UDC 624.012

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INDUSTRIAL UNCAPITAL UNGIRDER FRAME STRUCTURE FOR RESIDENTIAL BUILDINGS

Design features of uncapital ungirder frame structure of building are presented: the component elements, the advantages and disadvantages, usage experience.

Problem of affordable housing in Ukraine, which is relevant now successfully solved by the implementation into construction uncapital ungirder frame structure of building. The frame consists of the smallest number of precast concrete structures sizes, which are manufactured at plants.

The component elements of the system that have been tested in the laboratory of the department of reinforced concrete and masonry structures and strength of materials Poltava National Technical Yuri Kondratyuk University are presented. The examples of buildings, which constructed on this constructive system in Poltava are provided.

Keywords: *Uncapital Ungirder Frame Structure, constructive system, affordable housing.*

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ІНДУСТРІАЛЬНА БЕЗКАПІТЕЛЬНО-БЕЗБАЛКОВА КАРКАСНА КОНСТРУКТИВНА СИСТЕМА ДЛЯ ЖИТЛОВИХ БУДІВЕЛЬ

Викладено особливості конструкції безкапітельно-безбалкового каркаса будівлі: складові елементи, переваги та недоліки, досвід застосування. Проблему зведення доступного житла на території України, що є актуальною на сьогодні, успішно розв'язано за допомогою впровадження в будівництво індустріальної безкапітельно-безбалкової конструктивної системи, каркас якої складається з найменшої кількості типорозмірів збірних залізобетонних конструкцій, котрі виготовляються на заводах. Наведено складові елементи системи, що були випробувані в лабораторії кафедри залізобетонних і кам'яних конструкцій та опору матеріалів Полтавського національного технічного університету імені Юрія Кондратюка. Наведено приклади будівель, зведених за цією конструктивною системою в м. Полтава.

Ключові слова: *безкапітельно-безбалковий каркас, конструктивна система, доступне житло.*

Introduction. Modern construction industry in Ukraine is characterized by two equally urgent problems, the first of them – providing affordable housing for the middle level of the material layers of the population, and the second - the creation of structures of high energy efficiency of buildings. After all**,** industrialists assert themselves that today the cost of housing is on average almost 8 thousand hryvnia per square meter in buildings with common indicators making apartments and not less than 10 thousand hryvnia – with improved, so-called building as an elite type [1 – 4].

There are many reasons for the existence of such urgent problems in the sphere of housing for people. The main among them – still high labor intensity of the buildings construction because of the prevailing usage of imperfect structural systems, low level of mechanization in technological processes of construction, a small number of storeys of residential buildings, as well as considerable consumption of materials.

Analysis of recent sources of research and publications. There are many researches in which in one way or another as described aspects to address these problems. Nevertheless, even a short analysis shows [5 – 11] that it is more expedient to solve them through the introduction of new construction technologies. Among which the first attention should be given direction for further improvement of the well-known even from 1940 the use of offers in the construction Uncapital Ungirder Frame Structure [5 – 7] that is also supported by modern design [8 – 11].

Highlight unsolved parts of the general problem. As the analysis shows to solve the problem, structural systems like Delta, Kazan, Arcos, SARET, Dycore, [12 – 16] can be used. However, these constructive systems have nine floors. To solve this problem it is necessary to: increase speed of buildings construction, realize the ability to construct housing regardless of the climatic conditions and completely industrialized elements of the structural system.

Formulation of the problem. The improvement of the structural system KUB-2.5 in order to increase the number of floors from nine to sixteen and ensuring full industrialization of precast concrete structures of the system.

The main material and results. The solution of the problem of providing the population affordable housing is possible by implementing the technology of residential buildings construction based on the use constructive systems, among which the most preferred is uncapital ungirder frame structure with a minimum number of prefabricated structures (Fig. 1).

