High-tech innovative robotized systems efficiency use in construction

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Abstract. The article discusses the practical features of the promising use of 3D construction printers that print cement-based mixtures, like robotic systems. A construction robotized systems main categories brief description is given, as well as the technological aspects of their application are considered. The technical and economic efficiency of the building 3D-printers and printing mixtures on a cement basis use is analyzed.

Introduction  
Construction is one of the key types of human activity associated with the real estate various types creation. One of the construction features is that most of the created objects are located far from the resource and production base, which imposes certain requirements on the equipment used, its qualitative and quantitative composition.

Over the entire period of its existence, the equipment used in construction processes has undergone changes in accordance with the tasks to be solved, providing builders with the necessary productivity and efficiency. At present, the construction sector, like most other industries, is focused on increasing the main processes mechanization level. Mechanization is a factor capable of providing high performance and low cost. The construction activities mechanization process likely to be based on the gradual introduction into computer operation of construction equipment with computer control and flexible production concepts - construction robots. Mechanization of the construction process is designed to help or replace people in solving a specific task in the field, thus creating a promising growth potential [1,2].

The building robotic systems classification and general characteristics  
Construction robotics is a modern form of mechanization (automation) of construction work and individual operations, in order to reduce their cost by removing the process operator or increasing the efficiency of the machine using a control system. In practice, there are three general categories of construction robots:

1. Remote control systems, including remote control systems. The peculiarity of these machines is that the equipment should work in the field of view of a person acting as an operator [3].
2. Programmable construction machines. These machines include the majority of construction equipment, which is equipped with sensors and mechanisms to improve onboard operator performance.
3. Intellectual systems - unmanned construction robots operating in both semi-automatic and fully autonomous mode.

Table 1 presents a brief description of the construction robots selected categories.

| Category                | Brief description                                                                                                                                                                                                 |
|-------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Teleoperation systems   | The term “teleoperation” refers to the machines and systems remote control. In the teleoperation (called telerobots), the machine is controlled by means of remote control. Telecontrol systems are under the control of a person - an operator who monitors, records and interprets data. At the moment, there are many telebotic devices in the construction industry. These machines were developed as a response to production situations when there is a danger for the operator and equipment with remote control is needed. As a rule, hazardous working conditions are characteristic of the construction, mining and other industries [4]. |
| Programmable construction machines | Programmable construction machines are understood by society as robots. A machine given type operator can change a task to be carried out under certain restrictions, either by selecting functions from a preprogrammed menu or by teaching the machine new functions. Tasks performed by these machines can be either simple (for example, changing the speed of movement depending on conditions) or complex (for example, the transition from the placement of steel supports to the process of supplying concrete with the same mechanism) [5, 6]. As a rule, programmable construction machines are identical to traditional construction machines (for example, an excavator), but were modified for computer control (just as traditional processing machines, such as mills and lathes, turned into computer numerical control machines). Programmable construction machines can use electronic representation of the building site where their work should be conducted. |
| Intellectual systems    | Unlike remote-controlled and programmable construction machines, a fully automated construction robot must perform its task in a specific functional area without human intervention. A semi-autonomous construction robot will perform its task with a certain level of interaction planning under the direction of a person. In each case, the construction robot is expected to adapt to its environment, formulate a plan for completing its task and reprogrammed if necessary (possibly with some human help in a semi-autonomous mode). An intelligent construction robot must also determine when its task is not executable and request assistance [7,8,9]. |

To fully understand the building robotic systems key features, they should be considered according to the following criteria: 1) the use place; 2) multitasking; 3) the possibility of integration into the process.

Depending on the use place, robotic systems can be divided into robots used at the construction site (mobile robotic systems) and robots used outside the construction site (at a factory or other technological complex) (stationary robotic systems).

Depending on the number of tasks solved, robotic systems can be single-tasking and multi-tasking. As a rule, a greater number of tasks are accomplished through the creation of a unified platform and a large number of additional interchangeable components and mechanisms capable of performing various tasks. Some mechanisms are used in combination on a common fixed platform.

Another important characteristic of modern robotic systems is the possibility of their integration into existing and promising technological processes. Based on this feature, all robotic systems can be
divided into non-integrable (independent) and integrable. The integration possibility depends primarily on the purpose of the robotic system and technological versatility.

At the moment, the most common are robotic systems that perform one task, integrated into an existing process. Constructive robots for solving one task are systems that support workers when performing one particular construction process or task (for example, digging a pit, leveling concrete, concrete finishing, painting) or completely complementing its necessary physical activity. Single-task robots have the following general characteristics:

**Technological aspects of the construction 3D-printers future practical use as single-task integrable robotic systems**

3D printers building is one of the promising building robotic systems, printing materials on a cement basis. These systems are an independent class of construction equipment, which has been developed since the mid 2000s. To date, these systems are among the few used in modern practice.

