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EXPERIMENTAL AND NUMERICAL STUDY OF THE "BISON" POWER DECK USED AS A PERMANENT FORMWORK

Sergey M. Anpilov [1], Denis A. Panfilov [2], Alexander S. Bychkov [2]
[1] Novosibirsk State University of Architecture and Civil Engineering, Novosibirsk, RUSSIA
[2] Samara State Technical University, Samara, RUSSIA

Abstract: To conduct the research in this work, the BISON reinforcing deck was selected, this deck is used for the construction of steel-reinforced concrete floors as a permanent formwork. Its difference from the common types of deck used in the Russian Federation is the height of the profile and the configuration of the section, which reduces material consumption and affects its strength characteristics and, as a result, increases its bearing capacity and makes it possible to build longer spans without using intermediate supports.
Goal: Compare the data obtained during the experiment with the numerical model developed in the ANSYS finite element software, check the convergence and draw conclusions.
Materials and methods. The experimental model of the floor slab consisted of two sections a «BISON» 260-600-1.5., 1200 mm wide, connected longitudinally. The plate was tested according to a single-span scheme. The boundary conditions were set by one pivotally movable support and one fixed one. The numerical model in the ANSYS repeated the experimental scheme, the steel data was set taking into account physical nonlinearity, and the load was set using the step method.
Results. As a result of the experiment, data on the actual control vertical deflection of the profiled deck at a load of 995.83 kg/m2 and its maximum load-bearing capacity were obtained. The mechanical characteristics of steel have also been studied, and a yield strength of 308 Mpa has been established. A model was developed in the ANSYS, and the calculation was carried out taking into account the experimental data obtained.
Conclusions. The analysis of the experiment with the numerical model shows the convergence of the results. The stresses in the FE model exceeded the yield strength of the steel under extreme loads. The nature of the crumpling of the shelves in the FE model partially coincides with the nature of the crumpling in the experiment.

Keywords: FE model, ANSYS, profiled steel deck, non-removable formwork, reinforced concrete, composite plate, boundary conditions, non-linearity of steel, vertical deflection

ЭКСПЕРИМЕНТАЛЬНОЕ И ЧИСЛЕННОЕ ИССЛЕДОВАНИЕ СИЛОВОГО НАСТИЛА «БИЗОН», ИСПОЛЬЗУЕМОГО В КАЧЕСТВЕ НЕСЪЕМНОЙ ОПАЛУБКИ

С.М. Анпилов [1], Д.А. Панфилов [2], А.С. Бычков [2]
[1] Новосибирский государственный архитектурно-строительный университет, г. Новосибирск, РОССИЯ
[2] Самарский государственный технический университет, г. Самара, РОССИЯ

Аннотация: Для проведения исследования в этой работе был выбран настил армирующий «БИЗОН», данный настил используется для возведения сталежелезобетонных перекрытий в качестве несъемной опалубки. Его отличие от распространенных типов настила, используемых на территории РФ, является высота профиля и конфигурация сечения, снижающие материалоемкость и влияющие на его прочностные характеристики и как следствие повышающие его несущую способность и дающие возможность возводить более длинные пролеты без использования промежуточных опор.
Цель: сравнить данные, полученные в ходе эксперимента с численной моделью, разработанной в ПК ANSYS, проверить сходимость и сделать выводы.
Материалы и методы: Экспериментальная модель плиты перекрытия состояла из двух секций НС «БИЗОН» 260-600-1,5., шириной 1200 мм, соединенных в продольном направлении. Испытание плиты проводились по однопролетной схеме. Граничные условия были заданы одной шарнирно подвижной опорой и одной неподвижной. Численная модель в ПК ANSYS повторяла схему эксперимента, данные стали задавались с учетом физической нелинейности, нагрузка задавалась шаговым методом.

Результаты. В результате эксперимента получены данные фактического контрольного вертикального прогиба профилированного настила при нагрузке 995,83 кг/м2, его предельную несущую способность. Также проведены исследования механических характеристик стали, установлен предел текучести, равный 308 Мпа.
Разработана модель в ПК ANSYS, проведен расчет с учетом полученных данных в эксперименте.
Выводы: Анализ проведенного эксперимента с численной моделью показывают сходимость результатов. Напряжения в КЭ модели, при предельных нагрузках превысили предел текучести стали. Характер смятия полок в КЭ модели частично совпадает с характером смятия в эксперименте.

