Applying the Automated and Robotic Means for Increasing Effectiveness of Construction Projects

A V Malakhov¹, D V Shutin²

¹Department of Unique Buildings and Structures, Southwest State University, 94 50 Let Oktyabrya street, Kursk, 305040, Russian Federation
²Department of Mechatronics, Mechanics and Robotics, OSU named after I.S. Turgenev, 95 Komsomolskaya street, Oryol, 302000, Russian Federation

E-mail: 4ega@inbox.ru

Abstract. The paper considers increasing effectiveness of construction of bricks and blocks by applying mobile masonry robots. On the example of a specific object, the rates for its construction using manual labor and robotic means are considered. The results show that applying robotic means allows reduce costs for bricklaying 3-7 times in comparison with manual labor depending on method of accruing salaries. Other positive effects of using bricklaying automation, such as reducing construction time, increasing the quality of the result and simplification of staff management, are considered.

1. Introduction

Automatic and robotic systems increase the intensity of operations in various applications and therefore are mostly effective [1]. Construction industry is less automated than many other industries, and is characterized by a small number of implemented modern technical and organizational solutions. Among other reasons, it is due to the fact that construction projects often differ from each other significantly, so it is difficult to design enough universal and profit-making automatic systems. With that, technologies in automatics, such as machine learning, navigation and control systems, allow solving building problems as well. In particular, last several years masonry robotic systems are being designed and patented all over the world [2, 3, 4].

This article is focused on a mobile masonry robot for automation of the bricklaying process, including automatic positioning and laying bricks in the wall being built. The robot may deal with any dimensions and shape of the object being built due to its navigation system, with insignificant limitations connected with its own dimensions. The approximate scheme of such robot also illustrating the method of its operation is shown in figure 1.

In Russian Federation such solutions are actual due to the renovation project in many cities, such as Moscow, Orel and others [5, 6], that involves constructing new buildings instead of obsolete ones. The general estimation of effectiveness of a masonry robotic system is shown in [7].

This paper shows a more detailed estimation of complex efficiency of a masonry robotic system. Firstly, let’s figure out several groups of factors that influence on economic and technical and organizational parameters of bricklaying:

- human factor;
- organization of work at construction process;
- working efficiency;
- economic factors.
These factors are considered in more details below.

Figure 1. The general scheme of a mobile masonry robot
(1 – brickwork, 2 – robot’s base, 3 – chassis, 4 – bricks supplying device, 5 – manipulator).

2. Human factor
Human factor is a sufficient factor of construction productivity and safety. More than 60% of industrial accidents are caused by human errors. With that, more than 25% of failures at capital construction objects are the result of insufficient quality of construction works [8, 9].

Using automated means reduces several technological risks. The first is reduction of injury probability during the work that often happen because of insufficient organization level and occupational safety violation. The second is improving quality of building products that often is reduced due to insufficient stuff qualification, while automated and robotic systems are assisted only by several high qualified specialists.

3. Organization of the construction process
Work organization influence sat quality of building products, terms and costs of construction. There are several typical techniques in construction (staking out the building axes, workplace organization, materials supplying methods, methods of using special tools, etc.) automatisation of which can reduce time required for building operations and speed up the whole construction process achieving the required accuracy.

The technological aspects of bricklaying with masonry robots are considered in more details in [10].

4. Labor productivity
Labor productivity in masonry is determined by various factors, including the scheme of work (thread-dissected or thread-ring), team size and corresponding method of interaction during bricklaying (“two”, “three”) [11]. The selected methods and schemes of labor organization influence at economics of bricklaying. Increasing the number of workers reduces the construction time but increases the cost, and vice versa. So, it is better to measure the effectiveness of a masonry robot in relative terms, per a unit of the building product. When applied to brick construction, one can use the bricklaying volume...
units, measured in m$^3$, or the number of laid bricks, in pieces. The calculation of the average cost of laying a single brick is shown below.

Let’s consider a single typical storey of a multi-storey building, the scheme is shown in the figure 2. The required quantity of blocks for the storey is 253 m$^3$, including 147 m$^3$ for external walls, 31 m$^3$ for internal walls and 75 m$^3$ for partitions. 253 m$^3$ of the brick wall includes 99682 standard blocks sized 250x120x65 (sesquilateral size) with mortar layer thickness of 10 mm.

![Figure 2. The scheme of a typical section of a multi-storey living building made of bricks](image)

**5. Cost according to standards**

According to the current standards for manual bricklaying labor, making 1 m$^3$ of a wall for a storey height up to 4 m requires[12]:

- 5.66 man-hours – for external walls of medium difficulty;
- 5.21 man-hours – for internal walls;
- 1.44 man-hours – for non-reinforced partitions of half-block thickness.

So, making the specified amount of masonry takes 1102 man-hours, i.e. 28 days for a five-workers team working 8 hours every day.

