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ЗВЕДЕННЯ ПОЛЕГШЕНИХ МОНОЛІТНИХ ПЕРЕКРИТТІВ НА БУДІВЕЛЬНОМУ МАЙДАНЧИКУ

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Анотація. Розглянуто відомі зарубіжні та вітчизняні рішення зведення полегшених монолітних перекриттів в умовах будівельного майданчика. Наведено аналіз інноваційних технологій щодо зведення перекриттів з легкими вкладишами в нейтральній зоні монолітного диска. По кожному з наведених рішень описано особливості бетонування і контролю захисного шару арматури. Встановлені основні вимоги щодо виготовлення полегшених монолітних плит на будівельному майданчику. Описана технологічна послідовність зведення перекриттів з легкими вкладишами. У статті наведено дані щодо дослідження витрат на монтаж та демонтаж опалубних елементів. Представлені основні порівняльні показники щодо працемісткості бетонування суцільного та полегшеного перекриттів.

Ключові слова: перекриття, бетонування, легкі вкладиші, порожниноутворювачі, технологічність, витрати праці.

ВОЗВЕДЕНИЕ ОБЛЕГЧЕННЫХ МОНОЛИТНЫХ ПЕРЕКРЫТИЙ НА СТРОИТЕЛЬНОЙ ПЛОЩАДКЕ

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Аннотация. Рассмотрены известные зарубежные и отечественные решения возведения облегченных монолитных перекрытий в условиях строительной площадки. Представлен анализ инновационных технологий по возведению перекрытий с легкими вкладышами в нейтральной зоне монолитного диска. По каждому из приведенных решений описаны особенности бетонирования и контроля защитного слоя арматуры. Установлены основные требования по изготовлению облегченных монолитных плит на строительной площадке. Описана технологическая последовательность возведения перекрытий с легкими вкладышами. В статье приведены данные по исследованию затрат на монтаж и демонтаж опалубочных элементов. Представлены основные сравнительные показатели по трудоемкости бетонирования сплошного и облегченного перекрытия.

Ключевые слова: перекрытие, бетонирование, легкие вкладыши, пустотообразователи, технологичность, затраты труда.

ERECTION OF LIGHTWEIGHT SOLID SLABS AT THE CONSTRUCTION SITE

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Abstract. The known foreign and domestic construction solutions of lightweight solid slabs in the construction site were studied. An analysis of innovative technologies for the construction of slabs with light inserts in the neutral zone of solid disk was presented. For each of the solutions features of concrete and control of reinforcement protection layer were described. The basic requirements for the production of lightweight solid slabs on site were determined. Technological sequence of construction technology of slabs with light inserts was described. The article presents data on the study of costs for installation and dismantling of formwork elements. The main comparative figures on labor input and solid lightweight concrete floors have been presented.

Keywords: slab, concrete, light inserts, blackouts, labor costs.

Currently, solid slab are massively used in the construction of buildings and structures. Most often they are made of heavy concrete and have a solid cross-section. Using inserts of different shapes to form voids is and essential reserve of concrete saving. However, with the current regulations of Ukraine there is no indication on the slab installation with voids at the construction site.

Therefore, the goal of the presented work is to provide results of the analysis of modern technology of installation of lightweight monolithic slabs and coatings, to identify their characteristics and basic requirements that must be followed in the implementation of these technologies.

Introduction

During their construction, there is a task to facilitate the solid slabs and coatings. The problem of weight reduction of monolithic slabs can be solved – the device voids in the middle of the thickness of a solid reinforced concrete disk.

The first advantage of the slabs with voids is the increase of stiffness by increasing the thickness. Stiffening of the slabs makes them suitable for large spans overlapping.

Solid slabs' own weight reduction with voids makes their use for reconstruction of buildings with superstructure possible.

Third advantage of monolithic slabs with voids is the reduction of the material consumption of main components: the concrete and reinforcing steel.

