Magazine of Civil Engineering

ISSN 2712-8172

journal homepage: http://engstroy.spbstu.ru/

Research article

UDC 624.016

DOI: 10.34910/MCE.125.1

Bearing capacity of steel-reinforced concrete floor elements before the operation period

A.I. Bedov , ***Yu.A. Shaposhnikova*** ✉

Moscow State University of Civil Engineering (National Research University), Moscow, Russian Federation

✉ *yuliatalyzova@yandex.ru*

Keywords: combined action, condition survey, steel-reinforced concrete structures, structural assessment, stud connector, trapezoidal steel profiled sheeting, “Hoesch Additiv Decke®” technology

Abstract. The paper reflects the results of a survey and assessment of the technical condition of steel-reinforced concrete floor slabs using the “Hoesch Additiv Decke®” technology. Poor execution of concreting and reinforcing, lack of combined action between the elements of the slab, various deviations from the project significantly affect the stress-strain state of the steel-reinforced concrete floor. The aim of the work is to study the influence of various factors on the stress-strain state of steel-reinforced concrete floor slabs using the “Hoesch Additiv Decke®” technology before their operation. The main objectives of this study are: assessment of the technical condition of the steel-reinforced concrete floor slab, detection of defects and damage in the elements of the slab; check calculations of strength, deformability and fluctuation of individual elements, taking into account the identified defects and damage; search for the main decisive parameters in the production of construction and installation works, which significantly affect the strength, deformability and durability of the structure. The object of the study is the elements of the combined steel-reinforced concrete floor. The paper considers the influence of various factors on the stress-strain state of a combined steel-reinforced concrete floor before the start of operation. The authors apply the calculation-analytical method of research. The strength of the slab elements is checked using the “Scad Office” program. The verification of the deformability and fluctuation of the overlap is carried out by manual calculation in accordance with current regulations. Results. The authors performed check calculations of the slab elements, taking into account the identified defects and damages, the actual reinforcement and the thickness of the slab. Deficiencies in the construction and installation works and design errors led to a large number of defects in the floor, such as overloading of the slab, the appearance of force cracks in the slab above the beams, excessive deflections of structures, defects in reinforcement and in concreting. It is required to carry out comprehensive measures to strengthen the floor slabs according to a specially developed construction project developed by a specialized organization. Conclusions. The authors give recommendations on ensuring the operational characteristics of the examined bearing elements based on the results of assessing the technical state of the structures. The results of the research can be used in practical work by engineers in the design and construction of steel-reinforced concrete floor slabs, as well as in the examination and assessment of their technical state.

Citation: Bedov, A.I., Shaposhnikova, Yu.A. Bearing capacity of steel-reinforced concrete floor elements before the operation period. Magazine of Civil Engineering. 2024. 17(1). Article no. 12501 DOI: 10.34910/MCE.125.1

1. *Introduction*

The paper reflects the results of a survey and assessment of the technical condition of steel-reinforced concrete floor slabs made using the “Hoesch Additiv Decke®” technology (developed by ThyssenKrupp Bausysteme) for a three-story public building.

Technology “Hoesch Additiv Decke®” or “Hoesch Additive Floor®” is a system of lightweight prefabricated steel-reinforced concrete floors, made in Germany [1–3]. The system consists of metal rolled I -beams with a possible pitch of up to 5.9 m, a ribbed reinforced concrete plate and trapezoidal steel profiled sheeting used as a permanent formwork. The flooring type TRP 200 is used with a trapezoidal profile, 200 mm high or more. The profiled flooring is made in accordance with DIN EN 10346-2015 “Continuously hot-dip coated steel flat products for cold forming – Technical delivery conditions”. A distinctive feature of this technology is a patented method of supporting reinforced concrete slabs along profiled flooring on massive steel support elements. Supports are made of profiled steel of square section, which minimizes the construction height of the slab and maintains the useful height of the storey [1–3].

A typical design of a steel-reinforced concrete floor slab using the “Hoesch Additiv Decke®” technology is shown in Fig. 1 [4].

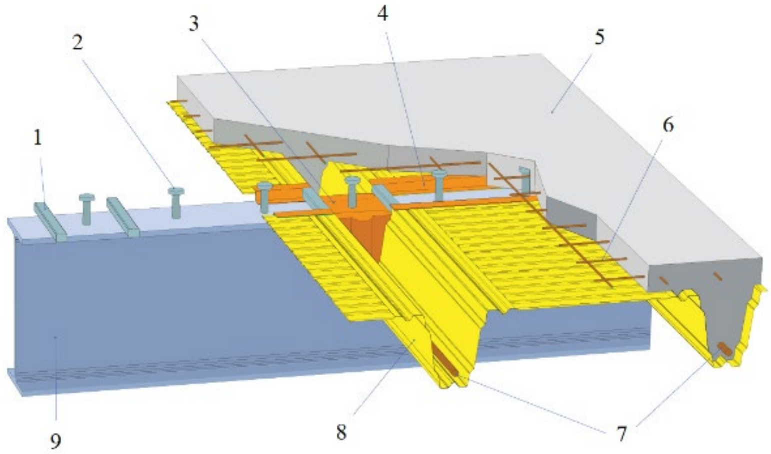

Figure 1. Steel-reinforced concrete floor slab using “*Hoesch Additiv Decke*®” technology: (1) steel support element, (2) stud connector, (3) plastic seal cover, (4) zigzag traverse, (5) ribbed reinforced concrete plate, (6) welded wire reinforcing mesh, (7) longitudinal ceiling reinforcement, (8) trapezoidal steel profiled sheeting, (9) composite steel beam.

In Europe, this technology is widespread and is used for multi-storey car parks and two-level parking areas. In the Russian Federation, this structural system was used in individual buildings in the cities of Moscow, St. Petersburg, Sochi and in some others, mainly for the construction of parking lots and shopping centers.

Steel-reinforced concrete floors have long been widely used both in the Russian Federation and abroad for buildings for various purposes [5–8]. The effectiveness of the use of such structures of floor slabs, their advantages and disadvantages are considered in [9–10]. Steel-reinforced concrete floors differ in design solutions, types and installation technology [11–12]. Traditional combined profiles have a height of no more than 70 mm and are installed on the upper shelf of a rolling I -beam. This significantly increases the building volume without increasing the useful height of the spaces.

The development of the construction industry contributes to the continuous improvement of existing and the introduction of new types of load-bearing structures, including steel-reinforced concrete floors. The use of modern load-bearing systems of buildings, which allow increasing the useful height without increasing financial costs, is especially relevant at the present time. The study of the operation of such floors, as well as the influence of various factors on the stress-strain state during construction and operation is of scientific and practical interest.

At the first stages of the development of steel-reinforced concrete structures, such domestic scientists as N.N. Streletsky, E.M. Gitman, E.E. Gibshman and others were engaged in the issues of their calculation and design. They were mainly engaged in large-span bridge structures or steel-concrete trusses. The possibilities of using steel-reinforced concrete in civil engineering were not considered at that time.

