, this reduced the requirements for the construction site, but at the same time, movable counterweights were additionally installed on the farm with the print head. Their task – to extinguish the vibrations of the structure, but this innovation has significantly

complicated the control program for the entire unit.

**Advantages:**

- Suitable for printing small structures of the same type.
- Does not require pre-align of the construction site.

**Disadvantages:**

- The size of the printed building is limited by the size of the 3D-printer.
- It is not possible to switch to multi-floor construction due to the limited design.
- The design does not ensure accuracy and print quality.

**Existing prototypes:**
«AMT-SPECAVIA» S-604
Working area 3500x3600x1000 mm
Print speed 12 m/min
Price: from $21.000

**3. Portal construction 3D-printer**

**Principle of operations.** The portal construction moves along a pair of rails that are separate from each other. To print the next layer, you need to move the entire unit, which weighs a lot. The movement itself invariably occurs with incessant accelerations and decelerations. It also needs a aligned construction site – but not for the unit itself, for the rails that guide the print. And the accuracy of laying the rails has to be incredibly high – higher than with the installation of construction cranes.

*Construction 3D-printer «AMT-SPECAVIA» S-604*

The best way is to just fill the stove under it. The second way is to make sure that the guide rails are parallel to each other without breaks.

**Advantages:**

- Suitable for printing small structures of the same type.

**Disadvantages:**

- The size of the printed building is limited by the size of the 3D-printer.
- To install such a structure, it is necessary to align the site before installing the equipment to ensure the correct architecture of the future building.
- It is not possible to switch to multi-floor construction due to the limited design.
- The mobile element is too bulky and therefore requires a lot of energy.

**Existing prototypes:**
Not exist.

*Concept of construction 3D-printer Contour Crafting Corporation*

**4. Construction 3D-printer with hand manipulator.**

**Principle of operation.** This is a design with a grab-handle that can be replaced by an extruder. The manipulator is programmed mechanically. The printer is not limited by the size of the working camera – simply because it does not have such a camera at all. But this saves the print area, and the hardware itself takes up much less space. The printer is designed so that the extruder moves at different angles and along different complex paths in three dimensions.

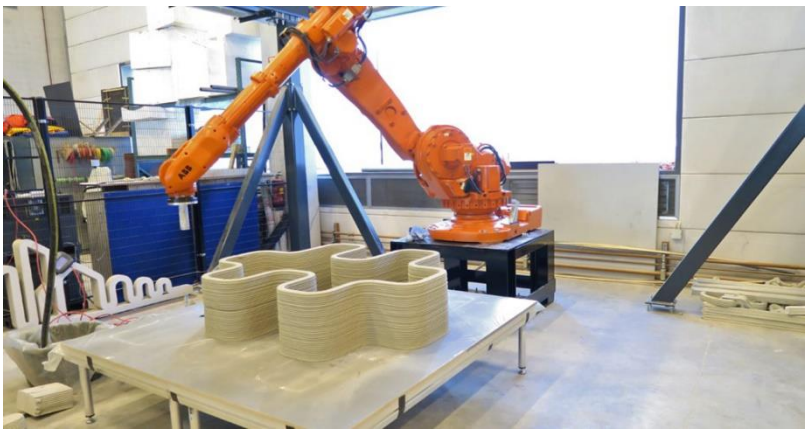
**Advantages:**

- High accuracy and print quality.
- Non-bulky mobile design.
- It is possible to switch to multi-floor construction by transferring equipment to the next floor.
- Many degrees of freedom of the manipulator hand allows printing complex architectural forms.

**Disadvantages:**

- The sizes of the printed building are limited by the radius of the manipulator arm.
- Installation requires pre-aligning and cementing of the site with subsequent anchoring of the equipment.

**Existing prototypes:**
CyBe R 3Dp
Print radius 2750 mm, height 4500 mm
Print speed 12 m/min
Price: $200.000



*Construction 3D-printer CyBe R 3Dp*

**5. Circular construction 3D-printer based on the type of tower crane.**

**Principle of operation.** Visually, it looks almost like a typical tower crane, but, in fact, it is a telescopic manipulator that moves around its axis. This device does not have guides, it is long, difficult and heavily to mount because of its own weight - it moves on the site without them. Therefore, there are no limitations on movement: if you create certain conditions, the printer can create 192 square meters of living space from a single installation point, in fact any height.

**Advantages:**

- High accuracy and print quality.
- Non-bulky mobile design.
- The print field is not limited to the size of the working camera.
- It is possible to switch to multi-floor construction by transferring equipment to the next floor.
- Easy installation and mounting, no pre-aligning required.
- Ability to print sloping complex architectural forms.

**Disadvantages:**

It is necessary to transfer equipment while printing building that exceeds the maximum radius of printer

**Existing prototypes:**

Apis Cor AC-03
Print radius 6500 mm, height 3300 mm
Print speed 10-20 m/min
Price: $120.000


*Construction 3D-printer Apis Cor AC-03*

**Methods of construction of a building structure**

*Constructions, created by sintering, Stone Spray Project*

We have considered the types of printers, but it is worth paying attention to the actual methods of construction of the structure in building. There are three ways, we will look at them in more detail:

1. Layer-by-layer extrusion of construction mixture,
2. Technology of sintering material,
3. Creating formwork for walls by layer-by-layer application of foam composition.