The main part

In recent years, new construction and technological solutions of such slabs have appeared. Installation technology of lightweight solid slabs implies the use of special formwork with blockouts or inserts in the form of caps, balls, tubes and prisms. Each solution has its own features [8].

U-Boot Beton formwork (Fig. 1) (www.daliform.com) is used for the manufacture of solid slabs with voids. It is a product of an Italian company Daliform Group, which holds a leading position in the creation and production of plastic products for construction. It is made of recycled polypropylene and was designed to create lightweight bidirectional slabs and foundations of reinforced concrete. Using U-Boot Beton formwork allows to install plates with holes in the slab thickness. In fact, due to conical lifting leg, immersing U-Boot Beton formwork in concrete, a grid of orthogonal beams comes out (closed at the top and bottom sides with a flat sheet) completed with a uniform filling. This formwork helps to significantly save concrete and steel.

U-Boot Beton allows to install slabs in buildings with large openings or carrying heavy loads, without beams.

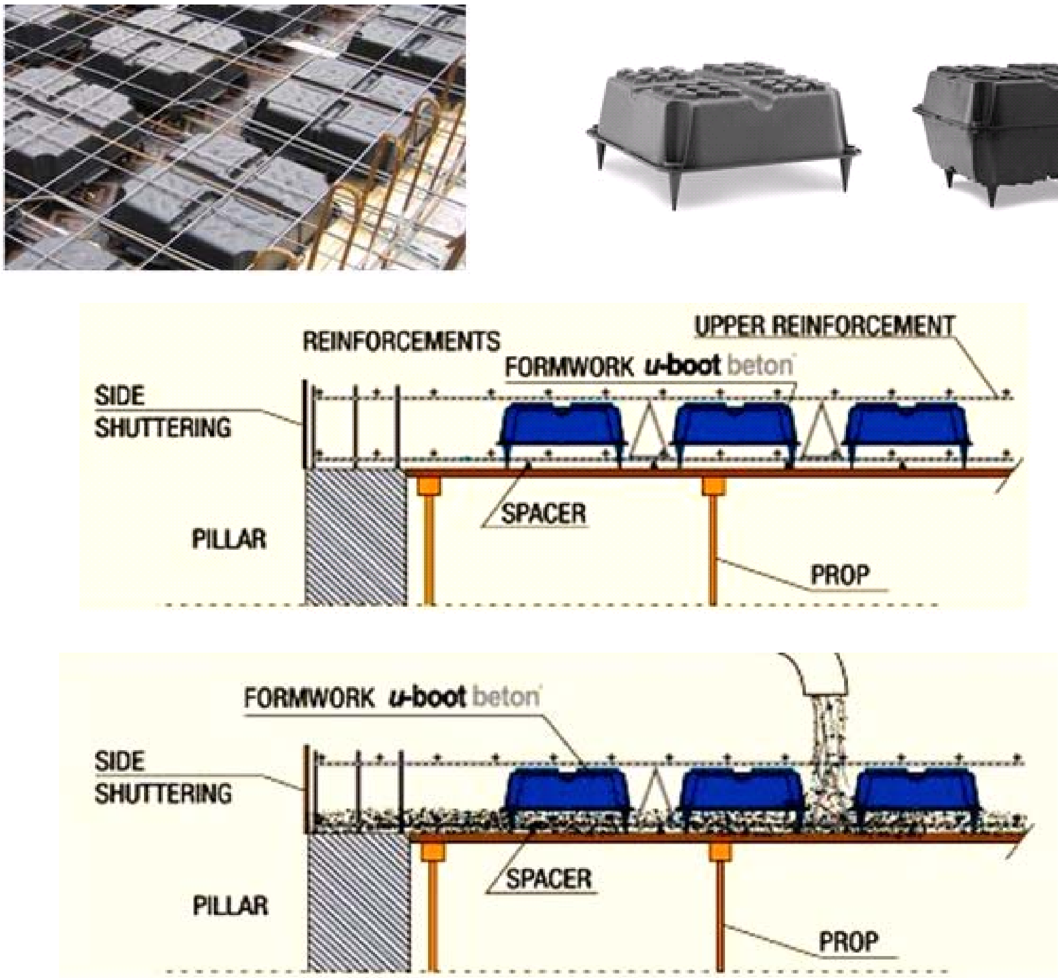

Figure 1. Installation of solid slab using the U-Boot beton system.