Many Russian and foreign scientists have studied the work of complex monolithic ceilings supported by metal beams. For example, E.S. Karapetov, C.T.T. Hsu, B. Jurkiewiez and others studied the problems and methods of including individual components of the steel-reinforced concrete floor in the joint work [13–15]. P. Colajanni, D. Kanchana, J. Qureshi and others dealt with the issues of shear resistance of an embedded joint between a reinforced concrete slab and a steel beam [16–18]. Researchers A. Albarram, J. Qureshi and A. Abbas studied the effect of rib geometry on the performance of composite beams [19]. F.S. Zamaliev, A.S.H. Suwaed and others considered the issues of joining the slab with metal beams

[20–21]. G.P. Tonkih, M. Konrad, S.W. Pathirana studied the joint work of a slab and metal beams by connecting with stud connectors and various anchor fasteners [22–24]. A.G. Tamrazyan, F.S. Zamaliev, S.N. Arutyunyan, E.G. Bikkinin studied the features of the stress-strain state of a steel-reinforced concrete slab during construction [25-26]. Features of the calculation of such floors are presented in the works of such researchers as D.A. Urgalkina, M.L. Porter, V.S. Kuznetsov and others [27–29]. In the works of Yu.L. Rutman, V.E. Tarasikova, L.R. Gimranov, K.A. Nazarova the issues of the influence of various factors on the deformability of steel-reinforced concrete floors were studied [30–33]. Numerical modeling of reinforced concrete composite beams with reinforcement is presented in the works of M. Ramezani, F. Alsharari, J.L.P. Tamayo and others [34–36]. L.H. Reginato, A.N. Mironov, D.V. Bely, V.M. Anishchenkov paid attention to the effect of creep and cracking on the stress-strain state of such floors [37–39].

Initially, in the Russian Federation and abroad, the calculation of the strength of steel-reinforced concrete floors was carried out in accordance with the distribution of forces, in proportion to the stiffness of the floor elements [40]. In Russia, since 1984, the calculation of steel-reinforced concrete structures has been carried out in accordance with SNiP 35.13330.2011 “Bridges and culverts” and its subsequent versions. And in 2017, a new regulatory document SP (Russian Construction Rules) 266.1325800.2016 “Composite steel and concrete structures. Design rules”, which provides more detailed and precise recommendations for the calculation of such floors. In Europe, the calculation and design of steel-reinforced concrete structures is currently carried out on the basis of “Eurocode 4: Design of composite steel and concrete structures”, as well as in accordance with design guides [41–42].

Such scientists as S.B. Krylov, A.G. Tamrazyan, V.O. Almazov, S.N. Arutyunyan and many others were engaged in comparing the methods of calculation and design of steel-reinforced concrete slabs with profiled flooring according to Russian and European standards [43–45].

The stress-strain state of individual elements and steel-reinforced concrete floors as a whole before the start of operation is influenced by many different factors. Among the main factors that require a detailed analysis are the following [26]:

- the property of steel-reinforced concrete structures to change their stress-strain state after laying the concrete mix and in the process of concrete hardening;
- the effect of creep and concrete contraction on the redistribution of stresses, as well as on the increase in deflections before the start of operation;
- the influence of the development of elastic-plastic deformations of concrete on the formation of additional stresses in steel elements (the effect of additional loading);
- the effect of compliance of the contact joint between a steel beam and a reinforced concrete slab on the operation of the system due to the close location of the seam to the neutral zone of the composite beam section;
- the influence of the development of elastic-plastic deformations of concrete on the formation of additional stresses in steel elements (the effect of additional loading);
- influence of compliance of the contact line between a steel beam and a reinforced concrete slab on the work on the system due to the close location of the contact line to the neutral zone of the composite beam section;
- influence of heat transfer processes due to cement hydration processes on the stress-strain state of steel elements.

Unsatisfactory performance of concrete work (overflow of concrete mix, poor-quality concrete mix, its overdrying during the hardening process), poor performance of reinforcing work, lack of joint work between the elements of the slab, lack of adhesion of the profiled sheet to reinforced concrete, solutions that do not meet the requirements of construction documents, etc., can significantly affect the stress-strain state of the steel-reinforced concrete floor structure.

The defects and damages identified during the building survey in the elements of the steel-reinforced concrete floor before the start of the operation indicate the need for a detailed consideration of the influence of these factors on the work of the floors. The study of the features of the stress-strain state of steel-reinforced concrete slabs before the start of operation to prevent the development of various negative phenomena in structures is of particular interest to project designers and engineers. Identification of the main decisive parameters and important technological features in the production of construction and installation works for steel-reinforced concrete slabs using the “Hoesch Additiv Decke®” technology is of practical interest to modern civil engineers and erection supervisors.

The purpose of this work is to study the influence of various factors before the start of operation on the stress-strain state of steel-reinforced concrete floor slabs made using the “Hoesch Additiv Decke®” technology.

The main objectives of this study were:

- assessment of the technical condition of the steel-reinforced concrete floor slab, detection of defects and damage in the elements of the slab;
- verification calculations of strength, deformability and fluctuation of individual elements of a steel-reinforced concrete slab, taking into account the identified defects and damages;
- search for the main decisive parameters of construction and installation works, which significantly affect the strength, deformability and durability of the steel-reinforced concrete floor structure.

2. Methods

The paper reflects the results of a survey and assessment of the technical condition of steel-reinforced concrete floor slabs made using the "Hoesch Additiv Decke®" technology for a three-story public building [1–3]. The survey was carried out in accordance with GOST (Russian Government Standard) 31937-2011 "Buildings and constructions. Rules of inspection and monitoring of the technical condition" and SP (Russian Construction Rules) 13-102-2003 "Rules of inspection of bearing structures of buildings and facilities".

The surveyed building is a detached 3-storey, single-span, rectangular in plan, floor height of 3.6 m. The structural scheme of the building is frame-and-link system, consisting of steel columns, welded steel and rolled beams, steel-reinforced concrete floors, portal brace between columns, half-timbered vertical and horizontal guides. Joints of beams with columns and columns with foundations are hinged. The load-bearing steel frame is a single-span three-story frame with a span of 15 m and a step of 5.2 m. Fig. 2 shows a bottom view of the second floor ceiling.

Figure 2. Bottom view of the floor slab of the second floor: significant deflections of the ribs of the profiled steel sheet.

The spatial rigidity of the building is sufficient, provided by the presence of a metal frame, united by monolithic steel-reinforced concrete floors along profiled steel flooring, as well as vertical portal brace and half-timbered vertical and horizontal guides from a square profile of 100×100×5 mm.

The ceiling is a monolithic steel-reinforced concrete slab. A monolithic slab on a profiled steel deck type TRP 200, with a total project thickness of 295 mm (flange thickness 90 mm), is laid on steel welded prestressed beams with reverse camber (650 mm high with a flange width of 180 mm). Joint work of beams and slabs is provided by stud connector welded to steel beams with a certain pitch. Profiled decking TRP 200–750 is used as a fixed formwork for reinforced concrete floors and rests through steel rectangular bars, 35 mm high, on the top flange of steel prestressed beams.

Steel-reinforced concrete beams are pivotally supported through a supporting steel plate using bolts on steel columns from an I-section 25K1 according to STO ASCHM (Russian Industry Standard of Association of Ferrous Metallurgy) 20-93 "Rolled steel sections. I-beams with parallel edges of flanges. Specifications". The metal of the beams corresponds to the declared design class C355 according to the results of physical-chemical analysis. There are no suspended ceilings at the time of the survey.

