BELARUSIAN-RUSSIAN INNOVATION: CREATION OF ENGINEERING STRUCTURES OF THE XXI CENTURY

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INTRODUCTION

The State Institution of Higher Professional Education "Belarusian-Russian University" (hereinafter BRU) about 20 years ago, initiated studies in perspective, in our opinion, direction: the development of a fundamentally new innovative design and manufacture of advanced constructions for various industries. Its level should correspond to the priority areas of modernization and technological development of economy of the Republic of Belarus and the Russian Federation. Theoretical and experimental studies have allowed creating a *composite (steel-concrete) bearing element of constructions (KNESK)*.

The scientists of BRU and the Federal State Budget Institution of Higher Professional Education "Moscow State University of Railway Transport" (the MIIT) take direct part in this work. Design and construction works are carried out jointly with specialists of "Mostostroy" and then holding company "Protos group of companies."

The innovative manufacturing technology based on KNESK includes a number of complex measures: the design of the construction, adapting of KNESK to the projected construction, project development and production technology of KNESK, the development of designs and manufacturing techniques of field joints and transport modules, the development of installation technology.

The wide variety of possible constructive forms and designs of KNESK allows its use as a basic element for a variety of purposes and structures with desired properties.

Design and technological solutions were used in the construction of some objects of bridge building in Mogilev, Minsk and Gomel.

The composition (KNESK) is flexible and perfect in manufacturing and installation technology, has achieved effective implementation in bridge construction of the Republic of Belarus, and can get a wide field of use in creating highly reliable and long exploited engineering structures of the XXI century.

DEFINITIONS OF KEY TERMS

Some terms used in this article require clarification. More details are discussed in the monographs [1, 2]. Here we present only the interpretation of key terms in the wording of the author of the above-mentioned monographs.

One of the promising areas of establishing effective civil engineering constructions in the XXI century is the development of innovative technical solutions *based on the principles of forming building structures:* a set of criteria for the selection of a set of structural forms the most advanced and effective solutions.

Shaping - the creation and development of structural forms: the creation of new and improvement of known structural materials and the creation of new techniques and high-efficiency technologies on their basis, updating of regulatory requirements for qualitative and quantitative criteria for the selection of structural form.

The structural form is understood as a set of constructions with a uniform set of materials and the same geometrical structure of bearing elements and relationships with the environment. Thus, quantitative characteristics of structures are ignored: their scale, aspect ratio, etc., but not the physical and mechanical properties of materials.

The bearing element - located in static or dynamic equilibrium a solid deformable body, perceiving external influences and reactions of relationships with other bodies. The bearing element may be homogeneous or composed of separate discrete components and perhaps these components may be surrounded by continual deformable solid medium (matrix), and the connection of the components determines the geometric dimensions of the element.

The detail - in the construction industry is, for example, the steel frame, fittings, base etc.

The matrix - reinforced concrete or some other aggregate.

The creation of new forms of design is largely driven by information technologies, the development of mechanics, mathematics, and experimental methods.

COMPOSITE BEARING CONSTRUCTION ELEMENT

Design features of the element

Several patents of the Republic of Belarus and the Russian Federation [3 - 5] protect the design KNESK. The options of constructive and factory KNESK performances are presented in Figure 1.

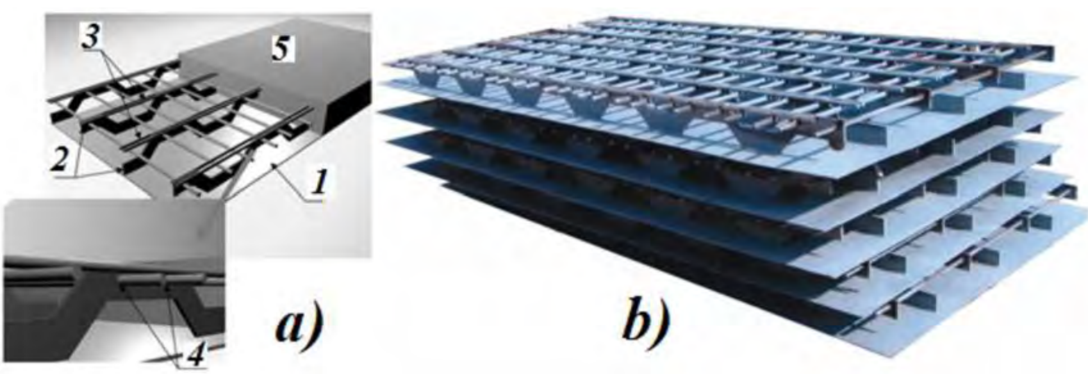
The forming sheet 1 provides implementation of mounting on high-strength bolts or welding and reducing the complexity of grouting of installation joints; tightness up to the vacuum; operation in harsh environments; explosion and fire resistance.