Such formwork with blockouts is easy to install and requires small labor costs. Due to its modularity, it allows the designer to modify at will the geometric parameters to adapt to different situations with great architectural freedom.

Structural system U-Boot Beton is especially well suited for tower constructions, shopping centers, parking lots, administrative and residential buildings, industrial facilities.

Second representative of Daliform Grou is modular formwork made of polypropylene U-Bahn Beton (Fig. 2) (www.daliform.com). This system is an ideal solution for the implementation of lightweight unidirectional slabs for all types of structures: residential, commercial, administrative and industrial buildings.

Overlap joint of the elements is a construction feature of this system, which provides creation of beams of any length. Due to the conical lifting legs, beams of equal thickness and height, which are parallel to each other, closed at both sides by flat plates, are created during concreting; all of this contributes to a significant economy of concrete and steel, as well as protection against fire in comparison to other lightweight elements of expanded polystyrene.

U-Bahn Beton formwork is convenient to install, rational in usage, resistant to bad weather and easy for storage on the construction site with minimal dimensions. Contrary to what happens with the classic hollow blocks made of ceramics, the space created by the U-Bahn Beton, can be used for wiring cables and pipelines.

Special type of U-Bahn Beton use corresponds to structures made using so-called «top-down» technology (with compartments or layers), where work was carried out from top to bottom instead from bottom to top: at first a slab is created, and then excavation is conducted. For the construction of parking lots in the city's historical centers this technology is often used due to many limitations associated with the buildings, as well as the need to quickly restore traffic. In such cases, the critical role is played by the possibility to provide easy and small-volume material to the construction site.

Slab concreting with U-Boot Beton and U-Bahn Beton systems is made in two stages in order to prevent a possible «float» of lightweight elements: the first layer of concrete is poured to fill the thickness equal to the height of the lifting legs. Filling of the first part of the slab is performed prior to the concrete setting. After reaching the appropriate setting level you can complete the filling, completely covering the U-Boot Beton. Next, alignment and smoothing is done in the traditional way (Fig. 3).

Forms for the cap-shaped voids installation are widely used in construction, wherein floors look like honeycombs. Plastic hemispheres (caps) with the dome up are installed in the body of a solid slab – Beeplate (Fig. 4) (www.beeplate.com). With this structure slab spans (the distance between columns or walls) may be increased to 10...16 m by increasing the plate thickness to 35...60 cm, reducing the specific consumption of concrete and reinforcement by 30 % compared to solid cross-section slabs.

When concreting flat slabs with holes in the form of inverted caps, concrete mixture fills the space inside the plastic shell, forming a protective layer up to 80 mm. For control of intrusion and fill of bottom plate area with the mixture, holes are provided at the top of the caps that using a special «probe» allow you to check the level of the protective layer of the lower reinforcement (Fig. 5).

There is an experience of voids installation in slabs using hollow plastic balls as forms – Bubble Deck (Fig. 6) (www.BubbleDeck-UK.com). Structurally balls are located between the upper and lower mesh of reinforcement. Sizes of balls are selected in accordance with the size of cells of longitudinal and transverse reinforcement bars considering thickness of the slab so that the balls are fixed with reinforcement mesh and thus the normal protective layers of concrete are ensured.

Figure 2. Installation of a solid slab using the U-Bahn beton system.

Figure 3. Two stages of lightweight slabs concreting using polypropylene systems.

