International Journal of Engineering & Technology, 7 (4.8) (2018) 152-156

International Journal of Engineering & Technology

Website:www.sciencepubco.com/index.php/IJET

Research paper

The Flat Slab Structural System for Cottage Construction

Andriy Pavlikov[1*], Nataliia Pinchuk[2]*, Oleksiy Fenko[3], Volodymyr Kyrychenko[4]

[1]Poltava National technical Yuri Kondratyuk University, Ukraine
[2]Poltava National technical Yuri Kondratyuk University , Ukraine
[3]Poltava National technical Yuri Kondratyuk University , Ukraine
[4]Poltava National technical Yuri Kondratyuk University , Ukraine
**Corresponding author E-mail: Natali.pinchuk.pntu@gmail.com*

Abstract

A perspective area of construction is the cottage buildings construction in suburban scenic areas. It is expedient to use prefabricated reinforced concrete structures, namely the industrial flat slab structural system, to reduce the cost and the construction time. The structure of the frame includes columns, rigidity elements and slabs of overlapping. Design schemes and testing equipment are developed and proposed for research bearing capacity of the main structural elements of the frame. The experimental investigation results of the reinforced concrete slabs from flat-slab constructive system of buildings are presented. In this case, the assessment of the main structural elements of the frame, the details of their construction are given. The flat slab frame constrictive system has already proved in practice the effectiveness of its application for the multistorey residential buildings construction. On the basis of the conducted research, constructive solutions for buildings of cottage type are proposed. Today, this frame has undergone many improvements, and therefore it can be offered for solving such problems. The proposed constructive decisions will facilitate the massive introduction of industrial frame structure in housing construction to solve the problem of providing affordable housing for the population.

Keywords: *cottage buildings, flat slab frame, constructive system, reinforced concrete element.*

1. Introduction

Today in the construction industry the problem of resource-saving buildings design remains to be actual. There are a lot of reasons for this problem in the construction area. Among them - the use of imperfect design systems and labor-intensive technological processes of works, low level of technological processes mechanization in building structures production and materials, the use of imperfect and outdated architectural and planning decisions, and others. The presence of noted and other reasons contributes not only to the existence but also to the increasing exacerbation of the social problem, which is now manifested in the inaccessibility of the purchase of housing, because of its high cost, the greater part of the population, which predominantly forms a little protected stratum of our country's society. The state target social and economic program of affordable housing construction has been launched on its importance and necessity of the first-rate solution. One of the ways to solve these problems may be to intensify the improvement of the residential buildings construction process through technical measures, in particular the introduction of effective constructional reinforced concrete systems in their technology, among which there are many that are characterized by both minimal number of elements and significant opportunities for accelerating the buildings construction. Implementation of these systems in construction can create conditions for solving the problem of buildings energy efficiency through a number of technical measures. One of them is the application of specially designed thin-walled multi-layer reinforced concrete blocks with high heat transfer resistance for enclosing structures. In addition to the noted positive qualities, such constructive systems of buildings also contribute to the widespread industrialization of the production of their individual elements at factories of prefabricated reinforced concrete products, which contributes to significant energy savings, the complete independence of construction from weather conditions and the reduction of its duration. The research results presented in this article confirm the significant advantages of the flat slab constructive system use, which allows, on its basis, to erect buildings of improved planning capable of meeting the needs of most of the population. This constructive system effectively solves the problem of reducing the cost of housing. The widespread introduction of the presented results will contribute to the restoration of the factories work for the production of prefabricated reinforced concrete products, to increase workplaces. The term of construction of buildings will increase. The intensity of housing construction will increase, and the opportunities of the population, given availability of its acquisition, will increase.

2. Cottage town structure

In Ukrainian town-planning arena, the cottage town as a phenomenon appeared relatively recently, namely, when it became possible to buy large areas of land. This kind of individual dwellings does not fit the Ukrainians mentally, therefore, and is not perceived by the masses as a norm. Cottages, villages, are considered to be the object of luxury.

The main feature of the cottage is the simultaneous or almost simultaneous construction of all houses in it. The main thing is that the towns are not built gradually, but at once, embodying a holistic architectural project. The site is received, the project is being developed, a complex of houses is being built (Fig. 1), and then are sold.

Copyright © 2018 Authors. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Houses in such cottage towns are built not by those who live in them, but by professional specialized construction organizations. The construction of small towns is a powerful industry, a system that begins with the acquisition of large di-arcades and ends with an organized sale of houses. There is a whole business area that deals with the construction of townships. Construction of cottages - it's extremely unclear. After all, for the construction of a house at a small place, which will be sold later in the price of 50 000 dollars, it costs not more than 20 000, and in large megacities houses are sold from 100 000. Therefore, the profit is obvious.

