Use of composite materials for reconstruction of flooring in industrial buildings

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Abstract. The paper highlights the relevance of using composite materials for reconstruction of heavy-duty concrete and reinforced concrete flooring in industrial buildings, stating that at the current stage of construction development special attention is paid to the use of steel fiber concrete flooring, as this material allows for reconstruction of industrial floors with minimum financial and labor expenditure. The novelty of the research lies in the fact that the adhesive between the flooring to be restored and reinforced and the new steel fiber concrete layer is a composite polymer-bitumen material with cement and graphite powder additives, which was previously experimentally developed by the authors. This material, given an adequate thickness, also serves as a structural spacing to level the surface of the underlying layer and reduce friction under the bottom of the upper steel fiber concrete layer and the existing floor. The paper describes the reconstruction workflow. The composition of the steel fiber concrete layer has been assumed based on the research of other authors. Although experiments proved the integrity and strength of the flooring after its reconstruction with the new technology, it is noted that the final characteristics of the proposed floor structures and workflow can only be assessed in the course of normal use, which can be the basis for further research aimed to optimize the thickness of the suggested composite layers. The experiment delivered certain labor and material cost figures for evaluating the economic efficiency of the use of the composites described below in the concrete flooring reconstruction.

1 Introduction
The relevance of the paper pertains to reconstruction of concrete and reinforced concrete flooring in modern buildings and facilities. It is common knowledge that over an estimated period of service life floor structures outlive their usefulness. It is also known that the use of composite materials for building reconstruction takes on particular importance at the current stage of development of the construction industry considering the economic efficiency and environmental friendliness of the related work procedures [1-5]. The importance, key benefits and technologies of making steel fiber concrete flooring in industrial buildings became a focus of interest of many publications [6-11]. A number of foreign research papers [12-19] mention the following benefits of steel fiber concrete structures: enhanced tensile strength and energy absorption, which make the load-bearing structures suitable for sustaining extreme loads; wear resistance; crack resistance; enhanced plasticity and, as such, convenience of layering, as well as other factors. Drawing on the fact that the main functions of earthquake-resistant buildings are the prevention of major destruction, which may result in severe injuries and fatalities among people, and the maintenance of building suitability for use after...
remedying all damages, steel fiber concrete is being put to use as part of cast-in-place load-bearing structures in earthquake-resistant buildings. Even when reconstruction is performed on cast-in-place buildings made of ordinary concrete, preference is given to the further use of steel fiber concrete in view of the fact that this helps reduce the weight of the structures requiring restoration and the building as a whole. The use of structures made of steel fiber reinforced concrete is beneficial as it allows eliminating the cracking and shrinking issues typical of conventional concrete structures. According to the results of research [20], steel fiber concrete flooring is consistently displacing construction ceramics which fails to meet the modern-day requirements (especially in terms of the cost of work). For the time being, the main deficiency of steel fiber reinforced concrete is thought to be its high cost. However, this problem can be resolved through immediate recycling of construction waste resulting from demolition of cast-in-place buildings and facilities, because the recycling of construction materials was demonstrated to be less costly than their production [21].

2. Research part

2.1 Experience of making steel fiber concrete flooring
In the contemporary construction practice, as shown by the analysis of the papers [5-10] referred to above, steel fiber concrete is used in place of blinding concrete in order to provide wear-resistant upper flooring layers in industrial construction systems. The thickness of the steel fiber concrete layer is a computed value factoring in the load projected onto the floor by industrial equipment. According to [22], the introduction of the construction technology featuring industrial flooring with a wearing layer made of steel fiber concrete has improved such physical and mechanical properties of floor coats as "tensile strength, bending strength (1.5 times), and abrasion resistance (1.2 times)". In another paper [23], the authors note that, from the economic perspective and in consideration of the performance of structures, it is the wearing layer where the use of steel fiber concrete for installation and reconstruction of flooring is the most advisable.

The substitution of the conventional reinforcement methods relying on frames and nets is also contributed by the fact that this helps reduce the labor-intensity of the work flow. This in turn is explained by a reduced number of process operations: apart from the regular reinforcing works, the workflow does not include compaction of the concrete layer with poker vibrators as well as cutting and sealing of joints. Basically, the same process procedures are excluded from the reconstruction of steel fiber concrete flooring. However, a critical aspect of the development of new technologies for flooring reconstruction to be paid special attention to is the adhesion of the new steel fiber concrete coat and the existing flooring. The authors suggest that a composite polymer-bitumen paste be used as an adhesive material containing in equal portions such additives as graphite powder and Portland cement, as experimentally obtained by the authors (Abramyan S.G., Oganesyan O.V.). This material demonstrates instant adhesion equal to 0.267 MPa. A more detailed description of the material is provided in [24]. The reconstruction of concrete flooring may include selective insertion of small volumes of composite materials. This function can well be performed by polymer-bitumen bands with double-side application of a mixture of graphite powder and Portland cement.

2.2 Suggested reconstruction technology using steel fiber concrete
The practical experience shows that the focal point as part of the reconstruction of industrial concrete flooring should be the removal of defects on the surface layer of the existing flooring seen in form of chips, dents, cracks etc.