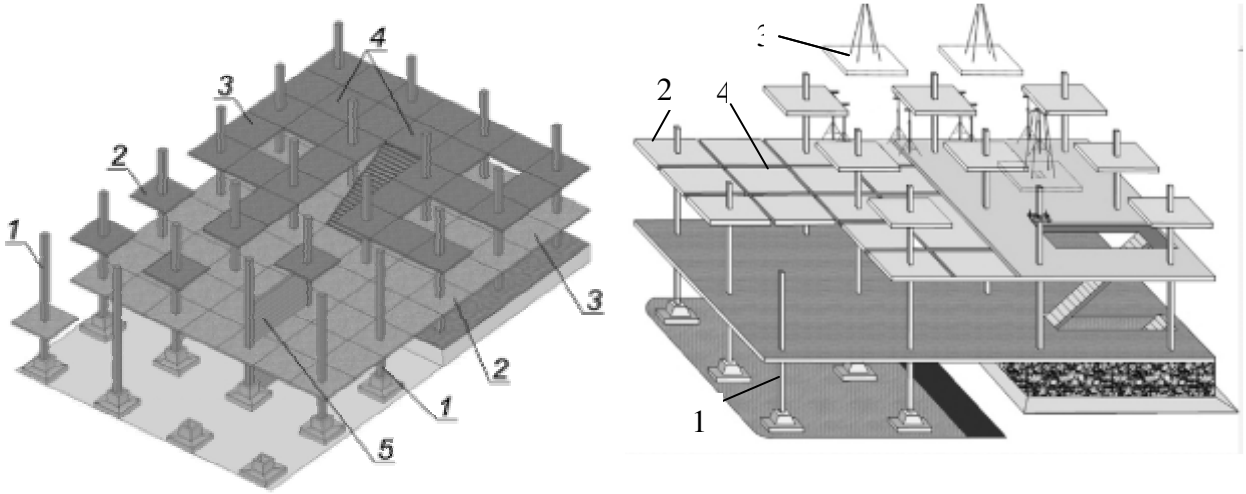

Figure 1 – Schemes of uncapital ungirder frame structure in residential building:
1 – column; 2 – overcolumned slab; 3 – intercolumned slab;
4 – middle slab; 5 – diaphragm

In its essence, this structural system is flat reinforced concrete slab directly connected to the columns by progressive decisions of their joints. In buildings with such frames beams, columns consoles and capitals are absent. It allows the fast transform a space for the new designation, provides automation of heating. And because the individual elements of space frame have a maximum of prefabrication, the use of this structural system is also one of the ways of renewal industrial production for manufacturing of precast reinforced concrete that will significantly save energy.

With the aim of testing the effectiveness of Uncapital Ungirder Frame Structure for the project of the State Design Institute of Urban Planning for the first time in Poltava were constructed buildings of affordable housing (Fig. 2, 3) and buildings for the other uses. Practice has confirmed its significant advantages in architectural planning and design solutions in comparison with buildings that are being built on the basis of other prototypes wall framing and structural systems.

Interfloor overlapping used in buildings with a framework (Fig. 1) consists of three types of precast concrete slabs: overcolumned (pos. 2), intercolumned (pos. 3) and middle (pos. 4). The thickness of the plate – 160 mm, their size in plan, in order to unify the formwork, made the same – 2980 × 2980 mm.

Figure 2 – Residential 16-storey building in Poltava Zhovtneva street, 60 d, during construction and after completion

Figure 3 – A general view of beginning the construction of 16-storey residential buildings in Poltava Bohdan Khmelnytsky street, 21 and their overall look after the completion

Overcolumned slabs (pos. 2) are fixed (Fig. 4) by welding embedded in slab casing (pos. 4) to the reinforcement of columns (pos. 1) and the assembly formed intervals of 20 mm between columns and slab casing and between the slabs are filled with a high-strength fine-grained concrete. In this case, in concreted spaces keys are formed (pos. 3), concrete of which is self-reinforced due to the work in conditions of full compression.

The vertical load-bearing elements of the frame are two-high reinforced concrete columns with cross-section dimensions 400 × 400 mm, and partially reinforced concrete stiffening diaphragms. Jointing of columns is compulsory due to entering the bar-lock of the bottom end of the upper column in slot of the top end the bottom column.

The frame developed for construction of 16 storey building in areas of seismic activity up to 9 points, fast mounted and has significant ease in the production of separate elements.