Multiple defects and damage to the main load-bearing above-ground structures were found as a result of the survey.

The concrete class of the floor slabs corresponds to class *B*20 according to the results of a series of strength tests in accordance with GOST (Russian Government Standard) 26633-2015 "Heavy-weight and sand concretes. Specifications", which is lower than the *B*25 class declared in the project.

The slab uses a profiled sheet TRP 200-750 with a thickness of $t \approx 0.9$ mm, which is less than the minimum thickness recommended by the "Hoesch Additiv Decke®" technology of 1 mm, and less than the $t = 1.25$ mm declared in the project. The metal of the profiled deck has a tensile strength of 343.77 MPa according to the results of a series of strength tests. The connection between the reinforced concrete floor slab and the profiled flooring using notches or anchors is not provided for by the project.

According to the results of the geodetic survey, deflections of rolled I -beams up to 18 mm were recorded, which is $l/833$, where the span of the beams between the columns is $l = 15$ m. The reverse bend provided by the project, up to 36 mm, is fixed only in some beams, which is up to $l/417$, where the span of the beams between the columns is $l = 15$ m.

The deflections of the profiled steel sheet ribs in the longitudinal direction reach up to 29 mm, which is $l/179$, where the span between the beams is $l = 5.2$ m. Deflection of the profiled steel sheet shelf in the longitudinal direction reaches a value of 75 mm, which is l/69, where the span between the beams is $l = 5.2$ m. The deflections of the corrugated board shelf in the transverse direction reach a value of 87 mm, which is $l/7$, where the span between the supports-ribs of the profiled sheet is $l = 0.58$ m.

The thickness of the cement-sand screed on the floor slabs was up to 60 mm. This is much more than the 30 mm declared in the project and leads to an excess of the constant load. There are no floor loads and operating loads at the time of the survey.

The deflections of the floor slab along the profiled steel sheet between the metal beams already exceeded the maximum allowable deflection $l/150$ at the time of the survey. Deflections of the profiled steel sheet in the transverse direction reached critical values up to $l/7$. These defects clearly indicate a significant overflow of the concrete mix of the floor slab over the profiled flooring. Inadmissible deformations indicate an insufficient design thickness of the profiled steel deck $t \approx 0.9$ mm, which is unable to support the weight of the concrete mix without significant deformations. The actual thickness of the floor slab flange reached 130 mm in some areas (up to 120 mm on average) due to the insufficient design thickness of the profiled sheet and the absence of its additional supports when concreting the floor slab. A significant overflow of the concrete mix and an almost 2-fold increase in the thickness of the cement-sand screed led to the fact that the actual load on the floor increased significantly. Overloading the floor slab with a constant load has a negative impact on the stress-strain state of the steel-reinforced concrete floor.

The joint work of the reinforced concrete slab and profiled deck is practically absent due to the excessive deflection of the profiled deck, as well as the lack of adhesion (for example, with the help of notches) of the concrete of the slab and the corrugated sheet.

Power cracks were fixed in reinforced concrete slabs above steel beams. Single or paired cracks are located in the direction along the steel beams for the entire width of the building, with an opening width of up to 1.5 mm for the entire thickness of the slab. The formation of such cracks indicates that the limiting tensile strains in the concrete of the slab are maximum. In the cross section of a steel-reinforced concrete slab above a metal support beam, only reinforcing bars work in tension. That is, in fact, the formation of a plastic hinge occurred in reinforced concrete floors in the supporting sections above the beams. Due to the occurrence of the described defects, the design scheme was changed from a multi-span reinforced concrete beam slab with design spans of 5.2 m to single-span hinged-supported slabs with a design span of 5.02 m for each (Fig. 3).

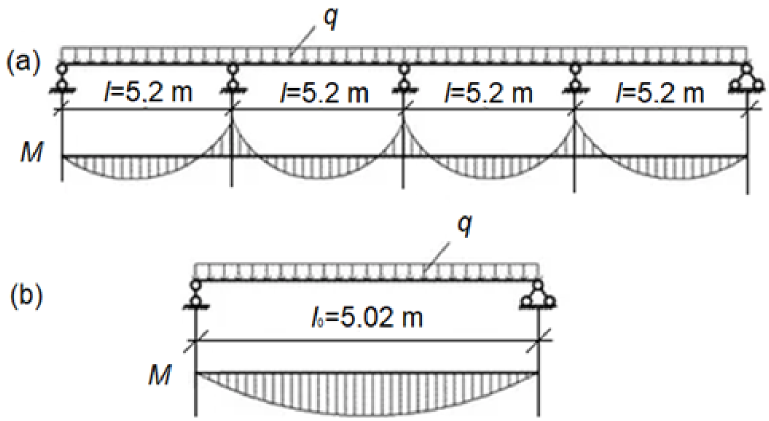

Figure 3. Calculation scheme of a reinforced concrete slab along a profiled deck: (a) initial multi-span, (b) single-span with hinged support.

The protective layer was exposed in several areas to reveal the actual reinforcement of the floor slab. As an example, the results of opening a protective layer in a section above a steel beam in the middle of its span are presented (Fig. 4). The geometric dimensions of the steel-reinforced concrete floor elements based on the results of opening the protective layer and measurements are shown in Fig. 4. The actual thickness of the concrete protective layer and the reinforcement of the slab were established based on the results of the examination of the openings.

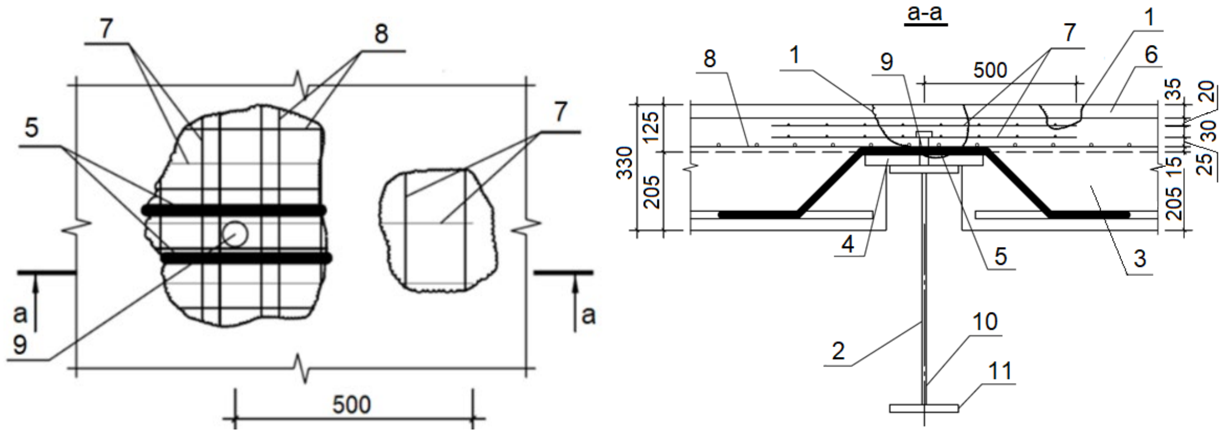

Figure 4. Section of the opening of the protective layer in the section above the steel beam: (1) opening area, (2) welded *I*-beam h = 650 mm, (3) monolithic reinforced concrete ribbed plate along the profiled deck, (4) steel support element, (5) bent reinforcing bars 2Ø14 A500S, (6) cement-sand screed, (7) reinforcing mesh 4B500-100, (8) reinforcing mesh 8A500S-100, (9) stud connector Ø22, (10) *I*-beam web 12×600 mm, (11) bottom flange *I*-beam 25×180 mm.