Ключевые слова: Конечно-элементарная модель, ANSYS, стальной профилированный настил, несъемная опалубка, сталежелезобетон, композитная плита, граничные условия, нелинейность стали, вертикальный прогиб

1. INTRODUCTION

To conduct the research in this work, the «BISON» reinforcing deck was selected, this deck is used for the construction of steel-reinforced concrete floors as a permanent formwork. Its difference from the common types of deck used in the Russian Federation is the height of the profile and the configuration of the section, which reduces material consumption and affects its strength characteristics and, as a result, increases its bearing capacity and makes it possible to build longer spans without using intermediate supports.

In this paper, the methods of testing are described, and the layout of the sample stand is shown. Data on the deflection of the deck and its maximum bearing capacity were obtained, and a finite element model of the floor was developed on their basis.

The stages of creating a model in the ANSYS finite element software are described, the nonlinear operation of galvanized steel used for the manufacture of the «BISON» FEA is taken into account, the methods of dividing the grid into finite elements are shown, the creation of contact between the overlap surfaces of the deck is shown, as well as the method of applying the load to obtain the most accurate calculation data.

The purpose of this article is to analyze the data obtained during field tests and compare them with the numerical model developed in the ANSYS, check the convergence and draw conclusions.

The investigated profile: Power deck PD “BISON” 260-600-1,5 according to TU - 1120-004-316631300162970-2019 [1] manufactured by Sole Proprietor Anpilov S.M. (Figure 1)

2. EXPERIMENTAL MODEL AND TEST SETUP

For testing, the profile PD "BISON" 260-600-1.5 made of S350 steel was used, with the following characteristics given in Table 1.

The experimental model of permanent formwork for a monolithic floor slab (Figure 2) consisted of two sections of PD "BISON" 260-600-1.5., 1200 mm wide, connected longitudinally by self-tapping screws. The plate is attached to a steel distribution plate in the support part with M16 bolts mounted in the center of the lower corrugations.

The non-removable formwork for the monolithic floor slab was tested according to a single-span scheme. The boundary conditions were set by one pivotally movable support and one fixed one (Figure 3).

Loading was carried out by evenly distributed load in stages in steps of no more than 10% of the design maximum permissible load.[2] Semi-dry vibro-pressing concrete slabs were used as an evenly distributed load. Loading was performed from the supports to the middle of the span, symmetrically relative to the middle of the span (Figure 4).