Such specialized towns often provide infrastructure such as shops, playgrounds, gardens and even schools. Their location along the roadway is extremely convenient.

A very important issue, which needs to be determined when planning a town project, is also the level of readiness of houses when delivered to the buyer. As a rule, future owners of such cottages strive for the realization of their individuality and the flight of fantasy and the embodiment of extraordinary interiors design decisions.

In case if for the facades of cottages to use identic collective solutions, as well as to make outdoor decoration and to cover the same materials, the project of the city will be more attractive. The only concept of the style should be kept in the design of yard fences, streets, drainage and drainage systems. The characteristics of the landscape are one of the decisive factors that largely affect the attractiveness of the town. Everyone likes the forest, the lake, the spectacular landscape, but you can not find them anywhere.

With sufficient certainty, we can assume further interest in the well-planned and well-implemented cottage townships on the cities outskirts. The trend of rising prices for apartments in oblast centers gradually inclines consumers to buy or build their own suburban home. The level of culture and psychology of the middle class gradually change. Therefore, the search for a constructive solution for such a development that will enable us to solve this issue at affordable prices is an urgent task.



Fig. 1: An example of a master plan for a cottage town.

3. The cottages traditional space-planning and design solutions

A cottage is a single-family residential building (urban or rural), in which there is a small plot of land. Cottages are mainly two-storeyed with internal staircases: usually on the ground floor there is a common room, a kitchen, a household, and on the second bedroom.

The cottage is intended for one family living in it. Each room in the building is subject to certain functional requirements, that is, each room must perform certain functions. The living room is intended for reception guests, active rest of the family members and can also serve as a room for eating. The common room is a place for active rest and a room for meals. The bedroom is a room that serves for the passive rest of family members. The cabinet is intended for work and creative activity, it is also possible to use it for reading books. The kitchen serves for cooking and eating. The boiler is intended for placing heating equipment in it. The bathroom is used for the personal hygiene of family members. The veranda has access to open space, as well as for additional illumination of the floor. The hall, in which the ladder is located, serves to store both outerwear and footwear, for communication between floors and other premises. Balcony overlooks the street and allows you to get to the fresh air without leaving your home.

As a rule, the typical flat-panel decision of a cottage house (fig. 2) is as follows: a basement above a height of 2.80 m and one or two floors with a height of 3.00 m. On the ground floor, the location of the pool, bath and boiler room or garage is possible.

Low-rise residential houses of a cottage type traditionally erected behind a wall constructive system. In this case, the cost of the foundation is about 15-20% of the cost of the house. The tape bases are made of concrete or concrete in combination with brickwork or stone masonry. The choice of type and depth of foundation is determined by the engineering-geological and hydrogeological conditions of the construction land. In modern construction quite effective are prefabricated foundations under the walls of buildings, executed from typical reinforced concrete blocks-pillows and concrete blocks-panels. The sediment is less than the ribbon type, so the pressure under its sole can be increased by 20-30%.

In case of using a wall constructive system, the walls simultaneously perform guarding and bearing functions. The main requirements of the walls are: strength, heat resistance, soundproofing ability, fire resistance, durability, architectural expressiveness and economy. Materials for wall erection are chosen depending on climatic conditions, purpose and capital construction of the building, its surface, on the technical and economic feasibility. The walls can be made of reinforced concrete panels with effective insulation, blocks of especially light concrete, but the most common material is a brick. As a ceiling construction, multi-wall reinforced concrete panels are commonly used.

The most common are attic and combined roofs. The attic ceiling provides thermal protection to the upper floors in cold weather. To ensure drainage of the water, the roof is performed in the form of sloping planes - slabs. The roof slope is designed taking into account the material of the roof and the climatic area of construction, as well as depending on the architectural and operational requirements. Each type of roofing material has its optimal and marginal deviations. The attic roofs with external water drainage usually used in low-rise construction. The supporting structures of pitched roofs consist of wooden rafters and latticework.

From the above description of the constructive solution of the building, there is a clear manifold of building materials and a large number of nomenclature of building products for the construction of the frame, in addition, brickwork works are extremely labor-intensive and require a lot of time and highly skilled workers. All this significantly affects the cost of this building and makes it inaccessible to the middle-income population. The state solves this problem by providing mortgage loans for housing, but it is more effective to overcome this problem by applying new engineering solutions and achievements of the construction industry. In particular, we propose to use for the construction of such buildings an industrial, flat slab frame structure, which has proven well in the construction of multi-storey residential buildings.