**1. Layer-by-layer extrusion of construction mixture.**

*Building, built by the method of layer-by-layer extrusion, Apis Cor*

**Principle of operation.** With this method of building construction, the extruder squeezes out a fast-hardening cement mix with various additives. Each following layer is applied on top of the previous one, so that a vertical structure is formed. The cement layers at the bottom are thus compacted, thereby increasing their ability to withstand the next layers, and thus the entire weight of the structure.

**Disadvantages.** The main problem when using this method is the need for careful selection of the mixture. We need high adhesive characteristics, to ensure that the layers adhere to each other efficiently. It is important to choose a mixture that meets the project conditions for the time characteristics – how quickly it solidifies.

**Advantages**. Probably, the most important properties of the final building for the construction sector are the solidity of the structure and high quality.

**2. Technology of sintering material.**

**Principle of operation.** It is necessary not to solidify the mixture, but to melt it. In the working area of the printer, concentrated laser or sunlight melts, most often, ordinary sand or local rock ground to the state of grains of sand. This is the main advantage of the method: 95% sand, 5% binder.

**Disadvantages.** It is not possible to create multi-layer products.

**3. Creating formwork for walls by layer-by-layer application of foam composition.**

**Principle of operation.** The formwork is made of polyurethane foam or plastic, then the cavities are filled with heavy cement. This method, in fact, is similar to block construction, when a fixed formwork is also created from polyurethane foam, later it is filled with cement concrete. It should take about half a minute after extrusion, then the material layer from the printer nozzle grows in volume and increases up to 80 times from the original one. Its density also changes: less than 30 kg / $m^3$ with a compressive strength of no more than 160 kPa.

**Disadvantages.** Uncontrolled swelling, which causes the formation of chaotic forms of both internal and external surfaces of the formwork. This, in turn, requires additional processing, which is possible if the goal is to ensure the reliability of the concrete structure.

**Conclusion**

The above examples of various 3D-printing technologies in construction indicate the interest of all countries in the development of this method of construction. At the same time, the solutions that are currently offered on the market of additive technologies in construction, in fact, have similar disadvantages. They are consequences of technical problems that have not been solved. List them:

- Uneven final surface of structures due to the rheological properties of the mixtures used.
- It is not possible to go beyond the size of the device in the size of the building.
- The need for costly alignment of the construction site before installing the unit.
- The long time it takes to install and install the device on the site.
- Inability to build multi-floor structures.

However, we can conclude that the solutions offered today are only the first stage for creating the foundations of a new construction technology. And so far, the main solution is to automate the construction process. Main tasks that need to be worked on for further development of 3D construction technology are:

- Improvement of equipment, both in terms of kinematics and mechanics.
- Development of a work program for the control equipment.
- Development and implementation of different building mixtures.
- Creating solutions for building design, which will take into account the capabilities of the received equipment, information in libraries.

In a number of countries, laboratories and research centers are developing options for implementing 3D-printing technology in practice. Meanwhile, the analysis of 3D-printer designs and construction techniques clearly shows that all additive processes occurring in construction must be based on common technological principles. This also applies to materials and structures. That is, the era of typical construction through 3D-printing has not yet come. There are no libraries of ready-made technical solutions or accurate statistics. In fact, all the buildings printed today are individual, not typical.

Since each project is unique, it is worth understanding that additive manufacturing can be cost-saving and can be very costly. With today's variety of additive manufacturing in construction, we have to state that the construction project started with the use of 3D-printers is a pilot project, a kind of experimental platform where knowledge is developed by obtaining practical skills. This is not the same as mass-scale typical construction, which is necessary, for which there is a market demand. The main barriers to the development of construction 3D-printing are obvious. The high cost of equipment due to the novelty of the technology does not significantly reduce the cost of the construction process. Also, the use of construction 3D-printing is difficult due to the lack of legislative and regulatory framework.

Meanwhile, the incentives to develop 3D-printing are also clearly visible. Unfortunately, labor productivity in the construction industry remains very low. It can be improved, including by automating construction processes, which one by one will remove the notorious human factor. Statistics show that about 60-70% of defects in the industry's production are related to the human factor, mainly with mistakes.

For private businesses, such a technology would be promising: it would be possible to save money by ensuring the safety of production. Fewer people on the construction site means there is less chance that something will go wrong, resulting in staff suffering. And, finally, it is worth remembering the number of difficult areas for development on the planet, where the construction of buildings by traditional methods is sometimes not just difficult, but impossible. In order for the young, just-born additive construction to grow and take root, it will require a lot of research and investment from both large consumers and scientific organizations. If current solutions in 3D-construction can only be considered as a demonstration of capabilities, then with proper support, 3D-construction printing can occupy a very wide niche, becoming a real breakthrough that will solve many problems of capital civil and industrial construction.