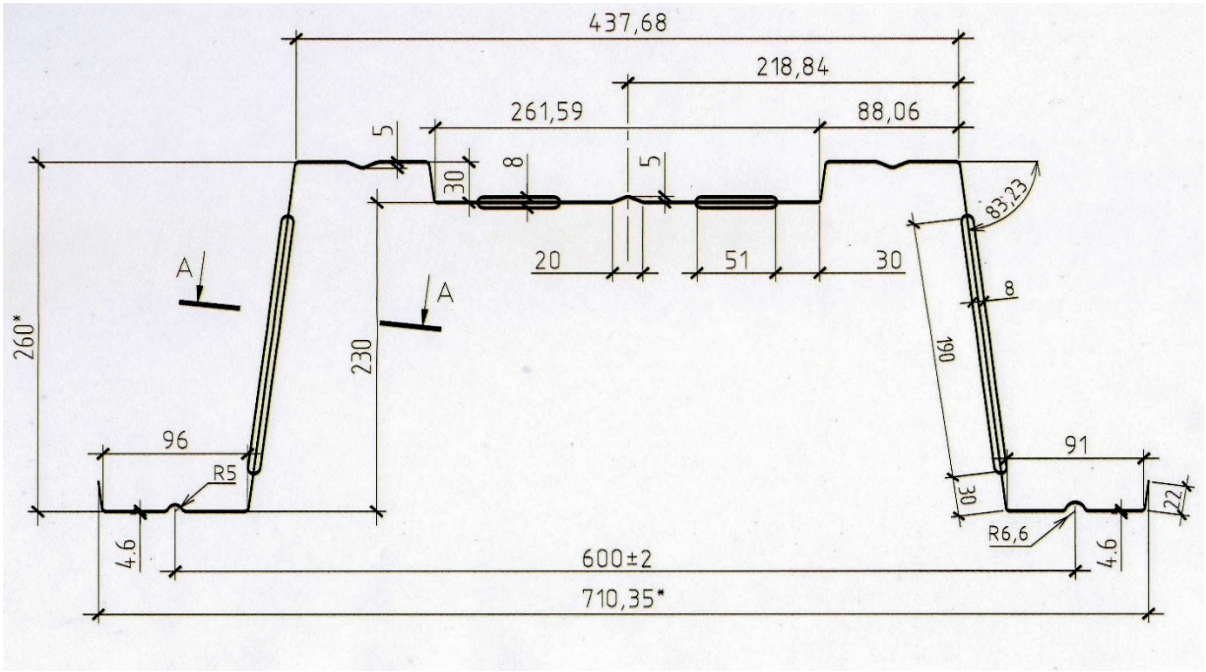


Figure 1. Geometric dimensions of the PD "BISON" 260-600-1.5

Table 1. Characteristics of PD "BISON" 260-600-1,5

Designation of the milled sheet	t, mm	Cross-sectional area of one corrugation F, cm2	Weight of 1 m length of 1 fr, kg	Reference values per 1 m width			Weight of 1 m^2, kg	Width of the workpiece, mm
				Moment of inertia of one corrugation, I_x, cm^4	Moment of resistance, cm^3			
					W_{x1}	W_{x2}		
PD "BISON" 260-600-1,5	1,5	18,75	14,59	1539,76	66,53	100,61	21,32	1250

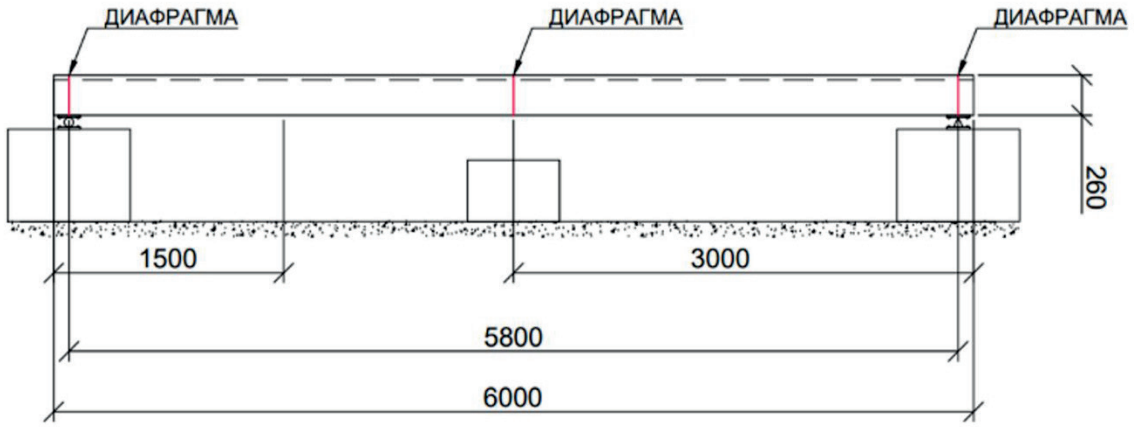


Figure 2. Test bench



Figure 3. Geometric dimensions of the test stand



Figure 4. Loading of non-removable formwork

3. EXPERIMENTAL RESULTS

The actual vertical reference deflection f_{exp} = 29.35 mm (close to the maximum deflection according to SP 20.13330) was achieved at the maximum permissible load q = 995.83 kg/m^2
When loading from 685 to 730.67 kg/m^2, there was a loss of local stability of the lowered part of the upper (wide) profile shelf (Figure 5).

When studying the mechanical characteristics of the steel of the selected samples, it was found that the yield strength of the steel is 308 Mpa.
When loading 1224.17 kg/m^2, the stresses in the cross-section shelves in the middle of the span reached the values of the yield strength of the steel, the shelves crumpled and warped, which led to a loss of bearing capacity.[3], [5]



Figure 5. Crumpling of the upper deck shelves

4. FE MODEL

A deck model in the ANSYS software package was developed for analysis and comparison with field tests.[3], [6]
The model was developed and boundary conditions were set as follows:

It was decided to dissect the scheme used in the experiment along the middle of the central corrugation, since the deck has the same geometry and loads along the line of symmetry. The deck and diaphragms were modeled as a shell with thickness parameters, and the support plates were modeled as three-dimensional elements. The overlap contacts of the decking on the central corrugation, the diaphragms on the edges and in the middle of the span, as well as the support plates were modeled as rigid joints between surfaces (bonded in ANSYS).
Boundary conditions.
The loads on the deck were applied exactly with the layout of the tiles in the experiment, the upper shelves of the deck were divided into sections of tile-deck contact and a load was applied to them (Fig.6.) equal to half of the maximum obtained during the experiment, since the model is made as half of the original permanent formwork for a monolithic floor slab.
The supports were modeled by limiting the movement of the node line on the support plates. A fixed pivot support was simulated on one part, where movement along all axes was blocked, and rotation along the X axis was prohibited and Y and Z were free. On the opposite part of the deck, a pivotally movable support was simulated, where movement along the X axis was free, and rotation along the Y and Z axes was prohibited, rotation along the X axis was prohibited, and rotation along the Y and Z axes was free.