Fig. 2: Typical design solutions cottage house

4. The flat slab structural system

The solution of the existing problem of providing affordable housing to the population is possible by improving the technology of building residential buildings on the basis of the introduction of constructive systems, among which the most attractive is the prefabricated, monolithic uncaptile-fissure skeleton with the minimum number of standard sizes of prefabricated constructions (Fig. 3)

In its essence, this constructive system is a flat iron-concrete overlap directly connected with the columns due to progressive solutions of their joints. There are no beams, console columns, capitals in buildings with such frames. It allows you to transform quickly the premises for a new purpose, provides autonomy for their heating. And since the individual elements of the spatial framework have a maximum factory readiness and their combination between them involves the installation of mounting gaps on small areas, the application of this constructive system is also one of the ways of resuscitation of industrial production at factories for the production of prefabricated reinforced concrete, which will significantly save energy resources.

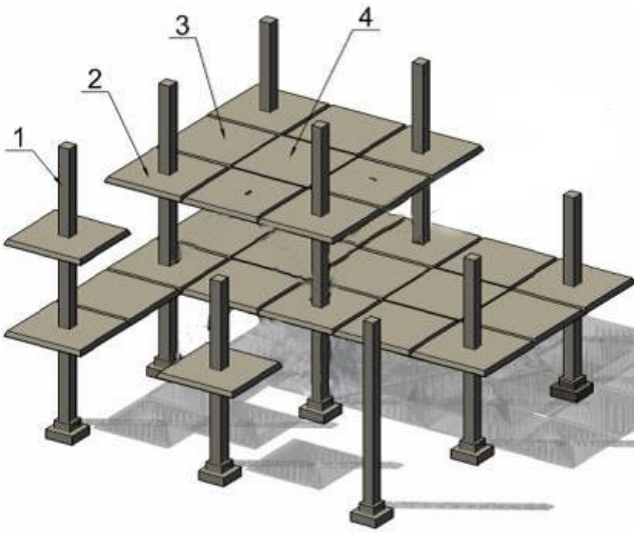


Fig. 3: Flat slab frame structure constructive scheme: 1 - a column; 2 – under-column slab; 3 - inter-column slab; 4 - middle slab

Interconnecting overlays in buildings with applied frame (Fig. 3) consist of three types of prefabricated reinforced concrete slabs: superstructures (item 2), interconverted (pos. 3) and middle (pos.4). The thickness of all slabs - 160 mm, their size in terms of, in order to unify formwork, adopted the same - 3000 × 3000 mm. The extraction slabs (2) are fastened (fig. 3) by welding the casing (4) in them into the column fittings (1), and the assembled spacings of 20 mm between the column and the clamp, as well as between the slabs, are filled with high-strength fine-grained concrete. At the same time, the keys (3) are formed in concrete-walled intervals, the concrete itself is self-restraint due to the work in conditions of all-round compression, contributing to the use of only mounting seams instead of the bathroom welding of reinforcing editions in columns. Vertical bearing elements of the frame are prefabricated concrete bunk columns with a section size of 400 × 400 mm, as well as partially reinforced concrete rigidity diaphragms. Sealing of columns is forcibly due to the entry of the rod-fixation of the lower end of the upper column to the nest of the upper end of the lower column.

The frame, designed for the construction of residential buildings of 16 storeys high, in areas with a seismicity of up to 9 points, is quickly mounted and endowed with considerable simplicity in the production of individual elements.

The spatial rigidity and stability of the applied frame of buildings is mainly due to linear beads (reinforced or metallic strings) and solid reinforced concrete rigidity diaphragms.

In the elements of the framework, the internal forces were counted using a PC in the software complex "Structure CAD 11.1" based on the method of spatial finite elements for the case of both linear and non-linear work of materials of bearing structures and soil foundation. In the calculation models of the flat-slab frame served columns, horizontal disks - the ceiling, made up from slabs. Vertical reinforced concrete diaphragms and pods have been adopted on the clay. Experimental-theoretical studies have shown that efforts in the elements of flat-slab frame system can be calculated by simple engineering methods, previously dissected the spatial framework into flat orthogonal frames in the form of cross-bars, supported by columns. In this case, the vertical load is perceived by columns, conditional bars, plates and partially the diaphragms of stiffness, and horizontal - only elements of stiffness [5-9].