Figure 4. Flat salbs with inserts in the form of inverted caps – Beeplate.

Figure 5. Control of filling lower zone of slabs with voids in the form of inverted caps with concrete mixture.

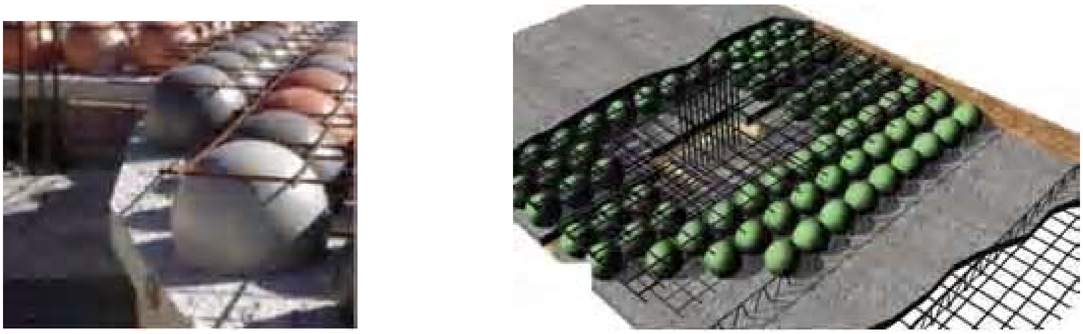

Figure 6. Flat slabs with ball-shaped inserts – Bubble Deck.

Other innovative solutions for lightweight slabs installation were developed in Ukraine.

With the erection of 17-storey building in Kiev on the 59 Zhylyanskaya street, field experiments of construction of solid slabs with tube-shaped voids were conducted (Fig. 7) [1].

Concreting technology of flat plates with voids in the form of pipes and balls is identical. Filling with concrete mixture under light inserts is carried out by the ascent of light material filled with air. Formation of a protective layer for the top reinforcement on account of additional fixation inserts with reinforcing frame.

During the reconstruction of a house with a superstructure in Donetsk on Dzerzhinsky Ave in 2008, an installation process of monolithic slabs with voids in the form of prisms of expanded polystyrene was proposed and implemented (Fig. 8) [6].

As studies have shown [6], not only material consumption, but also the complexity of its installation change with the formation of voids in the slabs using modern systems.

Installation and fixing of the light inserts, control of concrete mixture penetration in the lower zone of reinforcement, providing a protective layer for the upper reinforcement involve an increase in labor costs or the duration of the work. At the same time, due to the formation of voids in solid slabs up to 40 % of the material is saved, which greatly reduces the overall cost of the slab.

Researches were made on labor costs of slab concreting with light inserts in the form of expanded polystyrene prisms which determined the duration of the integrated process at work sectors of different expanded polystyrene prism sizes: 0,8 × 0,8 m, 0,9 × 0,9 m, 1,0 × 1,0 m, 1,1 × 1,1 m, 1,2 × 1,2 m [6].

As in the reviewed above lightweight solid slabs, concrete mixture with slump of 10...13 cm, P3 mobility was put directly to the place of installation, leveled and compacted. Simultaneously, control was carried out to ensure of the protective layer of bottom reinforcing mesh (Fig. 9). Air was going out through the openings in the void prisms displaced by the concrete mix from the side of the formwork. Fasteners of the upper protective layers of reinforcement prevented surfacing of the light inserts, thereby providing a protective layer of upper reinforcement.

For a comprehensive evaluation of the effectiveness of overlapping lightweight slab installation its comparison with the construction of a solid section slab must be performed. For this we use the standard document [3], which takes into account the resources for a full range of work: unloading and transportation of materials and products from an on-site warehouse to the place of construction or installation; installation and dismantling of scaffolding; installation, lubrication and removing of formwork taking into account its turnover; installation of fittings and reinforcing products for concrete structures, concrete mixes with gasket; curing, installation of temporary shrinkage, working and expansion joints.