Construction 3D-printers are products consisting of a frame with guides, drives and an extruder. The most complex design mechanism is an extruder, through which the working mixture enters the printed surface. The technical features of the extruder, the drives and the supply operation features of the working mixture determine its features. Most of the developed building 3D-printers have three basic types of construction: portal, deltoid, and “Robot arm” printer.

Table 2 presents a brief description of the main types of constructions of building 3D-printers.

| **Construction type** | **Construction peculiarity** |
|-----------------------|-----------------------------|
| **Portal**            | 3D printers resembling gantry cranes that move along rails with a long frame located above the created object. The “print head” (extruder), a device for feeding the working mixture, moves along the frame. Due to the frame movements synchronization on the rails (flat surface), head width and height, and the supply of concrete, the print head, squeezes out the working mixture in layers, repeating the digital pattern embedded in the printer program. Portal printers have large dimensions, and it is necessary to prepare the working platform with high precision for their work. |
| **Deltoid**           | “Deltoid” or “Three Axis” printers look like an inverted tripod consisting of three cables or rods on which the print head is fixed, and a high frame, on top of which are attached the machines that control the supply of cables or rods. The print head moves due to a synchronous change in the length of the cables or rods, repeating the pattern embedded in the program. Deltoid printers have a simple design and a minimum of moving parts, but also have large dimensions. |
| **Robot arm**         | They are constructive analogues of mechanical arms - manipulators, consisting of several flexible joints, giving them greater mobility. Similar in appearance to modern welding robots that stand on automotive production conveyors. At the end of the printer-manipulators is a printing head for the supply of concrete solution. Construction is carried out by repeating the movements of the manipulator and the solution supply device incorporated in the template's printer program. Printers-manipulators, on the contrary, compared to the deltoid and portal are quite compact, they are easy to transport and easy to install, however, such machines are complex, high-tech and expensive. |

The most common type of construction 3D-printers, printing concrete is a portal design. The total share of proposed and developed 3D-printers with a portal layout is about 57% of the total equipment
on the market. About 36% of construction 3D-printers are of the “Manipulator” type. The remaining 17% are 3D printers with a trapezoid type of construction or hybrids. Most of the building 3D printers on the market work with modified concretes, which make it possible to obtain a uniform surface with a given thickness. Almost all of the existing and developed 3D printers have a similar pattern of operation, in which the working mixture is uniformly squeezed out of the extruder and is applied successively to each other in layers, while the object being created may have a different number of contours.

Modern construction of 3D-printers can be classified as single-task integrable robotic systems operating in the conditions of their integration with other systems into one production line.

**The 3D-printers building practical use effectiveness**

To analyze the effectiveness of using construction robotized systems such as a 3D printer, it is advisable to consider these aspects from the perspective of the following categories — time, place, materials, and manufacturability.

The use of robotic technology reduces the standard model object creation period to several days depending on its complexity and bulk and, as a result, increases the productivity of equipment.

The 3D printing technology allows to ensure the performance of construction work at a distance from the technological and production base in remote areas, where the use of a large number of equipment is extremely difficult.

At present, ready-made certified mixtures are available for use. However, intensive research in this direction makes it possible to hope for new promising raw materials for additive technologies [11,12,13].

The use of high-tech innovative robotic systems allows you to automate certain stages of the construction process and reduce its complexity due to the release of labor and ensuring round-the-clock work.

The 3D printing technology has a number of obvious advantages, at the same time it also does not exclude restrictions for its use and use.

The cost of operating and maintaining a 3D printer is much higher than the cost of maintaining conventional construction equipment and the standard labor organization of workers.

To date, there is no regulatory and legislative framework that defines the features of the use and operation of robotic 3D printing systems in construction.

The technological chain in the stationary version should include at least the following links: 1) the place of storage of raw materials used in the production process; 2) a device for mixing raw materials and their supply; 3) a 3D printer that applies this filed material to the prepared site; 4) process control console. As a result, the robotic system operation efficiency depends not only on the direct operation of the system itself, but also on the additional supporting equipment. This factor, along with others, has a negative and inhibiting effect on the technology mass distribution and its competition with traditional construction methods.

**Summary**

Thus, today, innovative 3D printing systems are used mainly in low-rise and small-sized individual construction, as well as for the manufacture of small architectural forms and structural elements.

Modern high-tech robotic systems are one of the construction industry development vectors in the medium term. They appeared in response to the changing demands of modern society. The great potential of using additive technologies in construction is obvious [14-15]. At the same time, the existing level of construction robotized systems at the moment does not allow fully replacing standard construction methods and materials used. Nevertheless, intensive research in the development direction of these technologies allows to hope for the achievement of breakthrough results that can transfer them into the standard approaches category in the next decade.

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