A resource-efficient development of VELOX-technologies during erection and reconstruction of prefabricated monolithic floor slabs

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Abstract. A resource-efficient method of installation of prefabricated monolithic floor slabs by increasing the degree of their construction readiness is proposed in the article. This effect is achieved by the reducing of their own weight and the use of fixed formwork. The reduction in the dead weight of the precast-monolithic floor slab is ensured by the use of light three dimensional lined forms of trapezoidal or rectangular shape, preferably made of expanded polystyrene during the installation of the floor slab. The use of fixed timber formwork will obviate the need for the later implementation of labor-intensive finishing and insulation works. Thus, the installed floor slab will have an increased degree of building readiness immediately after its manufacture, and will also reduce the weight of the structure, which in turn will reduce the material consumption and accordingly the cost of the supporting structures of the building.

1. Introduction

The rise the technical level of the design and construction of buildings and structures from monolithic and precast-monolithic reinforced concrete as the most widespread and still advanced type of modern construction, it seems to us quite an relevant applied scientific task that falls under the recently developed synergetic scenario of socio-economic development of Russian economy with the need for new industrialization.

Today, a balanced approach is required to determine the area of rational use of precast and monolithic reinforced concrete. The installation of prefabricated and monolithic reinforced concrete floors of civil and industrial buildings and structures is characterized by significantly higher unit costs of resources, and accordingly the cost of their installation. In prefabricated construction, there are additional storage, installation and transportation costs. And in the case of a monolithic floor, a large set of formwork is required, determined by the significant time of commencement of work on floor slab stripping due to the need to design load accommodation immediately after the formwork. There are also disadvantages in the quality of the ceiling surface of prefabricated and monolithic ceilings, which are eliminated by finishing and insulating works, which also entails additional costs. In this regard, in recent years, compromise prefabricated monolithic building structures have also got widespread use in construction. With this option, it is possible to implement such a constructive scheme in which the economic performance of the project is significantly improved. The use of fixed plank formwork will eliminate the need for the subsequent implementation of labor-intensive finishing
and insulation works. The above mentioned facts determine the relevance of further scientific research and pre-design developments aimed at resource conservation in the installation of floors by applying innovative solutions in their constructive and technological design.

2. Analysis of publications
In Russia and abroad, prefabricated monolithic structural and technological systems of low-rise civil engineering are becoming more widespread. According to various estimates, the share of prefabricated monolithic structures for ceilings in the EU countries ranges from 20% to 35% [1]. In Russia, until 2008, such floor slabs were not used at all. While such structures have a lower dead weight, higher thermal protection and sound insulation indicators do not require the use of powerful lifting equipment and other related labor costs [2].

Focusing on the well-known foreign prefabricated-monolithic systems Porotherm floor slab (Austria, hollow liners made of ceramic blocks); TERIVA floor slab (Poland, hollow concrete liners, including expanded clay concrete); floor slab YTONG (Sweden, liners from aerated concrete blocks); Rectolight floor slab (France, curved pressed wood liners); floor slab FIT SLAB (Italy, stamped plastic ribbed liners), the Russian innovative technology SMP MARCO has been patented and developed in the Russian Federation [3, 4]. Also, Russian scientists conducted studies on the use of ceramic blocks in precast-monolithic reinforced concrete beam slabs [5]. Our proposals for the use of liners from blocks of limestone (shell rock) as a local material for the construction of low-rise buildings on the Crimean peninsula can be recognized as one of its possible improvements [6, 7]. Having taken the above-mentioned technologies as a basis, we developed and patented (patent RU No. 185868U1) our own prefabricated-monolithic floor structure with plastic liners of the master mould and placement [8].

For structural systems of multi-storey buildings with a complete monolithic reinforced concrete frame and flat floor slabs, their own weight can also be reduced abroad by replacing some of the concrete with plastic liners of various shapes: balls and similar rotating bodies (Bubbl Deck technology), rectangular parallelepipeds (NAUTILUS technology) and others. Moreover, in their pamphlets, developers present up to 35%, and even up to 50% savings in reinforced concrete with other improved technical and economic indicators resulting from this [9, 10]. Analytical studies were also conducted of the comparative strength and deformation properties of such systems as compared to a continuous reinforced concrete slab [11]. However, these studies in the mentioned work were not brought to the level of assessing the economic efficiency of introducing technology at specific facilities, at least in India.

In the Russian Federation it was also drawn attention to the listed structural systems and proposed their use to replace wooden floor structures as the most material-intensive structures of civil buildings, in particular, during their overhaul [12]. The authors developed and recommended technologies for the reconstruction of floors using non-removable spherical and prismatic liners made of plastic and expanded polystyrene, which reduce the duration of work by 18-20% with a corresponding improvement in other economic and operational indicators. The possibility of using lightweight structures when replacing floors in reconstructed buildings [13] is considered in the article. It is noted that this allows to reduce the load on existing structures of walls and foundations, as well as to reduce the material consumption of the ceilings themselves. Based on the results of the studies, the most optimal ratios of the bearing structures of the structures and the used core drivers in them are proposed.