Typical salary of a bricklayer for 1 m$^3$ for building parameters as described above is [12]:

- 297 rubles – for external walls of medium difficulty;
- 260 rubles – for internal walls;
- 74 rubles – for non-reinforced partitions of half-block thickness.

The cost of the work for the mentioned masonry volume is 57269 rubles. Applying the conversion coefficient that is 4.15 makes the final cost 237666 rubles.

**6. Cost according to market price**

Payment schemes for bricklaying workers may vary in different organizations. The calculation scheme based on normative documents mentioned above is commonly used by large companies that include construction and assembly departments. Many other companies conclude contracts with workers for a
certain construction project paying them for laying bricks by the piece. The typical market price in most regions of Russia is 5-7 rubles for one brick. Calculating the cost for the masonry volume of 253 m³ we get 598092 rubles for workers’ salary.

7. Cost using a masonry robot

Considering usage of the masonry robot, it is necessary to take into account a different cost structure comparing to manual labor. First of all, robot consumes electric energy for operation; also the working stuff includes an operator, an assisting mason and 2 maintenance workers. The calculation of the cost is shown in more details in [13]. The typical costs and salaries are as follow [14]:

- 50 rubles per m³ – electricity consumption;
- 50000 rubles per month – an operator’s salary;
- 40000 rubles per month – an assisting mason’s salary;
- 40000 rubles per month – maintenance workers’ salary.

Taking into consideration the robot’s productivity of 800 bricks per hour and a 8-hours working day, laying 253 m³ of masonry takes 16 days. The cost of such work is 79737 rubles.

The comparison of the cost for the considered cases is shown in the table 1.

|                        | Manual labor according to the Russian normative documents | Masonry robot according to the market price for laying bricks |
|------------------------|----------------------------------------------------------|-------------------------------------------------------------|
| Time (days)            | 28                                                       | 16                                                          |
| Cost (rubles)          | 237666                                                   | 598092                                                      | 79737 |

8. Discussion

The analysis of the obtained data shows that applying the masonry robot sufficiently reduces the building cost 3-7 times depending on different technical and economic factors that are Individual for every construction project. The considered technology also allows reducing the time of building comparing to manual labor. Reduced construction time also reduces borrowing costs and increases profitability of construction projects.

Another beneficial effect of applying masonry robots is stable quality of building products that also matches the requirements of normative documents and does not depend on workers’ qualification. It is worth noting that working with a large number of low-skilled staff is also a risk for an organization, which is reduced by applying masonry robots. High masonry quality allows avoiding increased finishing and reworking costs.

According to the considered facts we can conclude that applying masonry robots in construction projects may result in complex improving and optimizing of construction process in terms of its technical, economical and organizational parameters.

References

[1] Emelyanov S G, Bulgakov A G, Cheryyakov L M, Asmolov A S, Bychkova N A and Buzalo N S 2014 Robotics and Automation in Construction (Kursk: Southwest State University) p 323
[2] An Automated Brick Laying System for Constructing a Building from a Plurality of Bricks Patent AU2007203730 published 07.12.2007
[3] Brick Laying Robot for rising masonry Patent EP0836664 published 07.01.1999
[4] Brick laying robot Patent application WO2018099323 published 07.06.2018
[5] Procenko L 2017 Law Draft to Renovation of Housing Stock Russian Newspaper 51(7217)
[6] Regnum,RU 2017 URL: https://regnum.ru/news/economy/2309919.html
[7] Malakhov A and V Shutin D V 2015 Robotic complexes for construction objects from small-piece materials Young Scientist 11(91) pp 474-477
[8] Travush V I, Emelianov P N, Kolchunov V I and Bulgakov A G 2016 Mechanical safety and survivability of buildings and building structures under different loading types and impacts Creative Construction Conference (Budapest) pp 416-424

[9] Malakhov A V, Shutin D V and Marfin K V 2018 Applying automated and robotic means in construction as a factor for providing constructive safety of buildings and structures Integration, partnership and innovation in construction science and education (Moscow)

[10] Malakhov A V, Shutin D V and Klueva N V 2016 Technological aspects of applying the automatic robotic systems for building of bricks Textile Industry Technologies 1(367) pp 226-232

[11] Telichenko V I, Terentiev O M and Lapidus A A 2004 Technology of Construction of Buildings and Structures (Moscow: Higher School) p 446

[12] FER 81-02-08-2001 Part 8 Constructions of Bricks and Blocks 2014 (Moscow: Stroyinformizdat) p 20

[13] Malakhov A and V Shutin D V 2016 To justify the effectiveness of the use of bricklaying robotic devices taking into account technological and economic factors Integration, Partnership and Innovations in Construction Science and Education: Proceedings of the International Scientific Conference (Moscow) pp 270-274

[14] TRUD.com 2019 URL:http://russia.trud.com/salary/692.html