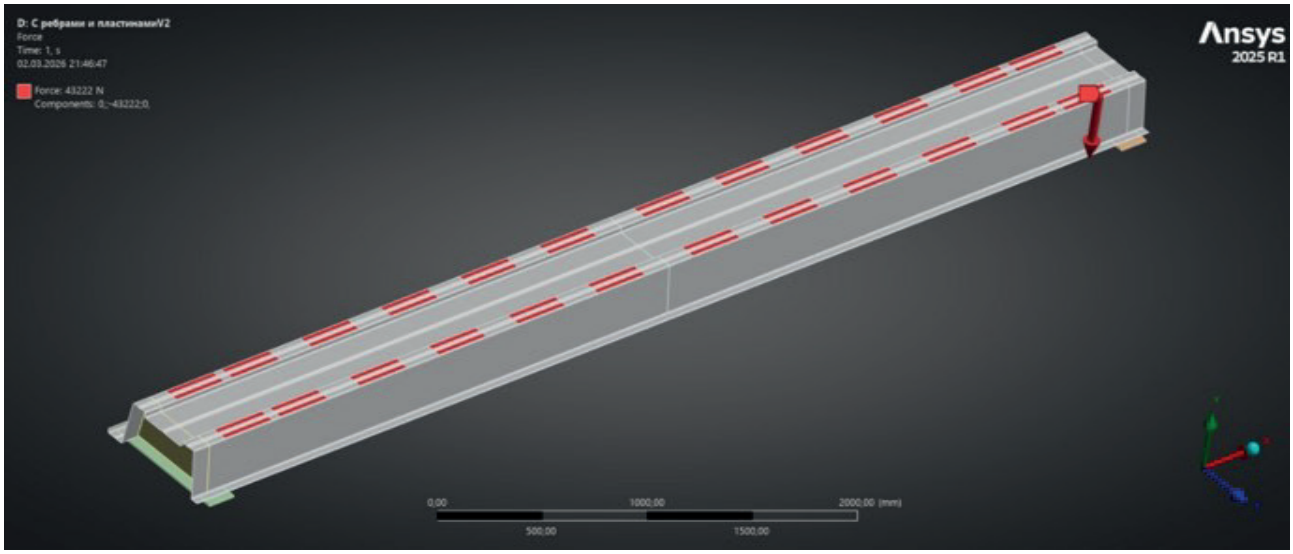


Figure 6. Load application scheme in the FE model

The introductory parameters of steel in ANSYS are modulus of elasticity = 2 * 10^5Mpa, yield strength of steel taken from experimental data = 308 MPa, Poisson's ratio = 0.3 and density = 7850 kg/m^3. To account for the nonlinearity of the material, a two-line deformation diagram was chosen.[7]

Finite element type

The SHELL281 element is used to model the steel sheet. This type of element is suitable for modeling a thin-walled steel profile, as it is subjected to large deformations. As a rule, a rectangular element is used, and where the geometry is complex, a triangular element is used (Figure 7) [2], [4], [11-15]. This decision was made based on the fact that the profile is not modeled in a simplified way, but exactly with natural dimensions, and some elements cannot be created using rectangular elements, as Kosarev, V. N. models in the LIRA-CAD FEA [8].

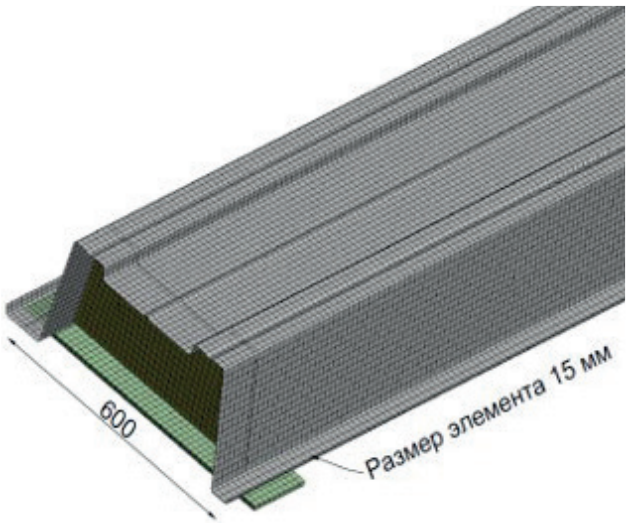


Figure 7. Finite Element mesh

5. FE RESULTS

The data obtained from the model calculation is shown below. The blue markers indicate the places where samples of data on displacements and stress values were taken in the same places as in the experiment. [2], [5], [9], [10], [16-20].

