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Economic efficiency of glass fiber reinforced concrete

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Abstract:

In this article, the technical and economic efficiency of glass fiber reinforced concrete in building structures has been comprehensively studied. In the research, the effect of adding 0.1–0.5% glass fibers to B25 class concrete on flexural and tensile strength was experimentally evaluated. The results showed that the fibers increase the crack resistance of concrete and strengthen the internal structure due to micro-reinforcement. This leads to a delayed appearance of cracks in structural elements and limits their development. It was also determined that there is a possibility to reduce the amount of reinforcement or optimize cross-sections. The article presents an economic comparison of mix compositions for 1 m³ of conventional B25 concrete and glass fiber concrete. According to the calculations, the application of fiber concrete provides an economic benefit of 22,410 sum per cubic meter. This benefit was also determined using the example of beam structures in a planned 4-story residential building in Namangan region. Considering the total concrete consumption of 123.4 m³ in the beams, the total savings amount to 2.77 million sums. It is scientifically substantiated that the economic benefit significantly increases when applied to numerous typical buildings and at the scale of concrete plants. The obtained results confirm the high efficiency of wide implementation of glass fiber concrete in practical construction.

Keywords:

Beam, glass fiber, fiber-reinforced concrete, structure, reinforced concrete

1. Introduction

In many countries of the world, in order to ensure the strength and reliability of buildings, scientific research is being conducted on the dispersed reinforcement of traditional concrete with glass fibers and the creation of a new generation of composite structures with high strength [1]. In world practice, scientific research on increasing the mechanical properties of concrete by dispersed reinforcement of fibers, in particular, its tensile and bending strength, limiting the development of cracks, and increasing the reliability of structures, is considered a priority [2]. In this regard, glass fibers are distinguished by their high strength, corrosion resistance, relative cheapness, and good adhesion to the concrete matrix, which makes them a promising dispersed reinforcing material for improving reinforced concrete structures[3]. Therefore, research on increasing the strength and performance of reinforced concrete structures dispersed reinforced with glass fibers is considered an urgent task[4].

The adopted regulatory legal acts on the development of the building materials industry in the Republic of Uzbekistan, the expansion of the production of modern, energy-efficient and competitive building materials based on local raw materials, and the introduction of innovative technologies, and the Presidential Decree “On Measures for the Development of the Building Materials Industry,” set out the tasks of “expanding the construction sector in the country, increasing the scale of production, as well as introducing ecological and resource-saving materials. In implementing these tasks, in particular, taking into account the rapidly growing volume of construction in our republic, the increase in the share of multi-storey buildings and structures, and the high seismic activity of the regions, it is important to increase the strength, durability and operational reliability of reinforced concrete structures, improve the mechanical and deformation properties of concrete by dispersing its reinforcement with glass fibers, reduce the

consumption of metal reinforcement, and ensure the economic efficiency of structures[5].

Today, the construction of strong, reliable and durable structures is one of the urgent issues in the construction industry. In particular, reinforced concrete beams serve as the main load-bearing elements of buildings [6]. The resistance of ordinary concrete to bending and cracking is limited, which can negatively affect the service life of these structures [7]. The use of modern materials, in particular glass fibers, in reinforcing reinforced concrete structures is yielding effective results[8]. Glass fibers increase the tensile, bending and cracking resistance of concrete, improving its resistance to deformation[9]. Therefore, in-depth study and scientific substantiation of the strength calculation issues related to fiberglass reinforced concrete beams is of great importance[10].

In the design of building materials and structures, not only their mechanical properties, but also their economic efficiency are important criteria. Fiber concrete reinforced with glass fibers, compared with traditional reinforced concrete, increases strength, durability and operational reliability, while reducing construction and operational costs. According to the results of experimental studies, the addition of glass fibers in an amount of 0.1–0.5% by volume of concrete significantly increases the bending and tensile strength of concrete. This leads to a later appearance of cracks in the structure, a decrease in the development of cracks. As a result, it becomes possible to reduce the working cross-section of concrete elements or reduce the amount of traditional reinforcement, which leads to a decrease in material consumption.

2. Research methodology

This study was aimed at determining the economic efficiency of concrete reinforced with glass fibers, and analytical and comparative analysis methods were used together. The objects of the study were ordinary concrete and

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fiberglass fiber concrete compositions of class B25. The subjects of the study were the consumption of materials and the total cost of preparing 1 m³ of concrete.

Each concrete composition was designed in accordance with current regulatory documents and construction standards. The composition of ordinary concrete was formed based on classical proportions, and the amount of glass fibers in the fiber concrete composition was selected in the range of 0.1–0.5% relative to the volume of concrete. Glass fibers were used to improve the mechanical and deformation properties of concrete, delay the formation of cracks, and increase strength. At the same time, market prices and average densities of materials were taken into account.