According to the results of openings and measurements, it was revealed that the slab is reinforced with non-tensioned reinforcement:

– over the entire area of the floor slab, a reinforcing mesh Ø8 A500S was laid, with a step of 100 mm in both directions, the thickness of the protective layer $a_z \approx 50-75$ mm from the upper surface of the concrete;

– in each rib of the reinforced concrete floor, along the profiled deck, a reinforcing bar Ø18 A500S is laid, the thickness of the protective layer is $a_z \approx 40-60$ mm from the bottom surface of the concrete rib;

– bent reinforcing bars 2Ø14 A500S are laid in the reinforced concrete floor when supported through a steel beam, the thickness of the protective layer is $a_z \approx 10-15$ mm from the lower surface of the concrete of the slab shelf;

– in the upper zone above the metal beams, two reinforcing meshes Ø4 B500 are laid with a step of 100 mm in both directions, the thickness of the protective layers is $a_z \approx 20-40$ mm and $a_z \approx 50-55$ mm from the upper surface of the concrete.

Reinforcement in the upper zone above the steel beams (two reinforcing mesh Ø4 B500 with a step of 100 mm in both directions) does not correspond to the one declared in the project (two reinforcing mesh Ø5 B500). The thickness of the protective layers of the floor reinforcement exceeds the design ones by 5–25 mm.

In accordance with Eurocode 4 and SP (Russian Construction Rules) 266.1325800.2016, the calculation of a steel-reinforced concrete floor slab traditionally includes two stages:

– the calculation of the profiled steel deck for the weight of the concrete mix during concrete placement;

– the calculation of the reinforced concrete slab with sheer studs (stud connectors) on the support beams, where the profiled deck is additional external working slab reinforcement.

For a reinforced concrete slab in operation, designers carry out strength checks along normal and inclined sections, check the maximum deflection of the slab under the design load, check the adhesion strength of the profiled flooring to concrete, and evaluate the compliance of sheer studs (stud connectors).

In the presented study, in order to assess the actual bearing capacity of the slab structure along the profiled decking, as well as the combined floor beam, verification calculations were performed taking into account the actual reinforcement, the identified thicknesses of the protective layers of the reinforcement, the actual thickness of the slab, and taking into account the indicated defects and damage. Taking into account that the connection of the floor slab and the profiled flooring by means of notches or connectors is not provided for by the project, the operation of the profiled steel flooring as external working reinforcement was not taken into account in the calculation of the slab. Loads were assigned in accordance with SP (Russian Construction Rules) 20.13330.2016 “Loads and actions”.

Calculations of the reinforced concrete slab for strength and deformability were performed in accordance with SP (Russian Construction Rules) 63.13330.2018 “Concrete and reinforced concrete structures. General provisions” for three sections:

- cross-section on the support, checking for transverse force (only the rectangular part of the cross-section of the floor slab on the profiled deck works);
- cross-section at a distance x from the support, where the T-section is fully included in the work on the action of the transverse force (taking into account the most unfavorable option – the size of the section according to the project, without pouring the concrete mix, and the maximum value of the transverse force on the support);
- cross-section in the span-zone of the slab with its actual thickness (taking into account the overflow of the concrete mix) to the action of the bending moment.

Verification calculations for strength, deformability and unsteadiness for a steel-reinforced concrete combined beam were performed in accordance with SP (Russian Construction Rules) 266.1325800.2016 “Composite steel and concrete structures. Design rules”.

3. Results and Discussion

The results of verification calculations for various elements of the steel-reinforced concrete floor are presented below. The strength of the normal sections of the slab along the profiled flooring was tested taking into account the deformation model, which is based on the principle of dividing the section into many sections [27]. The shear strength of composite floor slabs depends on many factors [9]. In view of the peculiarities of the operation of the floor using the “Hoesch Additiv Decke®” technology, as well as the identified defects in the design of the slab, the most dangerous sections of the slab are considered below.

3.1. Checking the strength of the rectangular section of the slab along the profiled deck for the action of the shear force Q on the support

Only the rectangular part of the T-section of the reinforced concrete floor slab works on the support. The following initial data for the calculation were accepted: general partial factor $\gamma_n = 1.0$; effective length $l_0 = 5.02$ m. The actual section of the floor slab adopted for the calculation: $b = 750$ mm, $h = 90$ mm, $a_1 = 13$ mm, $a_2 = 44$ mm. Concrete of class B20 is accepted. Reinforcement was taken for calculation: bottom 2Ø14 A500S (bended rods in the lower zone of the slab flange), upper – 6Ø10 A500S, which corresponds to the actual reinforcement of the upper zone of the slab (Fig. 4). There is no cross reinforcement according to the project. The work of a profiled deck as a cross reinforcement is not taken into account due to the lack of its adhesion to the concrete of the floor slab.

The design section of the floor slab is shown in Fig. 5.

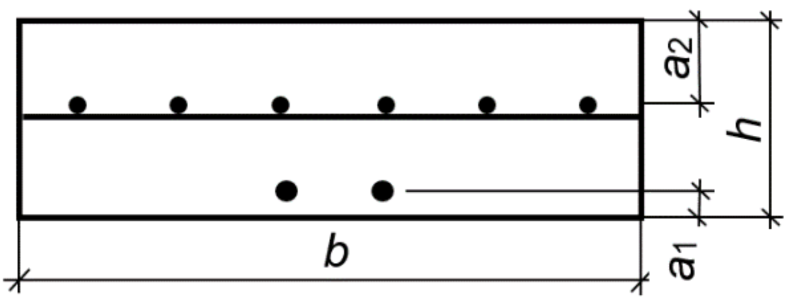

Figure 5. Design rectangular section of the floor slab.

Verification calculation was performed using the “Scad Office” program. The calculation results are presented in Table 1.

Table 1. Results of calculating the section of a floor slab on a support for the action of a transverse force.

Verification	Utilization ratio
Strength of a concrete strip between oblique sections	0.183
Strength of oblique sections without cross reinforcement	**1.4**

The reinforced concrete slab on the profiled deck does not meet the requirements of the standards for the strength of oblique sections in a rectangular section near the support.

3.2. Checking the strength of the T-section of the slab along the profiled deck near the support for the action of the shear force Q.

The check is carried out at a distance x from the support, where the T-section is included in the work on the shear force. The most unfavorable option is taken into account – the size of the section according to the project (without overflowing the concrete mix) and the maximum value of the shear force on the support. The following initial data for the calculation were accepted: general partial factor $\gamma_n = 1.0$; effective length $l_0 = 5.02$ m. The actual section of the floor slab adopted for the calculation: $b = 125$ mm, $h = 295$ mm, $b_1 = 750$ mm, $h_1 = 90$ mm, $a_1 = 40$ mm, $a_2 = 44$ mm. Concrete of class B20 is accepted. Reinforcement was taken for calculation: bottom 2∅18 A500S (in the ribs of the floor slab), upper – 6∅10 A500S, which corresponds to the actual reinforcement of the upper zone of the slab flange (Fig. 4). There is no cross reinforcement according to the project. The work of a profiled deck as a cross reinforcement is not taken into account due to the lack of its adhesion to the concrete of the floor slab.