The deflection in the FE model, at a load of 1224.17 kg/m^2, was 38.337 mm in the lower shelf of the central corrugation. Figure 8 shows the deflection data.

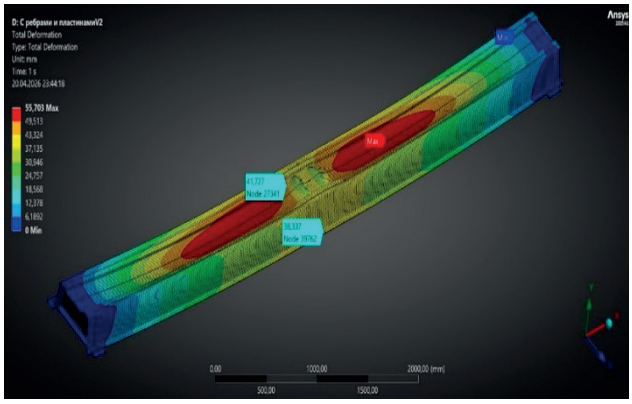


Figure 8. Deflection in the FE model

In the Figure 9, at a given load, the stresses in the lower part of the upper shelf exceeded the yield strength of the steel, and in the lower shelf they reached it.

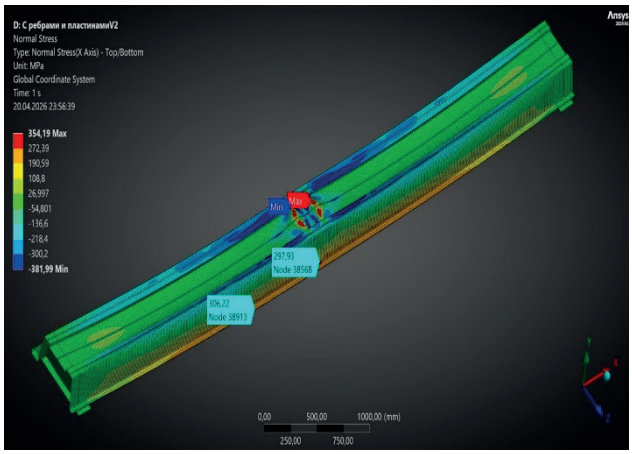


Figure 9. Normal stress in the FE model

CONCLUSIONS

The vertical deflection in the numerical model was 38.337 mm, in the central corrugation, where 2 deck sheets overlap, the discrepancy with experimental data in % terms was 2.62% (experimentally obtained deflection = 39.37 mm).

The stresses in the FE model in the upper shelf exceeded the yield strength of the steel obtained experimentally (308 MPa).

The nature of the crumpling of the shelves in the FE model partially coincides with the nature of

the crumpling in the experiment Figure 5, and Figure 9.

The results obtained during the analysis of the experiment and numerical modeling demonstrate the applicability of the numerical model to understand the operation of the deck, data on deflection and stresses in the numerical model can be used to analyze more massive structural solutions for large-span support schemes.

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Anpilov Sergey Mikhailovich, Honored Inventor of the Russian Federation, Doctor of Technical Sciences, Professor of the Department*,* Novosibirsk State University of Architecture and Civil Engineering, Novosibirsk, Russia. E-mail: anpilovsm@yandex.ru

Panfilov Denis Alexandrovich, associate Professor of the Department of Reinforced Concrete Structures*,* Samara State Technical University, Russia, Samara, Molodogvardeyskaya st., 194 E-mail: sk@samgtu.ru

Bychkov Alexander Sergeevich, Postgraduate Student Samara State Technical University Russia, Samara, Molodogvardeyskaya st., 194 E-mail: islezrbs@gmail.com

Анпилов Сергей Михайлович, заслуженный изобретатель РФ, д.т.н., профессор кафедры ЖБК, советник РААСН, Новосибирский государственный архитектурно-строительный университет (Сибстрин), Новосибирск, РФ. E-mail: anpilovsm@yandex.ru

Панфилов Денис Александрвафович, к.т.н., доцент, заведующий кафедрой ЖБК, Самарский государственный технический университет, Россия, г. Самара, ул. Молодогвардейская, 194.
E-mail: sk@samgtu.ru

Бычков Александр Сергеевич, аспирант, Самарский государственный технический университет, Россия, г. Самара, ул. Молодогвардейская, 194. E-mail: islezrbs@gmail.com