The possibility of using hollow forms in the construction of monolithic foundations is also considered. This is how the foundation slab of the middle part of the stylobate of the residential complex in the Moscow Region was designed, where the calculation of the base plate was carried out in the SCAD Office software package (version 21.1). Saving in concrete were 22,3%, reinforcement – 5% [14].

A significant effect on improving manufacturability can be obtained by using fixed formwork made of fiberboard with glued polystyrene liners or the same fiberboard (arbolite) slabs according to the
type of VELOX technology, where these slabs are called chip cement [15]. Similar slabs based on wood chips can be obtained using dolomite cementing of carbonate hardening being developed by our scientists [16]. In addition to saving the material and labor costs during the production of the floor slab itself, a ceiling surface is obtained that usually requires only finishing, which is certainly a more technologically advanced solution as it does not require time-consuming and heavy wet plastering or widespread gypsum plasterboard lining. However, this structural and technological system provides for the support of floors only on longitudinal load-bearing walls, i.e. it works as a beam [6, 8, 17].

According to our research its further resource-saving development related to the use of slab prefabricated-monolithic floor structure based on all four sides. The combination in this system of a monolithic reinforced concrete belt and precast-monolithic floor slab according to the VELOX technology improved in such a way with a support on all its sides will give a more significant, synergistic effect of saving materials especially heavy reinforced concrete. But in general, constructions of reinforced concrete floor slabs with fixed formwork with prefabricated monolithic load-bearing beams, between which are all kinds of liners that replace reinforced concrete with lighter building material, for example, expanded polystyrene, on top of which a thin reinforced concrete slab is concreted, seem more advanced to us. This provides significant savings in heavy concrete, reduces the own weight of the floor, thereby reducing the estimated constant load from the floor, under which the supporting structures are designed and the cost of finishing and insulating surfaces of the ceiling is reduced.

Considering all the advantages and disadvantages of the previously proposed options for the construction of prefabricated monolithic floors, the authors formulated the purpose of further research – improving the quality of the production of prefabricated monolithic floors by introducing a number of measures in their design and construction. The purpose identified a number of more specific research objectives:

1) reducing the dead weight of the floor slab by laying in the slab the tridimensional and lightweight materials that act as a core driver, while the load-bearing capacity of the slab remains unchanged;

2) the rise of the degree of construction readiness due to the elimination of concrete leaks on the ceiling surface of the created premises, as well as the displacement of individual boards in the process of concreting.

3. Results

Having analyzed the available literature references, research and production experience of their use as well as the results of previous authors’ research, the authors proposed and patented a useful model related to the field of construction, namely, prefabricated monolithic floors and ceilings with the use of fixed formwork and can find use in the installation of floors of low and multi-storey buildings and structures with their support on four sides of bearing stone walls or a similar reinforced concrete frame.

We have taken into account that a monolithic reinforced concrete beam floor slab is already known (according to patent RU No. 111 169 U1, class E04B 5/32), including a slab supported on a system of cross beams containing main beams and supporting beams resting on them. Such a structure assumes its support on two sides, i.e. it works as a beam structure, and characterized by the fact its length is several times greater than the width. It is generally recognized that if there is the possibility of supporting the floor on four sides at once, then it is desirable, for reasons of increasing the bearing capacity and rigidity of the floor structure, to ensure the placement of the bearing beams-ribs in two mutually perpendicular directions.

Therefore, as a prototype of the proposed utility model, a monolithic caisson floor was adopted (Eurasian Patent No 010219 B1, class E04B 5/32, E04G 11/40). This floor consists of slabs and beams made with reinforcement arranged in two directions and forming a grid with an aspect ratio of less than two. It contains vaulted hollow cells having a trapezoidal shape in cross section and located in the space between the beams in the body of the slab. Besides, the reinforcing frames of the beams have a
triangular shape in a plane that is perpendicular to their longitudinal axes, and the reinforcing mesh of the slab is connected with the reinforcing frame of each beam.

In the case of using this floor design in buildings after the stripping it is required an additional heat and sound insulation installation with the laborious finish of the lower ceiling surface. Thus, as a disadvantage that is eliminated in our utility model, the floor slab – the prototype has a relatively low degree of building readiness, which is eliminated in the proposed design of precast-monolithic reinforced concrete floor slabs.

The objective of the utility model is to increase the degree of construction readiness of the constructed precast-monolithic reinforced concrete floor structure.