The design section of the floor slab is shown in Fig. 6.

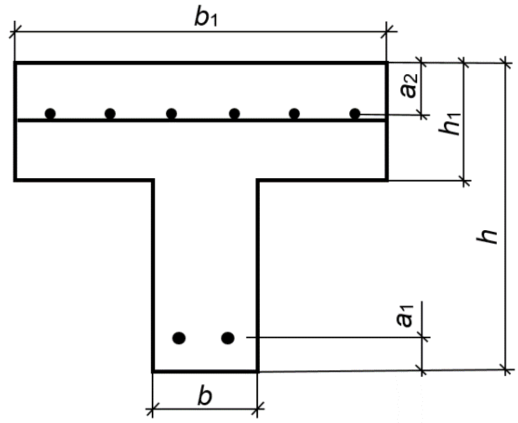

Figure 6. Design T-section of the floor slab near the support.

Verification calculation was performed using the “Scad Office” program. The calculation results are presented in Table 2.

Table 2. The results of the calculation of the floor slab on the support for the action of the shear force.

Verification	Utilization ratio
Strength of a concrete strip between oblique sections	0.183
Strength of oblique sections without cross reinforcement	1.4

The reinforced concrete slab on the profiled deck **does not meet** the requirements of the standards for the strength of oblique sections in a rectangular section near the support.

3.3. Checking the strength of the tee section of the slab along the profiled deck in the span, taking into account the overflow of concrete

The following initial data for the calculation were accepted: general partial factor $\gamma_n = 1.0$; effective length $l_0 = 5.02$ m. The actual section of the floor slab adopted for the calculation: $b = 125$ mm, $h = 325$ mm, $b_1 = 750$ mm, $h_1 = 120$ mm, $a_1 = 60$ mm, $a_2 = 53$ mm. Concrete of class B20 is accepted. Reinforcement was taken for calculation: bottom 1Ø18 A500S, upper – 5Ø10 A500S, which corresponds to the actual reinforcement of the upper zone of the slab flange (Fig. 4). There is no cross reinforcement according to the project. The work of a profiled deck as a cross reinforcement is not taken into account due to the lack of its adhesion to the concrete of the floor slab.

The calculated section of the floor slab is shown in Fig. 7.

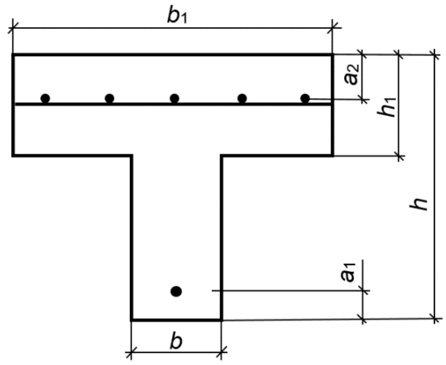

Figure 7. Design T-section of the floor slab in the span.

Verification calculation was performed using the “Scad Office” program. The calculation results are presented in Table 3.

Table 3. The results of the calculation of the floor slab in the span.

Verification	Utilization ratio
Strength at the ultimate moment of the section	0.794
Deformations in compressed concrete	0.208
Deformations in tension reinforcement	0.116
Crack width (short-term)	1.17
Crack width (long term)	1.396

According to the results of the verification calculation, the reinforced concrete slab on the profiled deck does not meet the requirements of the standards for the width of the target crack width. The maximum calculated deflection of the floor slab along the profiled deck, taking into account operational loads, does not go beyond the normative values and is 17.37 mm, which is less than the maximum allowable $l/167=30$ mm.

3.4. Verification calculation of a composite steel-reinforced concrete

The following initial data for calculation are accepted.

Steel welded beam made of C355 steel, design tensile strength of steel $R_y = 305$ MPa; reinforcement modulus of elasticity $E_s = 2.05\cdot10^5$ MPa. Beam span $l = 15$ m, beam spacing $B = 5.2$ m. Composite beam section dimensions: flange width 180 mm; flange thickness 25 mm; web thickness 12 mm; the total height of the steel beam is 650 mm.

A monolithic reinforced concrete slab with a thickness of 90 mm is laid on metal welded T-section beams. Haunch height is 35 mm (Fig. 8). The design width of the reinforced concrete slab is 180 mm. Class of concrete is B20, design resistance of concrete to compression $R_b = 11.5$ MPa, concrete modulus of elasticity $E_b = 27.5\cdot10^3$ MPa. Class of reinforcement is A500S, design tensile strength of reinforcing steel $R_s = 435$ MPa, reinforcement modulus of elasticity $E_s = 2.05\cdot10^5$ MPa (Fig. 3–5). The main geometric characteristics of the section are shown in Fig. 8.

Geometric characteristics of the section: $A_{f1,st} = 45$ cm^2 is cross-sectional area of the lower flange of the beam; $A_{f2,st} = 45$ cm^2 is cross-sectional area of the upper flange of the beam; $A_{w,st} = 72$ cm^2 is cross-sectional area of the beam web; $A_s = 1.0$ cm^2 is cross-sectional area of bar tension reinforcement;

$A_b = 225$ cm² is total cross-sectional area of a reinforced concrete slab with haunch; $A_{b,pl} = 162.0$ cm² is cross-sectional area of a reinforced concrete slab; $A_{b,h} = 63.0$ cm² is cross-sectional area of the reinforced concrete haunch of the slab; $A_{red} = 17.06$ cm² is area of the transformed section; $Z_{f1,st} = 32.5$ cm is distance from the center of gravity of the section of the steel beam C_{st} to the lower edge of its section; $Z_{f2,st} = 32.5$ cm is distance from the center of gravity of the section of the steel beam C_{st} to the upper edge of its section; $Z_{b,st} = 38.75$ cm is distance from C_{st} to the center of gravity of reinforced concrete section C_b; $Z_{st,red} = 2.27$ cm is distance from C_{st} to the center of gravity of the transformed section C_{red}; $Z_{b,red} = 36.48$ cm is distance from C_{red} to C_b.

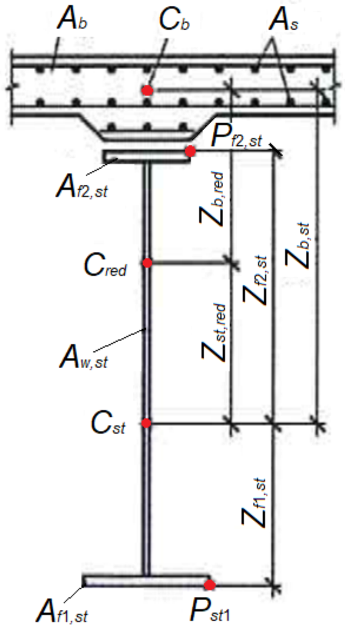

Figure 8. Geometric characteristics of the steel-reinforced concrete beam section: C_b is center of gravity of reinforced concrete section, C_{st} is center of gravity of steel beam section, C_{red} is center of gravity of the transformed section.

The dead weight of the steel beam is $P_1 = 0.134$ t/r.m.

The first stage of loading (on a steel beam from a monolithic reinforced concrete floor slab and profiled deck) is 0.493 tf/m².