Steel reinforcement 2 (ribbed reinforcing element - virtually waste-free cutting of flat steel) allows to increase the load-carrying ability of structures, to ensure the readiness of the erected structure bear load without aggregate and scaffolding, to reduce the tendency of the aggregate to crack, to improve the level of industrialization in structure fabrication.

The use of *reinforcing rods 3, 4* allows you to increase the grip of a shell reinforcement with an aggregate, to simplify the creation of prestressed structures.

The use of an *aggregate 5* (concrete and other materials - the *matrix*) provides increased resistance of a structure to the loss of bearing capacity and effective corrosion protection of a shell reinforcement.

Items 1 - 4 are combined by welding into a *steel component* KNESK (following terminology adopted above - *detail*), which is shown in Figure 1 b. Concreting was carried out after the installation of the metal structure of the overpass.



1 – shape-generating sheet; 2 – foliated reinforcement; 3 - rod longitudinal reinforcement; 4 – rod transverse reinforcement; 5 - aggregate (usually - modified concrete with additives of multifunctional action).

Figure 1. Options for the embodiment (a) and factory performance (b) of KNESK

Competitive advantages of KNESK

The features of element design and use of modern technologies provide:

- the ability to perform the installation on the high-resistant bolts or by welding, and as a result, relatively quick erection of structures;
- the minimum length of erection weld;
- to simplify the creation of complex three-dimensional shapes;
- the execution of shell reinforcement the function of permanent shuttering and retaining systems;
- to minimize the drawbacks of steel-reinforced concrete and welded shell structures;
- a high level of production industrialization.

KNESK has high resistance to thermal shocks, water resistance and tightness, increased adhesive properties, radiation shielding. It allows you to create a prefabricated structure with the same specific properties.

The broad scope of KNESK applications are due to the versatility of the materials used therein. The principal novelty lies in the fact that KNESK is a composite structure uniting hardening aggregate, especially a modern concrete, with a metal by connecting rod reinforcement and rolled steel sheet along with various types of aggregate. The proposed technology is superior to the existing analogues in terms of efficiency and technology, including the support of environmental and anti-terrorist security system.

The effectiveness of KNESK

Composite bearing elements are particularly cost-effective, in our opinion, when they are used for the construction of unique, complex structures. Examples of the implementation of the above-mentioned principles of formation, which are used by the authors in bridge construction practice, set out in a number of publications [6 - 10].

The effectiveness of use is proved by the implementation of KNESK in load-bearing structures of the deck of highway overpasses. On the territory of Belarus, four objects of bridge construction with KNESK application are designed, built and successfully operated. In 2005 a pedestrian bridge over the river Dubrovenka Mogilev (Figure 2a) was built. Unique road overpasses were built in 2008 in Minsk (Figure 2 b), and in 2011-2015 in Gomel (Figure 2 c). The leadership of holding "Protos Group" showed strong interest in the practical growth of the topic of the industrial use of the development. The company is working successfully in the Mogilev region.

Figure 2. Examples of KNESK in load-bearing structures of the overpass: a) pedestrian bridge in Mogilev; b) road overpasses in Minsk and c) Gomel.

Basing on the experience of designing for roadway of overpasses, geometrical parameters of structural components of steel component KNESK are recommended to prescribe, depending on the particular design of the overpass and conditions of operation, within the following limits:

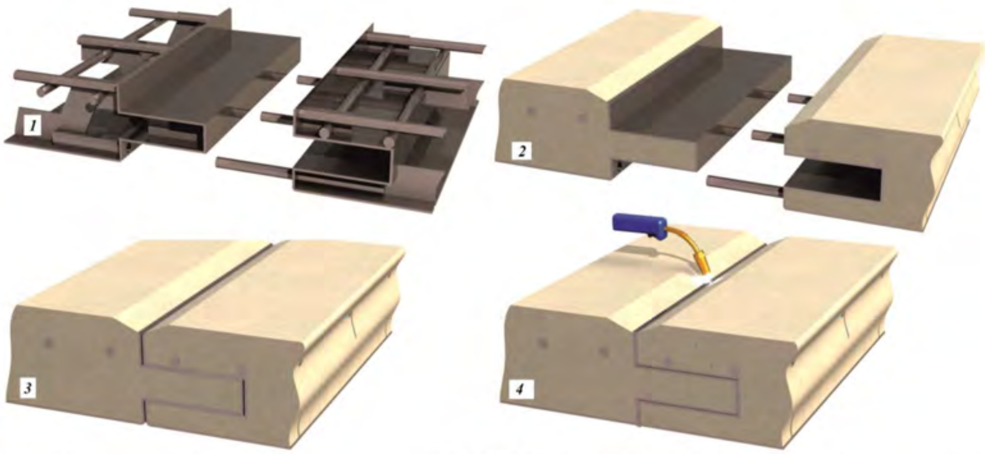
thickness of the forming plate - 4 . 12 mm;
thickness of a sheet of reinforcement - 4 . 16 mm;
height of a sheet of reinforcement - 70 . 170 mm;
wave height of a sheet reinforcement - 30-50 mm;
angle of a sheet reinforcement wave - 45°;
diameter of longitudinal rod reinforcement - 12 . 22 mm;
diameter of the transverse rod reinforcement - not less than 10 mm.