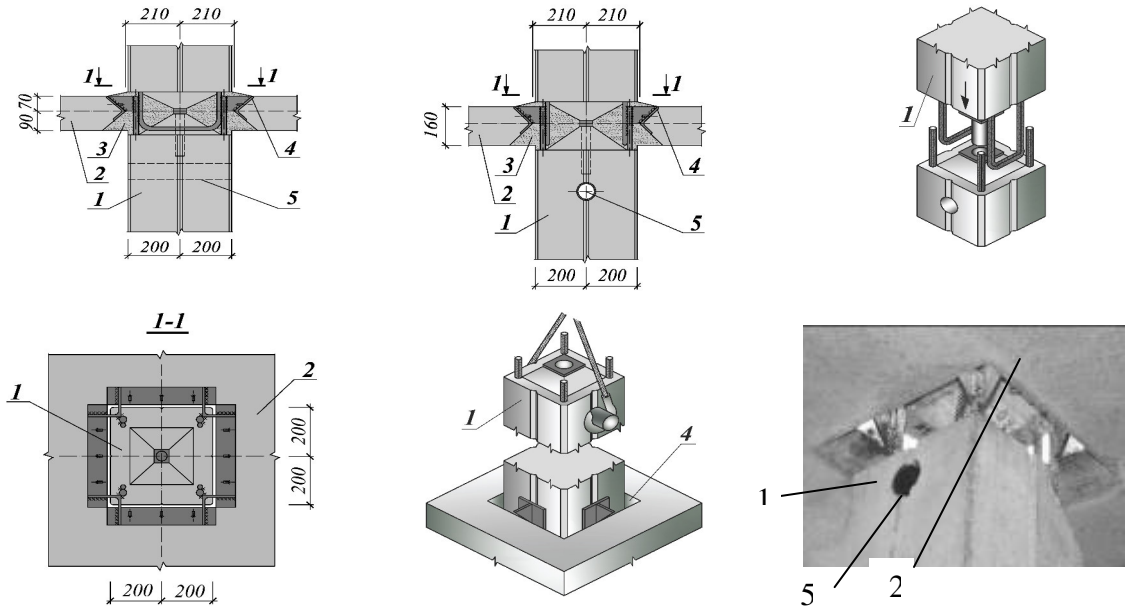

Figure 4 – Schemes of connection overcolumned slab with column
1 – column; 2 – slab (bottom view); 3 – concrete;
4 – steel slab casing; 5 – mounting hole

The linear connections (concrete or metal braces) and continuous concrete stiffening diaphragms mainly provide spatial rigidity and sustainability of the applied frame.

The internal forces in frame elements, from the external loads actions, is easy to calculate on PC using the software complex «SCAD 11.1». On the design diagram of space frame vertical elements are columns, horizontal discs are slabs of the overlapping. Reinforced concrete diaphragms and vertical struts accepted as bracing.

Experimental and theoretical investigations in Poltava National Technical Yuri Kondratyuk University have shown that efforts in the elements Uncapital Ungirder Frame Structure can be calculated by simple engineering methods. Previously, dividing the space frame on the plane orthogonal frames in the form of crossbars-slabs, which supported by columns. In this case, vertical loads are perceived by columns, conventional crossbars-slabs, and partially by stiffening diaphragms, and the horizontal – only by stiffening elements.

The designed elements had been tested in the laboratory of the department of reinforced concrete and stone structures and strength of materials PoltNTU. Moreover, for each element, namely: columns, slabs and staircases, some possible design schemes had been developed and test equipment were produced. For example, for overcolumned slab was implemented design scheme of slab not only as supported along the contour (Fig. 4.), but also as a beam – part of

the crossbar between zero points on the envelope diagram of bending moments (for a flat frame). Testing carried out on the effect of calculated load values. Loading carried out by hydraulic jacks (pos. 9) with capacity 500 kN using a pumping station (pos. 13).

In columns of constructed buildings (Fig. 2) is used bar reinforcement strength class A500 (4Ø28 – 6Ø28).

Overcolumned slab in zone of tension had two meshes. One of them contains bars in both directions 16Ø14 A500, and the other – 12Ø14 A500; compressed zone is reinforced wire mesh (strength class Bp-I) 20Ø4 in both directions.

In the intercolumned slab in zone of tension had two meshes with reinforcement of strength class A500 laid bars in both directions: on the one 16Ø14, on the other – 12Ø14; in compressed zone reinforcing mesh made of wire class Bp-I in both directions 20Ø4. In the middle slab in zone of tension reinforcing meshes (wire class Bp-I) were 12Ø8 and 7Ø8 in both directions each.