The second load stage (only on the combined beam) is 0.661 tf/m².

Load on steel beam $g_1 = 5.2 \cdot 0.493 + 0.12 = 2.697$ t/r.m.

Load on steel-reinforced concrete beam $g_2 = 5.2 \cdot 0.661 = 3.437$ t/r.m.

Full load on the steel-reinforced concrete beam $g = g_1 + g_2 = 6.134$ t/r.m.

Maximum bending moment in span (from full loads) $M = g \cdot l_0^2 / 8 = 172.53$ tf·m, where $l_0 = 15$ m – is the calculated span of the steel-reinforced concrete beam.

Bending moment of the first stage of work $M_1 = g_1 \cdot l_0^2 / 8 = 75.86$ tf·m.

Bending moment of the second stage of work $M_2 = g_2 \cdot l_0^2 / 8 = 96.67$ tf·m.

Maximum shear force on supports (from full loads) $Q = g \cdot l_0 / 2 = 46.01$ tf.

Verification of stresses in concrete in accordance with SP (Russian Construction Rules) 266.1325800.2016 is carried out according to the formula (1)

$$\sigma_b = \frac{M_2}{\alpha_b W_{b,red}} - \sigma_{bi} \geq \gamma_{bi} R_b, \quad (1)$$

where M_2 is the bending moment of the second stage of work; $\alpha_b = 22.36$ is reduction coefficient of concrete; $W_{b,red} = 3395.78$ cm³ is moment of resistance of the transformed concrete section; σ_{bi} is stresses in concrete; γ_{bi} is reliability factor for concrete ; $R_b = 11.5$ MPa is design resistance of concrete to compression.

$$127.3 > 103.5 \text{ kg/cm}^2$$

The required strength condition for concrete is not met.

Checking the stresses in the reinforcement in accordance with SP (Russian Construction Rules) 266.1325800.2016 is carried out according to the formula (2)

$$\sigma_s = \frac{M_2}{\alpha_s W_{b,red}} - \sigma_{si} \geq \gamma_{si} R_s, \quad (2)$$

where M_2 is the bending moment of the second stage of work; $\alpha_s = 1$ is reduction coefficient of steel; $W_{b,red} = 3395.78$ cm³ is moment of resistance of the transformed concrete section; σ_{si} is stresses in reinforcement; γ_{si} is reliability factor for reinforcement; $R_s = 435$ MPa is design tensile strength of reinforcement.

$$2846.8 < 4350 \text{ kg/cm}^2$$

The required strength condition for reinforcement **is met.**

Checking the stresses in the upper flange of the steel beam in accordance with SP (Russian Construction Rules) 266.1325800.2016 is carried out according to the formula (3)

$$\frac{M - z_{b,st} N_{bR,sR}}{W_{f2,st}} - \frac{N_{bR,sR}}{A_{st}} < \gamma_s R_y, \quad (3)$$

where M is bending moment; $Z_{b,st} = 38.75$ cm is distance from the center of gravity of the steel beam to the center of gravity of the reinforced concrete slab; $N_{bR,sR}$ is compressive force of the upper part of the combined section; $W_{f2,st} = 3370.38$ cm³ is moment of resistance of section to the upper flange of the steel beam; γ_s is reliability factor for reinforcement; $R_y = 305$ MPa is design tensile strength of C355 steel.

$$4584.9 > 3050 \text{ kg/cm}^2$$

The required strength condition for the upper flange of the steel beam **is not met.**

Checking the stresses in the bottom flange of the steel beam in accordance with SP (Russian Construction Rules) 266.1325800.2016 is carried out according to the formula (4)

$$\frac{M - z_{b,st} N_{bR,sR}}{W_{f1,st}} - \frac{N_{bR,sR}}{A_{st}} < \gamma_s R_y, \quad (4)$$

where M is bending moment; $Z_{b,st} = 38.75$ cm is distance from the center of gravity of the steel beam to the center of gravity of the reinforced concrete slab; $N_{bR,sR}$ is compressive force of the upper part of the combined section; $W_{f1,st} = 3370.38$ cm³ is moment of resistance of section to the bottom flange of the steel beam; γ_s is reliability factor for reinforcement; $R_y = 305$ MPa is design tensile strength of C355 steel.

$$4966 > 3050 \text{ kg/cm}^2$$

The required strength condition for the bottom flange of the steel beam **is not met.**

The vertical total deflection of the steel-reinforced concrete floor should be calculated taking into account the pre-operational deformed state [6, 24, 25]. However, due to the many defects and damages found in the combined beam, it is not possible to determine the completeness of the joint work of steel beams and steel-reinforced concrete floor slabs. It is required to carry out additional studies of the joint operation of the floor elements and additional verification calculations. In view of the above, the steel beam deflection is checked separately from the reinforced concrete floor according to the well-known formula (5)

$$f = \frac{5g^n l^4}{384E_s I_{red}} = 134.5 \text{ mm}, \tag{5}$$

where $l = 15$ m is design span of the combined beam, g^n is total design load on the beam; $E_s = 2.05 \cdot 10^5$ MPa is modulus of elasticity for steel class C355; $I_{red} = 123892.3$ cm^4 is inertia couple of the transformed section of the combined beam.

Taking into account the camber 50 mm, the deflection is $134.5 - 50 = 84.5$ mm.

$84.5 < l/150 = 100$ mm is the required condition for deformations **is met.**

From the results of the performed strength calculations, taking into account the actual reinforcement and the actual class of concrete of the slab, as well as taking into account the identified defects and damage, it follows that the combined floor beams do not meet the requirements of standards for strength.

3.5. Verification calculation of a combined beam for fluctuation

Limit deflections of floor elements of residential and public buildings, based on physiological requirements, are determined in accordance with SP (Russian Construction Rules) 20.13330.2016 “Loads and impacts” according to the formula (6)

$$f_u = \frac{g\left(p + p_1 + q\right)}{30n^2\left(bp + p_1 + q\right)}, \tag{6}$$

where $g = 9.8$ m·s^{-2} is acceleration of free fall; $p = 50$ kg/r.m. is the standard value of the load from people that excite vibrations; $p_1 = 70$ kg/r.m. is reduced standard value of the load on floors; $q = 772.5$ kg/r.m. is the standard value of the load from the weight of the calculated element and structures based on it; $n = 1.5$ is the frequency of application of the load when a person walks; b is the coefficient taken according to Table D.2 of SP (Russian Construction Rules) 20.13330.2016 “Loads and actions”.

According to the results of the sway analysis for the combined beam, the maximum allowable deflection is $f_u = 74.4$ mm. Calculated deflection of the combined beam is

$$f = 84.5 > 74.4 \text{ mm}.$$

The fluctuation condition for the combined beam **is not met.**

According to the results of the calculation for fluctuation for a slab on a profiled deck, the maximum allowable deflection is $f_u = 26.3$ mm. Calculated slab deflection is

$$f = 17.37 < 26.3 \text{ mm}.$$

The fluctuation condition for the floor slab along the profiled deck is met.

4. Conclusions

1. According to the results of the performed verification calculations:
   - steel-reinforced concrete slab on profiled deck does not meet the requirements of standards for strength from the impact of shear force and crack opening width;
   - combined floor beams do not meet the requirements of normative documentation for strength, deformability and fluctuation.