It should be emphasized that in the concrete part of KNESK – in *matrix* during concreting special cavities and channels for placing sensors and fiber optic cables for transmission of information can be formed.

Quickly erected structures based on KNESK

The usage of a common technology of monolithic and precast-monolithic construction of composite reinforced concrete structures, including ones based on KNESK is limited to low level of industrialization of the installation technology as it is defined by the hardening period of concrete, time of mounting and time of achieving technological strength by field connections.

The BRU developed and investigated the variants of design of field joints to ensure quick installation with the use of welding, without "wet" concrete processes [11 - 14]. Figure 3 shows factory fabricated field joint of quickly erected construction.



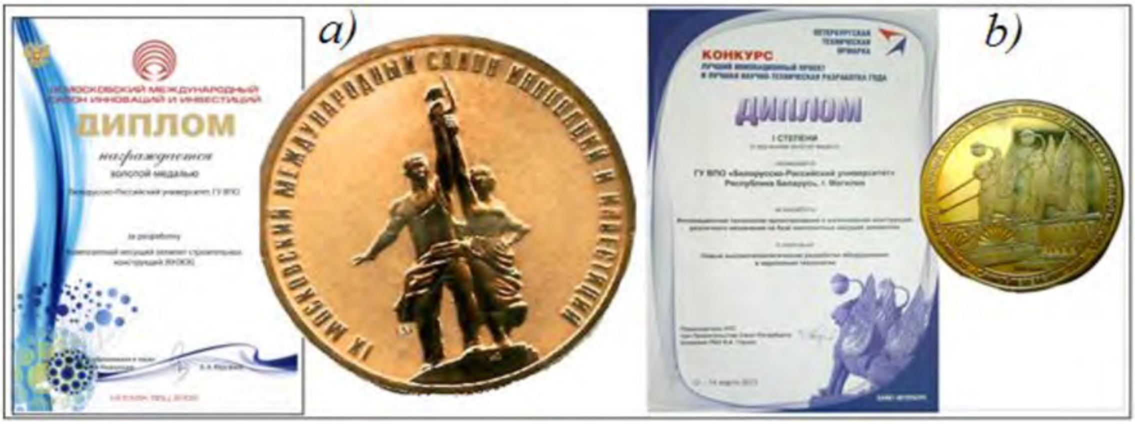
1 - mounted steel components of KNESK; 2 - filling with the hardening material (concrete); 3 - start of installation: assembling of the embedded details; 4 - the completion of installation: welding of field joint.

Figure 3. The procedure of factory fabrication of field joint of quickly erected construction

The production of the dimensional welded reinforcement KNESK (steel components) and subsequent filling with concrete are transferred to the shop floor. At the stage of the construction the mounting of the integrated segments (modules) is carried out, which are manufactured in the factory, already with a concrete component.

The proposed construction of field joints with welded connections for quickly erected segments based on KNESK, provide a sufficient bearing capacity, rapid welding assembly and ability to accept operational loads immediately after their implementation. Erection time is significantly reduced. The possibility of failure of the shuttering and retaining systems through the installation of ready-made segments that can take the load, both of its own weight and the weight of the personnel involved in the installation, reduces the cost of installation and reduce the additional costs arising from the use of formwork, retaining systems and organization of bypass roads.

The developments of Belarusian scientists were highly appreciated in Russia. Figure 4 shows the diploma and a gold medal of the IX Moscow Salon of Innovations and Investments (Moscow, 2009) and the St. Petersburg Technical Fair (St. Petersburg, 2013).



a) IX Moscow Salon of Innovations and Investments; b) St. Petersburg Technical Fair.