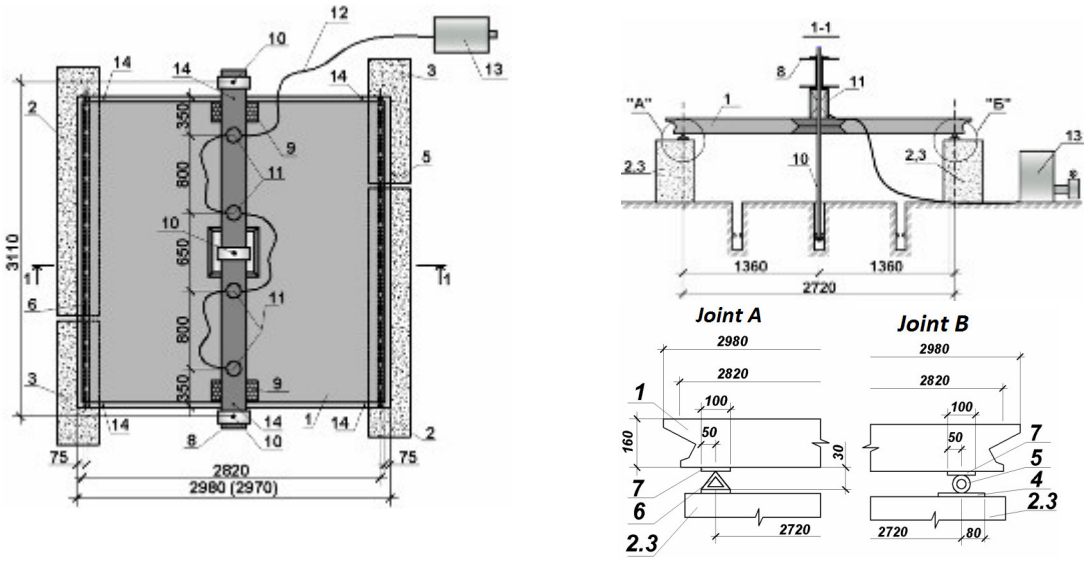

Figure 5 – Stand for testing the overcolumned slab ПН 30.30.1,6–2–1:
1 – slab ПН 30.30.1,6–2–1; 2 – block ФС 24.6; 3 – block ФС 12.6; 4 – metal lining;
5 – movable support (pipe ø 10,5x4); 6 – fixed support (L50x5; 100x8);
7 – metal lining; 8 – traverse, channel bar № 30; 9 – temporary supports;
10 – strands of reinforcement ø 30 A-I; 11 – hydraulic jacks F=500 kN;
12 – pressure pipelines; 13 – pump station; 14 – indicators: 6ПАО – ЛИСИ

Breaking of overcolumned slabs happened at total load 3.02 kPa, middle slabs – at 2.4 kPa, the intercolumned slabs – at 1.8 kPa.

As shown by researches and implementation on construction [9 – 11, 17 – 20] the frame application Uncapital Ungirder Frame Structure allows to realize in practice their main advantages:

1) extension part of overlapping along its perimeter gives each building unique architectural forms, which promoting the establishment of compelling variety of the urban landscape;

2) buildings characterized by autonomous in the architectural and planning decisions;

3) period of residential buildings construction is significantly reduced;

4) the launch of line for production of prefabricated elements is quite simple and is carried out in the shortest time.

Uncapital Ungirder Frame Structure has positively proved itself in the construction of buildings in more than 30 regions of Russia [9 – 11]. The volume of its development are annually increasing.

According to many projects and information sources [8 – 11] Table 1 shows the main indicators Uncapital Ungirder Frame Structure in comparison with the most famous.

Table 1 – The comparison of main indicators of Uncapital Ungirder Frame Structure

Indicator	Constructive systems		
	Monolith	КПБ-135	КУБ
Total mass of steel per m^2 of overlapping	27 kg/m^2	48 kg/m^2	18 kg/m^2
Total volume of concrete per m^2 of overlapping	0,28 m^3/m^2	0,8 m^3/m^2	0,2 m^3/m^2
The thickness of overlapping	200 mm	160 mm	160 mm
Distance between columns	6,3×6,3 m	6×3 m	6×6 m
Architecture and planning solution	free	fixed	free
Labor costs for the installation of 1 m^2 overlapping (supplying concrete by concrete pump)	21 people/ hour·m^2	1,1 people/ hour·m^2	0,7 people/ hour·m^{22}
Installation period of 12 floors	6 months	3 months	3 months

Conclusions. Implementation of Uncapital Ungirder Frame Structure in construction of multi-storey buildings reduces the cost of 1m^2 of almost 40% in comparison with traditional wall buildings and frame design systems. Meanwhile the rate of buildings construction increased by 50%, the intensity of the provision of housing increases and its ability in terms of affordability, is greatly enhanced.

In addition, the implementation of developments, aimed at the mass manufacturing application of Uncapital Ungirder Frame Structure in construction of buildings will help to revive work of precast concrete plants.

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Received 25.04.2016