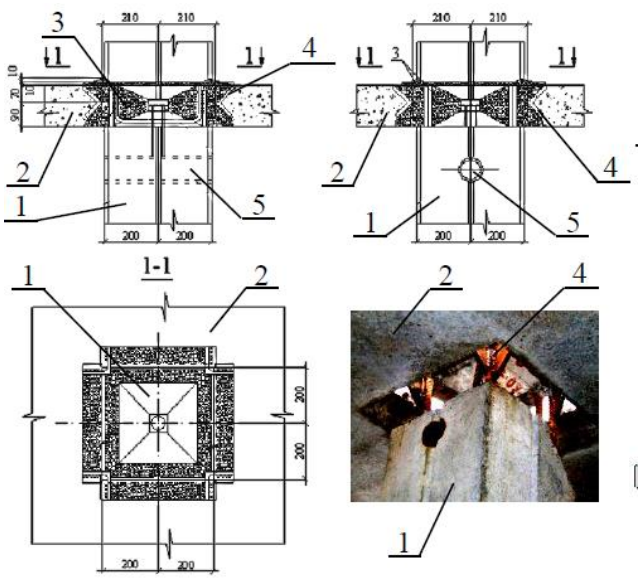


Fig. 4: Connection schemes of slab with column: 1-column; 2 - slab (bottom view); 3 - concrete; 4 - steel clasp; 5 - mounting hole

Designed for use in the framework of the building elements were tested in PoltNTU in the laboratory of the department of reinforced concrete and stone structures and strengthmaterials resistance. In this case, for each of the elements, that is, columns, slabs and staircase marches were invented individual possible calculation schemes and manufactured test equipment.

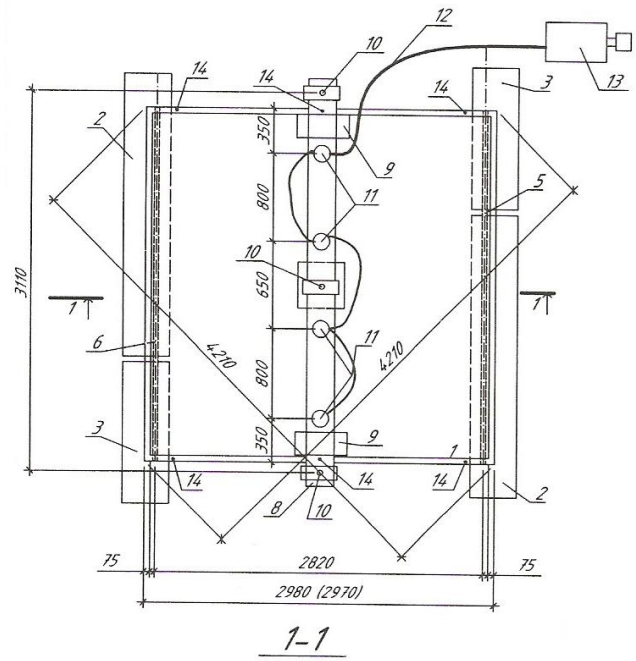
In a inter-column slab in a stretched zone were installed two reinforcement meshes of strength class A-500 in both directions of bars: in one 16Ø14, in the perpendicular - 12Ø14; The compressed zone was reinforced in both directions by 20Ø4 wire of the class Bp-I. In the middle stove in the stretched zone in wire mesh of the class Bp-I there were 12Ø8 and 7Ø8 in both directions in each, the compressed zone was designed without fittings.

In the combined buildings in columns used bars strength class A500 in the number of 4Ø28 - 6Ø28. The flat stripline in the stretched has two grids of class A-500 fittings: one containing rods in both directions of 16Ø14, and the other - by 12Ø14; The compressed zone is reinforced with wire of class Bp-I by 20Ø4 in both directions (Fig. 5).