Slab weight changes with the insertion of lightweight inserts. This factor affects the process of installation of the formwork. It affects the process of shuttering. In particular, the number of elements of formwork and their construction change, time and labor content of installation and removal of the formwork processes performance change [7]. Not the whole construction of formwork changes, for example, deck area does not change, while step of the main beams and pillars of the formwork increases.

When installing lightweight covering of 100 m^2,the number of main beams is reduced by 9...20 %, the number of racks by 30...50 % in comparison with the full-bodied stove. This, in turn, affects the cost reduction in the procurement and transportation of formwork system for the construction of the building as a whole.

Formwork elements, fittings and reinforcing products, light inserts lightweight slabs installation are delivered and stored at the construction site for slab installation. The concrete mix is delivered and fed directly to the place of installation. Conditions of concrete mixture delivery for lightweight slabs and solid cross-section are the same. In the first case the number of vehicles is reduced due to the decrease in volume of the concrete structure. In this case light inserts must be brought and stored at the construction site.

According to [3], labor expenses of construction workers per 100 m^3 of reinforced concrete make up to 833.75 man hours, during the installation of slabs of a thickness exceeding 200 mm, at the height from the reference site up to 6m. The labor content of the installation of a lightweight slab generally increases with respect to a solid slab in 1.03...1.13 times.

Concrete consumption decreased by 4.3 m^3 or by 21.5 % for 100 m^2 of a solid slab with such voids; weight of the reinforcement decreased by 0.28 tones or 13.6 %.

The total economic impact of the introduction of the new construction technology of lightweight slabs with prisms of expanded polystyrene compared to solid slab was 260.34 UAH/m^2 considering the cost, transportation and storage of light inserts, reducing reinforcement expenses, concrete pillars and formwork beams. Herewith labor content is increased by 3–13 %.

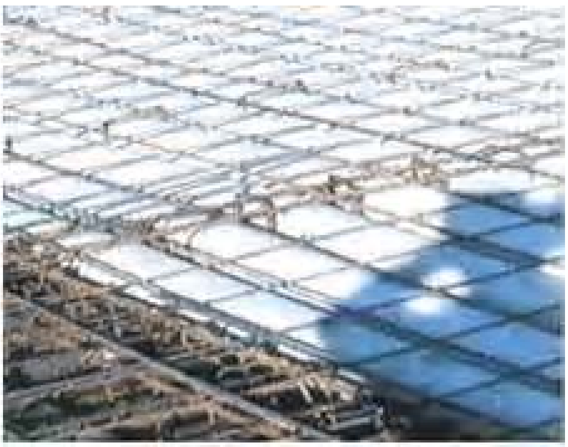

Figure 7. Solid slab installation with pipe-shaped voids.

Technology analysis shows that with the introduction of voids in the solid slab body, certain requirements should be met within their manufacture:

- Ensuring collaboration of reinforcement and slab concrete – § 4.4.2.3 [2]. The protective layer of reinforcement should be smaller than the diameter of the working reinforcement, both from the side of outer plate and the side of the insert;
- Dimensions of embedded material (voids), their position relative to the reinforcement and the formwork, the mobility of the concrete mix must provide final penetration across the bottom of plates, as well as for inserts;
- Location of embedded materials (voids) must provide strength of oblique section of a slab in areas of bearing on a wall or column. Therefore, voids should not be located in the bearing zone of slabs. During the layout of voids, beams can be formed in the body of the slab, to which local increased load can be applied;
- Unrestricted air removal from the bottom slab area and the ability to control the penetration of the concrete mix;
- Fixing light inserts (voids) and reinforcement products from floating during concreting.

Conclusion

1. World experience of the construction of monolithic reinforced concrete slabs with voids showed their advantages and prospects for development of this direction [5, 9–11].
2. Installation technology of lightweight solid slabs involves the use of special formwork with light inserts in the form of caps, balls, tubes, or prisms.
3. Efficiency of the developed in Ukraine technology of solid slabs installation with inserts of expanded polystyrene prisms compared to full-bodied slab makes up to 260.34 UAH/m^2.