2. Violations in the course of construction and installation works and design errors led to the occurrence of a large number of defects in the installation of the floor slab: overloading of the slab, force cracks in the slab above the beams, excessive deflections of structures, deficiencies in reinforcement and concrete work.
3. The technical state of the floors is unacceptable. It is required to carry out complex measures to strengthen the floor slabs according to a specially developed project, carried out by a specialized organization.
4. When assessing the stress-strain state of steel-reinforced concrete structures, it is necessary to take into account the actual geometric characteristics of the section and the initial geometry of the deflection of the slab due to the possible overflow of the concrete mix.
5. During the construction of steel-reinforced concrete floor slabs, including the “Hoesch Additiv Decke®” technology, it is necessary:
    - apply design solutions, taking into account the recommendations of manufacturers and in accordance with all the necessary requirements of the applied technology;
    - strictly follow the design requirements for reinforcement and concrete work, check the class of concrete mix supplied to the construction site;
    - ensure collaboration between the elements of the steel-reinforced concrete slab by following the correct design decisions;
    - ensure the adhesion of profiled sheets to reinforced concrete with the help of notches or special anchors;
    - perform internal quality control, and if necessary, external quality control at all stages of design and construction and installation works.
6. As a result of the defects and damages identified during the inspection, it is currently not possible to accurately determine the completeness of the joint work of steel beams and a steel-reinforced concrete floor slab. It is necessary to study the influence of the identified defects and damages on the operation of the contact line, arranged by means of stud bolts, between the slab and the rolled beam. Additional verification calculations are required to evaluate the joint operation of the floor elements. This direction is a separate voluminous topic for analysis. The solution of the issues of the influence of various factors on the mating of the plate elements will be considered in future studies.
7. The results of the research can be used in practical work by engineers in the design and construction of steel-reinforced concrete floor slabs, as well as in the examination and assessment of their technical condition.

References

1. Jurisch, F. Hoesch Additive Floor® - The success story of an innovation. 2006.
2. Dujmovic, D., Androić, B., Lukačević, I. Hoesch Additive Floor. Composite Structures According to Eurocode 4. 2015. DOI: 10.1002/9783433604908.ch22
3. Dujmovic, D., Androić, B., Lukačević, I. Calculation of Simply Supported Composite Beam According to the Plastic Resistance of the Cross-Section. Composite Structures According to Eurocode 4. 2015. DOI: 10.1002/9783433604908.ch8
4. Sholts Y., Arutyunyan S.N. Profnastil i ankernyye upory v stalezhelezobetonnykh perekrytiyakh – bolshe chem konstruktiv! [Corrugated sheeting and anchor supports in steel-reinforced concrete floors are more than constructive!]. URL: proflist.ru/techinfo/ARSS201703.pdf (date of application: 15.03.2023). (rus)
5. Babalich, V.S., Androsov, E.N. Stalezhelezobetonnye konstrukcii i perspektiva ih primenenija v stroitel'noj praktike Rossii [Steel-reinforced concrete structures and the prospect of their application in the construction practice of Russia]. Uspehi sovremennoj nauki. 2017. 4. Pp. 205–208. (rus)
6. Egorov, P.I., Korolev, S.A. The composite slabs. Far East: the problems of the development of the architectural and construction complex. 2015. 1. Pp. 310–313.
7. Zamaliev, F.S., Tamrazyan, A.G. To calculation of steel-reinforced concrete ribbed plates for refurbished floors. Building and Reconstruction. 2021. 5 (97). Pp. 3–15. DOI: 10.33979/2073-7416-2021-97-5-3-15
8. Kinzhitaeva, A. Primenenie i raschet stalezhelezobetonnyh konstrukcij v rossijskoj i zarubezhnoj praktike (obzor) [Application and calculation of steel-reinforced concrete structures in Russian and foreign practice (review)]. Innovatsii. Nauka. Obrazovaniye. 2021. 45. Pp. 157–166. (rus)
9. Ahmed, I.M., Tsavdaridis, K.D. The evolution of composite flooring systems: applications, testing, modelling and Eurocode design approaches. Journal of Constructional Steel Research. 2019. 155. Pp. 286–300. DOI: 10.1016/j.jcsr.2019.01.007
10. Tamrazyan, A.G., Arutyunyan, S.N. To the assessment of the reliability of steel slabs of slabs with profiled floorings. Bulletin of Civil Engineers. 2015. 6 (53). Pp. 52–57.
11. Vasdravellis, G., Uy, B., Tan, E.L., Kirkland, B. Behaviour and design of composite beams subjected to sagging bending and axial compression Original Research. Journal of Constructional Steel Research. 2015. 110. Pp. 29–39. DOI: 10.1016/j.jcsr.2015.03.010
12. Zamaliev, F.S., Zakirov, M.A. Some results of numerical studies of steel-concrete composite slabs. News of the Kazan State University of Architecture and Engineering. 2015. 3 (33). Pp. 56–63.