Figure 4. Diploma and a gold medal for the development of KNESK

The creation of engineering barriers for the safety of underground nuclear power stations

One of the major problems that must be solved in the construction of underground nuclear power stations is the creation of a highly reliable complex of engineering barriers for the safety of nuclear power stations. This fully applies to the storage of radioactive waste (RW): high-level waste (HLW) and spent nuclear fuel (SNF). The problem is relevant for Belarus in connection with the prospects of the development of nuclear power in the Republic. It is also necessary to ensure an adequate level of security of such plants in the event of accidents. It is also necessary to take into account the possibility of a military or terrorist attack that can cause not only a great material damage, but also lead to an environmental disaster.

Leading Russian scientists, in collaboration with BRU, proposed the construction of composite membranes based on KNESK placed inside the trunk space created in the areas of a reactor and storage [15 - 17].

A complete encapsulating of the space is provided with the shells based on KNESK. Completely seal the space around all sides of the shells KNESK.

Such shells may be with a gap nested within each other, creating a highly reliable barrier of any desired degree of long-term protection from radiation. The barrier in the form of a shell KNESK creates favorable conditions for thermodynamic dissipation of local one-sided thermal field.

Using KNESK also facilitates the construction of prefabricated anti-radiation and protective shelters that protect personnel engaged in assembly, from dangerous radiation exposure and the lowest possible length of welds and volume of assembly operations.

Use of the basic elements of KNESK in designs of vertical cylindrical tanks

One promising area of development is the use of basic elements or segments of KNESK in the construction of tanks and gas tanks [18]. Reservoirs of different structural performance up to 200 thousand m^3 for storage of aggressive oil or flammable liquids and gases, may be regarded as relatively quickly erected buildings.

The size of the segment of KNESK limited to bearing capacity of the equipment for installation, transportation and manufacturing sections, space limitations of production facilities and the expected route of transportation. The use of large basic elements simplifies installation and eliminates the need for welding sheets of large thickness. The main part of the welding work is carried out only inside of the tank. The walls of tanks constructed of KNESK have an increased fire and explosion-proof. Concrete aggregate ensures reliable protection of steel components from aggressive atmosphere or weather changes and shaping steel plate seals and allows the tank to operate in hostile environments, destroying the concrete. Due to the use of KNESK metal content can be lowered compared to tanks manufactured by traditional technology.

The composite bearing block and the field joint of bearing blocks for prefabricated buildings

The MIIT has developed and patented in Russia [19] new carrying prefabricated concrete and steel-reinforced concrete building elements, including ones using KNESK.

The invention relates to the construction of engineering structures with supporting framework in the form of prefabricated composite structures with shell, plate or shell-plate large-sized structure, which can be single- or multi-connected, including cellular. These include the installation of reinforced concrete blocks with steel or non-metallic reinforcing rods, with the possible inclusion in the shells and plates thin-walled shell elements made of steel sheet metal with embedded metal parts forming the connection between the mounting blocks and other building structures.

The proposed structure is recommended for applications in many fields of construction, for example, such as bridge building, demersal and overhead tunneling, and construction of tanks. They can be used in the construction of retaining walls, transportation galleries, columns, walls and floors of industrial buildings, high-rise buildings, toroidal tanks, domed, cylindrical and conical vaulted structures, including underground and underwater at depths up to 500 m, fixed and mobile bases platforms for the production of hydrocarbons offshore. They will also be useful in the construction of ventilation pipes and chimneys, cooling towers, sea and river piers and terminals; the use of such structures in shipbuilding is possible.

CONCLUSIONS

1. Increased use of KNESK in the future leads to the development of the famous and the creation of new forms of engineering structures design, which will generate long-term technical solutions and determine the potential core innovations for composite reinforced concrete in the field of civil engineering of the XXI century.

2. The design features of a steel component of KNESK allow you to create *quickly erected constructions* on their basis for various industries. The developed basic structures of welded field joints have up to 80% of bearing capacity of the base material and provide a framework assembly without the use of “wet” technology of concreting directly into the installation process.

3. Based on the results of the studies the thesis and three thesis for a master’s degree in technical sciences were done and defended.

4. The authors worked out new technical solutions for the various structures using this innovative development [20 - 25]:

- for transport construction, including the approaches to the bridge through challenging obstacles and extensive overpasses, foundations and intermediate supports of bridges, demersal tunnels;
- for the construction of toroidal tanks;
- for underground structures – complex barrier such as vertical shafts of small nuclear power plants (NPPs) and storage of high level waste (HLW) and spent nuclear fuel (SNF);
- for shipbuilding and marine underwater fishing platforms for shore protection, artificial islands, etc.

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