This decreases:

- concrete consumption by 21.5 %;
- the weight of the reinforcement by 13.6 %;
- the weight of lightweight solid slab by 20...25 %;
- the number of elements of formwork – the main beams by 9...20 %;
- rack number by 30...50 %.

Increases:

- labor expenses by 3...13 %;
- storage costs by 2.5 %.

4. When installing lightweight solid slabs, the requirements laid down in the article must be complied.

Figure 8. Flat slabs with inserts in the form of rectangular expanded polystyrene prisms.

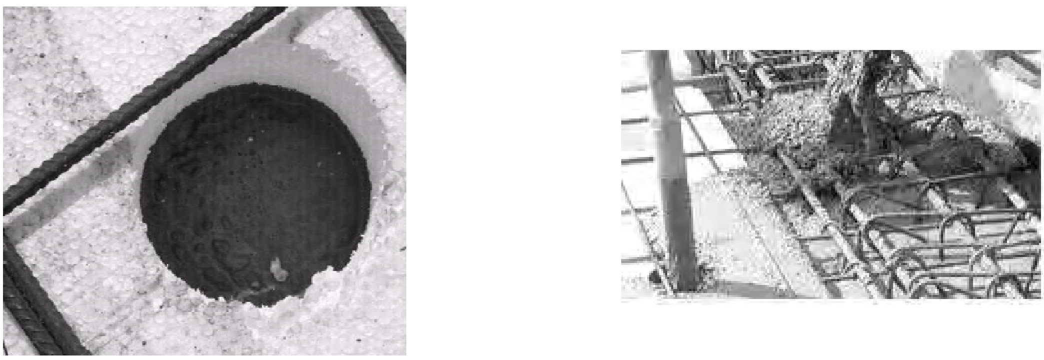

Figure 9. Control of filling the lower zone of a slab with voids in the form of expanded polystyrene prisms with concrete mixture.

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Шавва Кузьма Іванович – д. т. н., професор; кафедра технології будівельного виробництва Одеської державної академії будівництва і архітектури. Наукові інтереси: вдосконалення технологій будівельних і гідромеліоративних робіт.

Таран Валентина Володимирівна – к. т. н., доцент кафедри технології і організації будівництва Донбаської національної академії будівництва і архітектури. Наукові інтереси: підвищення ефективності конструктивно-технологічних рішень при зведенні монолітних каркасних цивільних будівель шляхом зменшення енергомісткості, трудомісткості, матеріаломісткості і вартості будівельної продукції.

Менейлюк Александр Иванович – д. т. н., профессор; заведующий кафедры технологии строительного производства Одесской государственной академии строительства и архитектуры. Научные интересы: инновационные зарубежные технологии в строительстве.

Шавва Кузьма Иванович – д. т. н., профессор; кафедра технологии строительного производства Одесской государственной академии строительства и архитектуры. Научные интересы: совершенствование технологий строительных и гидромелиоративных работ.

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Meneiliuk Olexandr – DSc (Eng.), Professor, the Head of Technology of Building Production Department, Odessa State Academy of Civil Engineering and Architecture. Scientific interests: innovative foreign technologies are in building.

Shavva Kuz'ma – DSc (Eng.), Professor, Technology of Building Production Department, Odessa State Academy of Civil Engineering and Architecture. Scientific interests: perfection of technologies of building and hydro-reclamation works.

Taran Valentina – Ph.D (Engineering), Associate Professor, Technology and Organization of Building Department, Donbas National Academy of Civil Engineering and Architecture. Scientific interests: improving the effectiveness of the constructive-technological solutions at erection of monolithic wireframe civil buildings, reducing energy consumption, material, labor and cost of construction products.