13. Hsu, C.T.T., Punurai, S., Punurai, W., Majdi, Y. New composite beams having cold-formed steel joists and concrete slab. Engineering Structures. 2014. 71. Pp. 187–200. DOI: 10.1016/j.engstruct.2014.04.011
14. Jurkiewiez, B., Braymand, S. Experimental study of a pre-cracked steel-concrete composite beam. Journal of Constructional Steel Research. 2007. 63(1). Pp. 135–144. DOI: 10.1016/j.jcsr.2006.03.013
15. Karapetov, E.S., Atanov A.A. Analysis of existing methods of incorporation of steel and reinforced concrete in combined action. Proceedings of Petersburg Transport University. 2018. 15(4). Pp. 592–604.
16. Kanchana Devi, A., Ramanjaneyulu, K., Gandhi, P. Shear resistance of embedded connection of composite girder with corrugated steel web. Journal of Constructional Steel Research. 2021. 187(2). 106994. DOI: 10.1016/j.jcsr.2021.106994
17. Colajanni, P., Mendola, L.L., Monaco, A. Review of push-out and shear response of hybrid steel-trussed concrete beams. Buildings. 2018. 8(10). P. 134. DOI: 10.3390/buildings8100134
18. Qureshi, J., Lamb, D., Yea, J. Effect of shear connector spacing and layout on the shear connector capacity in composite beams. Journal of Constructional Steel Research. 2011. 67. Pp. 706–719. DOI: 10.1016/j.jcsr.2010.11.009
19. Albarram, A., Qureshi, J. Abbas, A. Effect of rib geometry in steel-concrete composite beams with deep profiled sheeting. International Journal of Steel Structures. 2020. 20 (3). Pp. 931–953. DOI: 10.1007/s13296-020-00333-5
20. Zamaliev, F.S, Ismagilov, B.T. Numerical and full-scale studies of anchor links of steel reinforced structures. News of the Kazan State University of Architecture and Engineering. 2018. 3 (45). Pp. 121–128.
21. Suwaed, A.S.H., Karavasilis, T.L. Demountable steel-concrete composite beam with full-interaction and low degree of shear connection. Journal of Constructional Steel Research. 2020. 171. Pp. 106–152. DOI: 10.1016/j.jcsr.2020.106152
22. Pathirana, S.W., Uy, B., Mirza, O., Zhu, X. Bolted and welded connectors for the rehabilitation of composite beams. Journal of Constructional Steel Research. 2016. 125. Pp. 61–73. DOI: 10.1016/j.jcsr.2016.06.003
23. Tonkih, G.P., Chesnokov, D.A. Shear resistance of nailed connectors in composite beams with steel decking. Industrial and civil engineering. 2022. 7. Pp. 17–23.
24. Konrad, M. Headed studs used in trapezoidal steel sheeting according to Eurocode 4. Structural Engineering International. 2009. 19 (4). Pp. 420–426. DOI: 10.2749/101686609789847118
25. Tamrazyan, A.G., Arutyunyan, S.N. Issledovanie nachal'nyh naprjazhenij i progibov profnastila, voznikajushhih pri vozvedenii stalezhelezobetonnyh plit perekrytij [Investigation of initial stresses and deflections of profiled deck arising during the construction of composite floor slabs]. Bezopasnost' stroitel'nogo fonda Rossii. Problemy i reshenija [The Safety of the construction Fund of Russia. Problems and solutions]. 2017. Pp. 139–146. (rus)
26. Zamaliev, F.S, Bikkinin, E.G. The main factors influencing the initial stress-strain state of steel-concrete composite structures. News of the Kazan State University of Architecture and Engineering. 2015. 4(34). Pp. 161–165.
27. Porter, M.L. Eckberg, C.E. Design Recommendations for Steel Deck Floor Slabs. ASCE Journal of the Structural Division. New York. 1976. 11 (102).
28. Urgalkina, D.A. Application of deformation model to calculation of reinforced concrete lines on steel profile sheet. World Science. 2019. 6 (27). Pp. 527–531.
29. Kuznetsov, V., Shaposhnikova, Yu. Features of calculation and design of complex concrete monolithic slabs. MATEC Web of Conferences. 2018. 251. DOI: 10.1051/matecconf/201825102027
30. Tarasikova, V.E. Vlijanie stad-boltov na deformativnost' stalezhelezobetonnoj plity perekrytija po stal'nomu profilirovannomu nastilu [Influence of stud bolts on the deformability of a steel-reinforced concrete floor slab over a steel profiled deck]. Mezhdunarodnaja nauchno-tehnicheskaja konferencija molodyh uchenyh BGTU Im. V.G. Shuhova [International scientific and technical conference of young scientists of BSTU named after V.G. Shukhov]. Belgorod State Technological University. V.G. Shukhov. Belgorod, 2021. Pp. 1655–1658. (rus)
31. Gimranov, L.R., Fattakhova, A.E. Flexible stop’s force determining method in a combined plate using profiled flooring. Monthly Journal on Construction and Architecture. 2021. 16(8). Pp. 997–1005. DOI: 10.22227/1997-0935.2021.8.997-1005
32. Nazarova, K.A. Naturnye jeksperimental'nye issledovanija stalezhelezobetonnogo perekrytija [Full-scale experimental studies of steel-reinforced concrete floors.]. Aktual'nye problemy sovremennogo stroitel'stva [Actual problems of modern construction]. Materialy LXXIV Vserossijskoj nauchno-prakticheskoj konferencii studentov, aspirantov i molodyh uchenyh [Materials of the LXXIV All-Russian Scientific and Practical Conference of Students, Postgraduates and Young Scientists]. In 2 parts. Part 1. Saint Petersburg: Saint Petersburg State University of Architecture and Civil Engineering, 2021. Pp. 136–149. (rus)
33. Rutman, Yu.L., Chepilko, S.O. Stress and strain state of the steel-concrete composite beam. Bulletin of Civil Engineers. 2018. 4(69). Pp. 53–63. DOI: 10.23968/1999-5571-2018-15-4-53-63
34. Ramezani, M. Performance of composite connections strengthened with CFRP laminate. Magazine of Civil Engineering. 2021. 6(106). Pp. 10614. DOI: 10.34910/MCE.106.14
35. Alsharari, F., El-Zohairy, A., Salim, H., El-Sisi, A.E. Numerical investigation of the monotonic behavior of strengthened Steel-Concrete composite girders. Engineering Structures. 2021. 246(3)ю 113081. DOI: 10.1016/j.engstruct.2021.113081
36. Tamayo, J.L.P., Franco, M.I., Morsch, I.B., Désir, J.M., Wayar, A.M.M. Some aspects of numerical modeling of steel-concrete composite beams with prestressed tendons. Latin American Journal of Solids and Structures. 2019. 16(7). 1. DOI: 10.1590/1679-78255599
37. Mironov, A.N., Belyj, D.V., Anishhenkov, V.M. Investigation of the actual operation of steel-reinforced concrete slab structures using profiled flooring. Metal Constructions. 2020. 26(3). Pp. 117–129.
38. Mironov, A.N., Belyj, D.V., Anishhenkov, V.M., Volchkov, A.N. Creep of concrete in steel-reinforced concrete slab structures using profiled flooring. Metal Constructions. 2021. 27(1). Pp. 17–28.
39. Reginato, L.H., Tamayo, J.L.P., Morsch, I.B. Finite element study of effective width in steel-concrete composite beams under long-term service loads. Latin American Journal of Solids and Structures. 2018. 15(8). DOI: 10.1590/1679-78254599
40. Umansky, A.A. Spravochnik proektirovshhika promyshlennyh, zhilyh i obshhestvennyh zdanij i sooruzhenij. Raschetno-teoreticheskij [Directory of the designer of industrial, residential and public buildings and structures. Calculated-theoretical]. 2nd edn. Moscow: Stroyizdat, 1972. 609 p. (rus)
41. Design Manual for Composite Slabs. ECCS – Technical Committee 7 – Cold Formed Thin-Walled Sheet Steel Technical Working Group 7.6 – Composite Slabs. First Edition. 1995.

42. European Committee for Standardization (CEN): EN 1994-1-1: 2004, Eurocode 4: Design of composite steel and concrete structures – Part 1-1: General rules and rules for buildings. Brussels. December. 2004.
43. Krylov, S.B., Semenov, V.A., Konin, D.V., Krylov, A.S., Rozhkova, L.S. On the New “Manual on Design of Composite Steel and Concrete Structures (in Elaboration of Formulary SP 266.13330.2016 “Composite Steel and Concrete Structures. Design Rules”)”. ACADEMIA. Architecture and Construction. 2019. 1. Pp. 99–106. DOI: 10.22337/2077-9038-2019-1-99-106
44. Almazov, V.O., Arutjunjan, S.N. Design of composite reinforced concrete slabs according to Eurocode 4 and Russian recommendations. Monthly Journal on Construction and Architecture. 2015. 8. Pp. 51–65.
45. Kobylina, M.A., Zolotozubov, D.G. Comparison of calculation methods for composite reinforced concrete slabs according russian recommendations and Eurocode 4. Moderne technologien im bauwesen. Theorie und Praxis. 2020. 2. Pp. 15–20.

Information about authors:

Anatoly Bedov, *PhD in Technical Sciences*
ORCID: https://orcid.org/0000-0002-7003-3022
E-mail: bedovai@mgsu.ru

Yulia Shaposhnikova, *PhD in Technical Sciences*
ORCID: https://orcid.org/0000-0001-7740-9400
E-mail: yuliatalyzova@yandex.ru

Received 21.06.2023. Approved after reviewing 08.12.2023. Accepted 27.12.2023.