In the process of economic analysis, the main attention was paid to determining the direct costs of preparing 1 m³ of concrete. The consumption and market prices of cement, fine aggregate, coarse aggregate, water, and chemical additives were determined for each composition. The results are summarized in Table 1 and Table 2:

Table 1
Material consumption and cost for 1m³ of B25 grade concrete

Material	Unit of measurement	Material consumption	Price, sums	Total price
Cement PS-400	kg	430	600	258000
Fine aggregate 0÷5 mm	kg	950	80	76000
Coarse aggregate 5÷20 mm	kg	870	25	21750
Water	l	175	6	1050
Super plasticizer	l	3.6	11000	39600
Tot				396400

Table 2
Material consumption and cost for 1 m³ of B25-grade glass fiber-reinforced concrete

Material	Unit of measurement	Material consumption	Price, sums	Total price
Cement PS-400	kg	400	600	240000
Fine aggregate 0÷5 mm	kg	950	80	76000
Coarse aggregate 5÷20 mm	kg	870	25	21750
Water	l	190	6	1140
Fiberglass	kg	2.6	13500	35100
Total				373990

Based on the data in the table, the economic difference between the compositions of ordinary concrete and fiberglass reinforced concrete was determined, and a saving of 22,410 sums per 1 m³ of concrete was determined. The calculations were checked several times and the results were evaluated for their suitability for practical construction conditions. This methodology is of practical and scientific importance, since it allows not only to analyze the cost of materials, but also to determine economic efficiency, taking into account the strength and operational characteristics of concrete.

3. Results and Discussion

Comparing the data in Tables 1 and 2 shows that the use of glass fiber reinforced concrete showed an economic efficiency of 22,410 sums per 1 m³ of concrete.

The feasibility of using dispersed fiber reinforced concrete based on glass fibers in a 4-story residential building with planned dimensions of 27.5×13.8 m, planned to be built in the Chartok district of the Namangan region, was economically analyzed. In the building frame system, the main load-bearing elements are the beams located in the longitudinal and transverse directions. In accordance with the design solution, the cross-section of the beams is assumed to be 0.4×0.4 m.

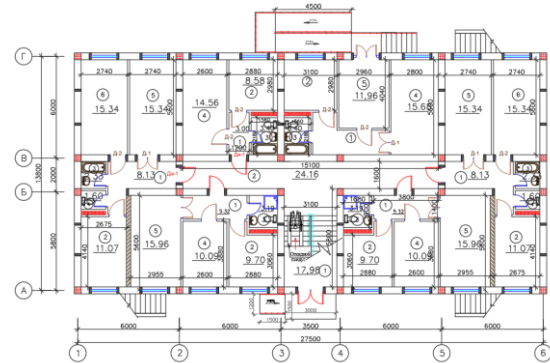


Fig. 1. Floor plan of a 4-story residential building with planned dimensions of 27.5×13.8 m

According to the given plan, there are 4 beams of 27.5 m in the longitudinal direction of the building, each of which extends along the entire length of the building. Therefore, the total length of the beams in the longitudinal direction per floor is $4 \times 27.5 = 110.0$ m. In the transverse direction, there are 6 beams of 13.8 m, their total length is $6 \times 13.8 = 82.8$ m. As a result, the total length of the beams per floor is 192.8 m. Since the cross-sectional area of the beams is $0.4 \times 0.4 = 0.16$ m², the volume of concrete used in the beams per floor is $192.8 \times 0.16 = 30.85$ m³. Considering that the building has 4 floors, the total volume of concrete required for the beams on all floors is 123.4 m³.

According to the results of the above economic analysis, the use of fiber concrete reinforced with glass fibers provides an economic benefit of 22,410 sums per 1 m³ of concrete compared to B25 class concrete without fibers. When calculating this indicator specifically for the beams of this building, the total economic benefit is $123.4 \times 22,410 \approx 2.77$ million sums.

If fiberglass reinforced concrete is used in 5 buildings of this type, the economic benefit for the beams alone will be 13.85 million sums, and when used in 10 buildings, it will be 27.7 million sums. In the process of building small

residential areas or blocks (20-30 buildings), this figure increases to 55-83 million sums, respectively.

The economic efficiency of this approach becomes even more evident when evaluating it on an industrial scale, that is, in a concrete plant. If we assume that the average daily production of concrete in a plant is 100 m³, the daily economic efficiency of using fiber concrete reinforced with glass fibers is determined as follows:

$$100 \times 22410 = 2241000 \text{ sums}$$

Thus, the concrete plant provides an economic benefit of 2.24 million sums per day. When this indicator is evaluated in relation to the monthly production volume (assuming an average of 30 working days), the total economic benefit is $2,241,000 \times 30 = 67,230,000$ sums.

4. Conclusion

1. According to the results of the economic analysis, the cost of 1 m³ of conventional B25 class concrete was 396,400 sums, and the cost of fiber concrete reinforced with glass fibers was 373,990 sums. As a result, economic savings of 22,410 sums per 1 m³ of concrete were achieved.

2. The total economic benefit from using fiberglass reinforced concrete in the beams of a four-story residential building (concrete volume 123.4 m³) was approximately 2.77 million sums, which confirms the practical effectiveness of this material.

3. The results of the study showed that by applying this technology in 10 similar buildings, the economic benefit will reach 27.7 million sums, and in residential complexes consisting of 20-30 buildings, the economic benefit will increase to 55-83 million sums.

4. It was determined that in industrial conditions, that is, in concrete plants producing an average of 100 m³ of concrete per day, the use of fiberglass reinforced concrete provides economic efficiency in the amount of 2.24 million sums per day and 67.23 million sums per month.

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