Fig. 5: The location of the reinforcement in the slab formwork





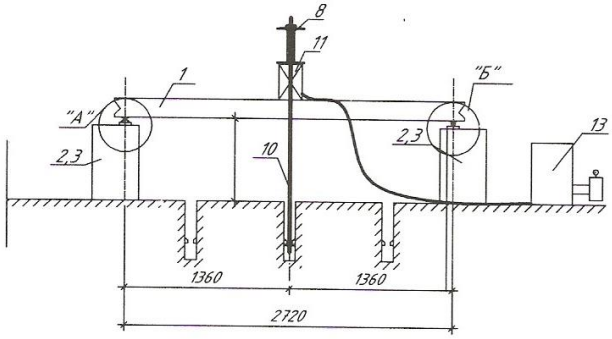


Fig. 6: Scheme of the equipment for the test of a superstructure: 1-stove; 2,3-pillars; 4,7-metal plates; 5,6 - movable and stationary supports; 8 - traverse from the channel №30; 9 - mounting supports; 10 - gravity; 11 - hydrodrives; 12, 13 - pumping station; 14 – flexometers

The slabs destruction occurred in general load 3,02 t / m^2, medium - at 2,4 t / m^2, inter-column - at 1,8 t / m^2.

The calculation scheme of the slab was implemented not only in the form of a curved circuit (Fig. 6), but also as beams - parts of the crossbar between its zero points on the circular bending of the bending moments (for a flat slab frame) for the superconducting plate. The test is performed on the calculated load values. The

loading was carried out by hydraulic jacks (8) with a capacity of 500 kN by means of a pumping station (10).

Consequently, a non-lethal unconstrained constructive system for the construction of residential buildings was completed by laboratory full-dimensional testing of all structural elements. Technical specifications have been developed [1-4] for each structural element (columns, slabs and stairs) on the department of reinforced concrete and stone structures and the strength of materials of the Poltva National Technical Yuri Kondratyuk University.

Several 16- and 9-storey residential buildings have already been built in Poltava, thanks to this constructive system that is successfully used by residents. Therefore, the use of this constructive system is advisable to adapt and under low-rise housing cottage type. For example, we will develop a schematic plan of a typical cottage house measuring 9x9m, which is presented in Fig. 2. As a result, we hold the building (fig. 7), the frame of which consists of a minimum number of constructive elements that are industrial (manufactured in factories of reinforced concrete products, and therefore have high quality) and are quickly mounted with the help of cranes. Owner can freely plan with their preferences the space inside the building.

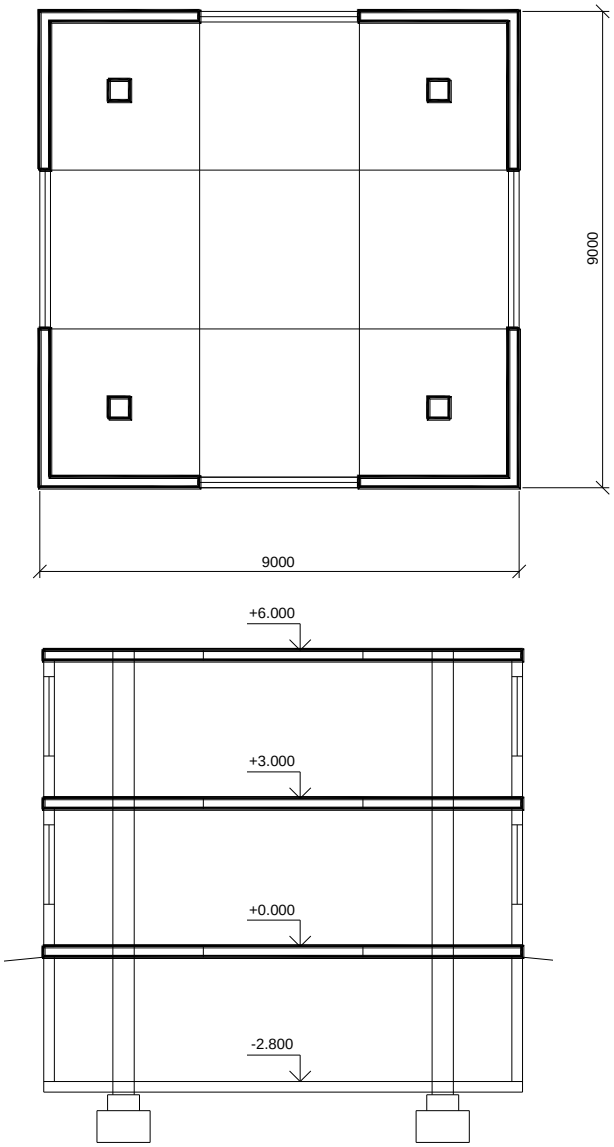


Fig. 7: The example of a cottage plan and crosscut designed by flat slab structural system

5. Conclusions

Experimental studies have shown that the use of flat-slab frames for the construction of residential buildings of the cottage type allows to realize in practice the following main advantages:

1) the landscape of the building is attractively diversified by providing each building with unique architectural forms;

2) buildings are characterized by autonomy in architectural and planning decisions;

3) the construction period is significantly reduced;

4) the launch of the production line for the production of prefabricated elements is simple enough and carried out in the minimum terms.