To solve this problem a precast-monolithic reinforced concrete slab is proposed, consisting of slabs and beams made with reinforcing bars located in two directions and forming a grid with an aspect ratio of less than two. In this case, the reinforcing frames of the beams have a triangular shape in a plane that are perpendicular to their longitudinal axes, and the reinforcing mesh of the plate is connected with the reinforcing frame of each beam having a triangular shape. Between the beams it is placed the cells that are not filled with concrete, having a trapezoidal shape in cross section and located in the space between the beams up to the slab. Distinctive features of the proposed precast-monolithic floor slab is the presence of a fixed plank formwork with non-fillable concrete cells made of expanded polystyrene and bottom bar supports fastened with screws through adjacent boards. The adjacent formwork boards have a tongue and groove connection.

In figure 1 it is presented the proposed precast-monolithic reinforced concrete floor slab, its part in isometric projection with a partial section inside the monolithic reinforced concrete. In the same figure 1 it is shown a section 1-1 and the floor part in the installation zone of the bottom bar support before concrete placement (connection A).

The proposed precast-monolithic reinforced concrete floor slab consists of jointly made slab 1 and beams 2 with reinforcement 3 located in two mutually perpendicular directions and forming a grid with an aspect ratio of less than two. In this case, the reinforcing frames 4 of the beams 2 have a triangular shape in a plane perpendicular to their longitudinal axes and the reinforcing mesh 5 of the slab 1 is connected with the reinforcing frame 4 of each beam having a triangular shape. Between the beams 2 there are placed cells 6 that are not filled with concrete, having a trapezoidal shape in cross section and located in the space between the beams 2 to the slab 1. The distinctive features of the proposed precast-monolithic slab is the presence of a fixed timber formwork 7 with non-filled concrete cells 6 made of expanded polystyrene and bar support 8 of the bottom reinforcement 3. These bar supports 8 are fastened with screws 9 to the adjacent formwork boards 7. The adjacent formwork boards 7 have an additional tongue-and-groove connection 10.

The installation technology of a monolithic reinforced concrete floor along with upper slab 1 and beams 2 made at the same time is done in the following way. On the transverse temporary support beams it is installed a fixed formwork of boards 7 with prefixed (glued) cells 6, for example, of expanded polystyrene. Each formwork board 7 is laid next to the previously laid followed by their tongue and groove joint 10. In this case, the tongue and groove joint can be of various shapes because its main purpose is to prevent the displacement of adjacent boards and the leakage of concrete mix in a regular connection. After connection of these boards 7 to each other the supports 8 of the bottom reinforcement 3 are installed which are then attached to the boards 7 in the area of the tongue and groove joints 10 with self-tapping screws 9.

After the manufacture of the formwork 7, the reinforcing frames 4 are laid between the cells 6 made of expanded polystyrene and the lower reinforcement 3 is installed in the first place in the supporter 8 in one direction, and then the triangular-shaped frame 4 is installed in the other perpendicular direction. A reinforcing mesh 5 is installed along the upper edge of the frame 4, after which the concrete mixture is laid, forming at the same time slab 1 and beams 2. Thus, after setting concrete, the proposed precast-monolithic reinforced concrete floor slab is formed.

Applying the proposed design of the ceiling, even in the technological process of its manufacture, it will be possible to obtain a structural system that ensures the performance of load-bearing, insulating
and finishing functions without the need for the subsequent implementation of labor-intensive finishing and insulation works. This is ensured by a previously created hermetic continuous solid fixed formwork by means of screw connection of individual boards by spikes and plastic supports of the bottom working reinforcement.
Figure 1. Advanced precast-monolithic reinforced concrete slab according to the basic VELOX technology: 1 – precast monolithic slab; 2 – monolithic beam; 3 – reinforcement; 4 – reinforcement cage; 5 – grid reinforcement; 6 – trapezoidal liners made of expanded polystyrene; 7 – fixed timber formwork; 8 – bottom reinforcement supports; 9 – self-tapping screws; 10 – tongue-and-groove connection of boards from wood concrete

These supports simultaneously play the role of rigid joints of individual shields into a geometrically stable and unchangeable system until strength is gained by the monolithic part of the floor slab structure.

Thus, the designed structure will have an increased degree of building readiness immediately after its manufacture in one integrated construction and technological process.

4. Summary
Consequently, as a result of preassembly and subsequent concreting of the remaining space between the liners and above them, a precast-monolithic floor slab with reinforced concrete ribs in two mutually perpendicular directions can be obtained, which is based immediately on four sides. Moreover, the resulting design immediately after manufacture will acquire both load-bearing and heat-insulating functions of the floor as well as the finishing properties of the ceiling system. It means that a constructive system of an increased degree of building readiness will be obtained that requires only finishing works on the installation of finish floorings and ceilings.

Thus, the developed and presented constructive-technological system can be recommended as a resource-saving and effectively developing basic VELOX technology with recommendations for its possible application in the Russian Federation.

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