In general, the main process operations as part of the reconstruction of industrial concrete and reinforced concrete flooring with the use of the new adhesive material and steel fiber concrete are:

1. Preparation of the surface of the existing concrete flooring: cutting along the boundaries of the area to be repaired, dismantling or removal of defective flooring sections (leveling rough places on the old concrete surface layer, filling dents, chips and cracks), removal of dust and debris with an industrial vacuum cleaner, deoiling and complete drying of the old concrete flooring;
2. Application of a slightly preheated composite polymer-bitumen adhesive material [24] (with a band or paste depending on the area of the flooring requiring reconstruction);
3. Casting of the steel fiber concrete to form a layer with a required (design) thickness. The casting process shall continue until complete cooling of the paste.
4. Surface compaction and leveling of the concrete layer;
5. Forming the upper floor coating where necessary after the steel fiber concrete layer cures to achieve the necessary strength.

The flooring structure for the two options of flooring reconstruction, i.e. without and with an upper layer, is shown below (see Figure 1).

![Figure 1. Structure of flooring subject to reconstruction using steel fiber concrete: (a) - without upper coating; (b) - with upper coating: (1) - existing flooring, (2) - adhesive material; (3) - steel fiber concrete layer; (4) - upper layer where necessary](image)

The work sequence for the flooring reconstruction with the use of composite materials (adhesive polymer-bitumen material and steel fiber concrete) is shown below (see Figure 2).

![Figure 2. Work sequence of flooring reconstruction: 1 - preparation of the destroyed flooring (filling dents and cracks, removal of chipping), 2 - flooring adhesive ready for application, 3 - part of the floor with the applied adhesive polymer-bitumen layer, 4 - part of the floor with the cast fiber concrete layer, 5 - surface compaction and leveling of the concrete layer, 6 - finished flooring with a steel fiber concrete layer, 7 - finished flooring with additional coating (where necessary). The above listed works shall be performed in strict compliance with the work sequence including the necessary breaks.](image)

2.3 Experimental research
The main experiments were performed in order to determine the strength of the resulting structure of the flooring subject to reconstruction with the use of steel fiber concrete. Based on the research conducted by Voilokov I.A. [25], the following formula was used to make up 1m$^3$ of steel fiber...
concrete mixture: "400 - 405 kg cement, natural sand with a medium particle size of 2.7 - 720 kg, broken stone with a medium particle size up to 10 mm - 1.050 kg, steel fiber - 40 kg, SikaPlast plasticizer - 2.8 kg, with a water-cement ratio of 0.43". The mixture was prepared immediately on the work site using the Elba concrete mixing equipment. For the experiment purposes, the thickness of the upper steel fiber concrete layer was assumed equal to 100 mm. The strength of the resulting double-layer structure was determined by shear test. The strength values obtained as a result of the test were in accordance with the regulatory requirements, with an accuracy error for various samples falling within the limits of ±(0.05...0.1) MPa.

The experiments conducted by the authors showed that the use of a composite polymer-bitumen material with additives, such as graphite powder and cement, as an adhesive ensures the integrity of both the existing cement flooring and the newly laid steel fiber concrete layer. It is worth noting that the final characteristics of the suggested structure and the technologies suitable for reconstruction of industrial flooring can only be fully understood and determined in the course of normal use, which in itself may become the basis for further research aimed at optimizing the thickness of layers of the composite materials suggested for use.

2.4 Feasibility study for reconstruction of industrial floors with the technology suggested

The feasibility study covering the use of steel fiber concrete for reconstruction and repair of industrial concrete flooring can be based on a comparative analysis of the amount of work effort, cost of workforce and cost of materials. Below are given the comparative values of the parameters of flooring featuring three types of upper layer, as the previously developed adhesive material is applicable for making new layers of concrete and reinforced concrete flooring (see Figure 3).

![Figure 3](image-url)  
**Figure 3.** Comparative values of labor cost, concrete and steel consumption for reconstruction of flooring made of various materials: (a) - labor costs; (b) - concrete consumption; (c) - steel consumption

Additionally, the paper identifies the economic result of the reconstruction of industrial flooring using the technology suggested in accordance with the regulatory documents effective in Russia [26].
The algorithm used for their identification was as follows: evaluating the reduced costs associated with the use of regular concrete; evaluating the reduced costs associated with the use of steel fiber concrete; calculating the coefficient of service life variation for steel fiber concrete flooring as compared with flooring made of regular concrete; estimating the savings with regard to the use of concrete and steel fiber concrete flooring over the estimated service life of the floors; calculating the economic result delivered by the use of steel fiber concrete. Assuming that the service life of flooring is equal to sixty years, the annual economic effect accomplished by the reconstruction of 1,000 m² industrial flooring with steel fiber concrete using the technology suggested shall be 10,167 thousand in Russian Rubles.

3 Summary
The new technology of reconstruction of industrial concrete flooring with a wearing layer made of steel fiber concrete using composite polymer-bitumen paste and band demonstrates obvious benefits: the opportunity to use old concrete flooring together with the new surface layer made of steel fiber concrete; reduction of the cost of workforce, consumption of utilities and improvement of the materials-output ratio. Also, the use of an upper layer made of steel fiber concrete also eliminates the need for work associated with floor reinforcement by means of topping.

Besides, the structural spacing consisting of a composite polymer-bitumen material, given the necessary thickness, can be used for leveling the surface of the underlying layer, reducing friction under the bottom of the upper layer and independent deformation of layers (the existing flooring and the newly laid coating) when exposed to thermal effects.

Therefore, the novelty of this research is associated with the use of a composite polymer-bitumen material with addition of cement and graphite powder as an adhesive layer between the existing concrete or (reinforced concrete) flooring which is subject to restoration and strengthening and the newly laid steel fiber concrete layer.

The practical value of the research stems from the fact that its results can be used in making organizational and technological decisions as well as economic decisions associated with the reconstruction of flooring in industrial buildings and facilities using steel fiber concrete.

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