References

[1] Pavlikov A. M. Bezkapitelno-bezbalkova karkasno-konstruktyvna systema budivli: osoblyvosti ta dosvid vykorys-tannia pid dostupne zhytlo / A. M. Pavlikov, Ye. M. Babych, B. M. Peter // Budivelni konstruktsii : mizhvid. nauk.-tekhn. zb. nauk. pr. (budivnytstvo) / DP DND IBK. – V. 78: v 2-kh kn. Kn. 1. – K. : DP NDIBK, 2013. – pp. 28 – 46.

[2] Pavlikov A. M. Bezkapitelno-bezbalkovi konstruktyvni systemy dlia budivel dostupnoho zhytla: konstruktyvni osoblyvosti, umovnosti rozrakhunkiv, propozytsii z udoskonalennia / A. M. Pavlikov, Ye. M. Babych, S. M. Mykytenko // Resursoekonomni materialy, konstruktsii, budivli ta sporudy : zb. nauk. prats. – Rivne : NUVHP, 2014. – V. 29. – pp. 451–460.

[3] Pavlikov A. M. Konstruktyvni systemy shvydkoho zvedennia zhytlovykh budivel / A. M. Pavlikov, N.M. Pinchuk, T.Iu. Kachan // Resursoekonomni materialy, konstruktsii, budivli ta sporudy.-2016.-V. 32.-pp. 373-380.

[4] Pavlikov A. Industrial uncapital ungirder frame structure for residential buildings / A. Pavlikov, N. Pinchuk, O. Garkava // Zbirnyk naukovyx pracz. Seriya: Galuzeve mashynobuduvannya, budivnycztvo. – Poltava : PoltNTU, 2016. – V. 2(47). – pp.96-103. http://reposit.pntu.edu.ua/handle/PoltNTU/1714

[5] Shuenn-Yih Chang, Experimental Studies of Reinforced Concrete Bridge Columns under Axial Load Plus Biaxial Bending, *Journal of Structural Engineering*, Vol. 136, No 1(12), (2010), pp. 12-18, https://doi.org/10.1061/(ASCE)0733-9445(2010)136:1(12).

[6] L. Pallarés, J.L. Bonet, P.F. Miguel, M.A. Fernández Prada, Experimental research on high strength concrete slender columns subjected to compression and biaxial bending forces, *Engineering Structures*, Vol. 30, No 7, (2008), pp. 1879-1894, https://doi.org/10.1016/j.engstruct.2007.12.005.

[7] J.L. Bonet, M.L. Romero, P.F. Miguel, Effective flexural stiffness of slender reinforced concrete columns under axial forces and biaxial bending, *Engineering Structures*, Vol. 33, No. 3, (2011), pp. 881-893, https://doi.org/10.1016/j.engstruct.2010.12.009.

[8] Bishnu P. A new method of applying long-term multiaxial stresses in concrete specimens undergoing ASR, and their triaxial expansions [Text] / P. G. Bishnu, K. P. Daman // Materials and Structures. – 2016. – Vol. 49 (9). – pp. 3409-3508. – doi: 10.1617/s11527-015-0734-z.

[9] Jin-Keun Kim, Sang-Soon Lee, The behavior of reinforced concrete columns subjected to axial force and biaxial bending, *Engineering Structures*, Vol. 22, No. 11, (2000), pp. 1518-1528, https://doi.org/10.1016/S0141-0296(99)00090-5.

[10] Kochkarev, D., & Galinska, T. (2017). Calculation methodology of reinforced concrete elements based on calculated resistance of reinforced concrete. Paper presented at the MATEC Web of Conferences, , 116 https://doi.org/10.1051/matecconf/201711602020

[11] Piskunov, V. G., Gorik, A. V., & Cherednikov, V. N. (2000). Modeling of transverse shears of piecewise homogeneous composite bars using an iterative process with account of tangential loads 2. resolving equations and results. Mechanics of Composite Materials, 36(6), 445-452. https://doi.org/10.1023/A:1006798314569

[12] Piskunov, V. G., Goryk, A. V., & Cherednikov, V. N. (2000). Modeling of transverse shears of piecewise homogeneous composite bars using an iterative process with account of tangential loads. 1. construction of a model.Mechanics of Composite Materials, 36(4), 287-296. doi:10.1007/BF02262807