**References:**

1. Inozemtsev A.S., Korolev E.V., Zyong Thanh Kui. Analysis of existing technological solutions 3D printing in construction // Vestnik MGSU. 2018.V. 13. Vol. 7 (118). S. 863-876. DOI: 10.22227 / 1997-0935.2018.7.863-876

2. J'son & Partners Management Consultancy. Current situation and prospects for the application of 3D printing in construction (3DCP) in Russia and the

world. 2019. [Electronic resource] - URL: http://json.tv/ict_telecom_analytics_view/tekuschaya-situatsiya-i-perspektivy-primeneniya-3d-pechati-v-stroitelstve-3dcp-v-rossii-i-mire-20190726054004

3. Luneva D.A., Kozhevnikova E.O., Kaloshina S.V. The use of 3D printing in construction and the prospects for its development // Bulletin of Perm National Research Polytechnic University. Construction and architecture. - 2017. - T. 8, No. 1. - S. 90-101. DOI: 10.15593 / 2224-9826 / 2017.1.08

4. Company COBOD. 3D construction printers. [Electronic resource] - URL: https://cobod.com/

5. Company SPETSAVIA.AMT. Modern 3D printing technology. [Electronic resource] - URL: http://specavia.pro

6. Apis Cor. Technical documentation. [Electronic resource] - URL: http://apis-cor.com

7. CyBe Construction Company. Specification. [Electronic resource] - URL: https://cybe.eu

8. Company Contour Crafting Corporation. Building. [Electronic resource] - URL: http://contourcrafting.com

9. Anna Kulik, Inder Prakash Singh Shergill, Peter Novikov. The project "Stone Spray". 2012.

10. Massachusetts Institute of Technology. 3-D printing offers a new approach to creating buildings. [Electronic resource] - URL: http://news.mit.edu

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## ФОРМИРОВАНИЕ ПОРЫВОВ И МИКРО ПОРЫВОВ ВЕТРА В НАХЧЫВАНСКОЙ АВТОНОМНОЙ РЕСПУБЛИКЕ

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## NAXÇIVAN MUXTAR RESPUBLİKASINDA KÜLƏYİN ANİ ŞİDDƏTİ VƏ MİKRO ŞİDDƏTLƏRİNİN MEYDANA GƏLMƏSİ

***Məhbub Kazımov***

## FORMATİON OF GUSTS AND MİCRO GUSTS OF WİND İN THE NAKHCHİVAN AUTONOMOUS REPUBLİC

***Mahbub Kazimov***

**Аннотация**. В статье рассмотрены процессы формирование и развитие порывов и микро порывов ветра в Нахчыванской котловине. Показаны результаты научных исследований по формирование и развитие порывов и микро порывов ветра на территории Нахчыванской АР. Рассмотрены особенности порывов ветров, в зависимости от географических условий региона. Анализировано динамика потер скорости при зигзагообразном обтекании через горных ущелий и узких проходов и влияние этих потер на характеристику порывов ветра.

Проведенные исследование полностью подтвердили серьезную опасность порывов и микро порывов ветра на территории Нахчыванской АР. Полученные результаты подтвердили существование сильных нисходящих порывов и микро порывов ветра в Нахчыванской котловине.

Məqalədə Naxçıvan çökəkliyində küləyin ani şiddəti və mikro şiddətlərinin yaranması və inkişafı proseslərinə baxılmışdır. Naxçıvan Muxtar Respublikası ərazisində küləyin ani şiddəti və mikro şiddətlərinin əmələ gəlmə səbəbləri və inkişafları ilə bağlı aparılan elmi tədqiqat işlərinin nəticələri göstərilmişdir. Bölgənin coğrafi şəraitindən asılı olaraq küləyin ani şiddətinin xüsusiyyətləri öyrənilmişdir. Küləyin ani şiddətinin dağ dərələri və dar keçidlərindən keçərkən sürət itkisinin dinamikası və bu itkilərin küləyin ani şiddətinin xüsusiyyətlərinə təsiri təhlil edilmişdir.

Aparılan tədqiqatlar Naxçıvan Muxtar Respublikası ərazisində küləyin ani şiddəti və mikro şiddətlərinin təhlükəli olduğunu tamamilə təsdiqlədi. Əldə edilmiş nəticələr Naxçıvan çökəkliyində küləyin ani şiddəti və mikro şiddətlərinin vövçud olduğunu təsdiqləyir.

**Abstarct**. The article discusses the processes of formation and development of gusts and micro gusts of wind in the Nakhchivan basin. The results of scientific research on the formation and development of gusts and micro gusts of wind in the territory of the Nakhchivan Autonomous Republic are shown. The features of gusts of winds are considered, depending on the geographical conditions of the region. The dynamics of speed loss during a zigzag flow through mountain gorges and narrow passages and the effect of these losses on the characteristics of wind gusts are analyzed.

The studies fully confirmed the serious danger of gusts and micro gusts of wind in the territory of the Nakhchivan Autonomous Republic. The obtained results confirmed the existence of strong downward gusts and micro wind gusts in the Nakhchivan basin.