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ТЕХНИКАЛЫҚ ҒЫЛЫМДАР ЖӘНЕ ТЕХНОЛОГИЯЛАР СЕРИЯСЫ / TECHNICAL SCIENCES AND TECHNOLOGY SERIES/ СЕРИЯ ТЕХНИЧЕСКИЕ НАУКИ И ТЕХНОЛОГИИ

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Experimental evaluation of the strength of the floor slab of a volume block

U.Altigenov[1], A.Bespaev[2], A.Tulebekova*[1], Ye.Zharkenov[1]

[1]*L.N. Gumilyov Eurasian National University, Astana, Kazakhstan*
[2]*Kazakh research and design institute of construction and architecture investment (JSC "KazNIISA"), Almaty, Kazakhstan*

(E-mail: krasavka5@mail.ru)

Abstract. Modular construction is a new method that uses standardized blocks to construct buildings quickly and efficiently. This approach can significantly reduce construction time and costs, as well as improve the accuracy and quality of work. One of the key aspects of modular construction is careful design and material selection to ensure that structures are durable and safe. The study presents an experimental evaluation of the strength of the floor slab of a volumetric block. The research methodology includes the creation of laboratory conditions to recreate real operational situations, as well as the application of modern methods of measurement and data analysis. The results obtained allow conclusions to be drawn on the strength characteristics of the floor slab, which showed that the experimental failure load exceeded the control failure load by 11%. The vertical deflections of the slab before failure did not exceed 8 mm, which characterizes the floor slab as having high stiffness. The information obtained is an important basis for designing and constructing buildings where volume block is used. The work significantly contributes to the efficiency of construction processes and provides more reliable structural performance, which is critically important in the field of construction industry and engineering solutions.

Keywords: volume blocks, floor slab, crack resistance, stiffness, strength, load.

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[1]*the corresponding authour

Introduction

The current stage of development of large cities of the Republic of Kazakhstan is characterized by a change in the structure towards an increase in the share of multi-story buildings [1]. This is due to the urbanization of cities, the increase in the cost of land, and limited territories. At the same time, the main part of buildings is constructed with a height of 9 -16 floors, and some buildings are built with a height of 25 floors or more [2-3]. The trend of development of the construction industry allows us to assert that in the coming years, the height of individual representative buildings will approach 100 floors [3-4].

The experience of constructing buildings with higher stories in the developed countries of the world shows that they usually use a wall or frame-bonded structural system [5]. The increase in the number of stories of buildings causes an increase in the forces in load-bearing structures, which necessitates the use of high-strength materials. Currently, in Switzerland, France, USA, Sweden, Romania, FRG, and Czechoslovakia, the construction of buildings from volumetric blocks with the use of wood and metal is carried out [6]. In recent years, the volume-block (modular) construction of multi-story buildings has been revived in several European countries. The volume-block technology is based on manufacturing large parts of buildings in factory conditions with partial or full finishing [7-8]. It provides short construction terms, high-quality construction and installation works in factory conditions, and low cost of construction. Volumetric blocks are produced in three main types. The first type is "cap," which consists of four walls and a ceiling plate combined with a floor or molded floor plate.

The second type is "glass," which includes four walls and a floor plate. The third type is "lying glass," which comprises three walls, a floor, a ceiling plate, and an inserted facade panel. An important direction of ways to improve the efficiency of volume-block construction of multi-story buildings with increased floor area is the manufacture of volume blocks of expanded concrete, which reduces the calculated vertical loads, and reduces the need for cranes and vehicles with increased capacity.

In sustainability, literature acknowledges the potential benefits of volumetric blocks in reducing material waste, energy consumption, and construction time [9]. The modular nature of volumetric blocks allows for enhanced precision in fabrication, minimizing environmental impact and contributing to the growing interest in eco-friendly construction practices. Researchers explore how the incorporation of sustainable materials and construction methods within volumetric blocks can lead to environmentally conscious and resource-efficient building solutions.

Furthermore, the literature highlights the importance of computational modeling and simulation techniques in evaluating the performance of volumetric blocks. Advanced tools enable researchers to analyze structural behavior, predict load responses, and optimize designs before actual construction, thereby enhancing the reliability and safety of new structural solutions. This intersection of technology and structural engineering is a notable trend in current literature, indicative of a broader shift towards data-driven and digitally informed design processes.

Today, the development of new structural solutions for buildings requiring the study of the performance of volumetric blocks remains open. The study presents the evaluation of strength, stiffness, and crack resistance of reinforced concrete floor slabs under the action of uniformly distributed vertical loads.

The methodology

The floor slab integrates the walls of the volume block into a single system and supports the variable (service) vertical load in the volume block room. These tests are designed to verify the floor slabs' strength, stiffness, and crack resistance under a uniformly distributed vertical load [10-11]. For this purpose, the volume block was placed on a rectangular pedestal with a height of about 1.8 m, constructed from foundation block tapes (Figures 1 and 2).

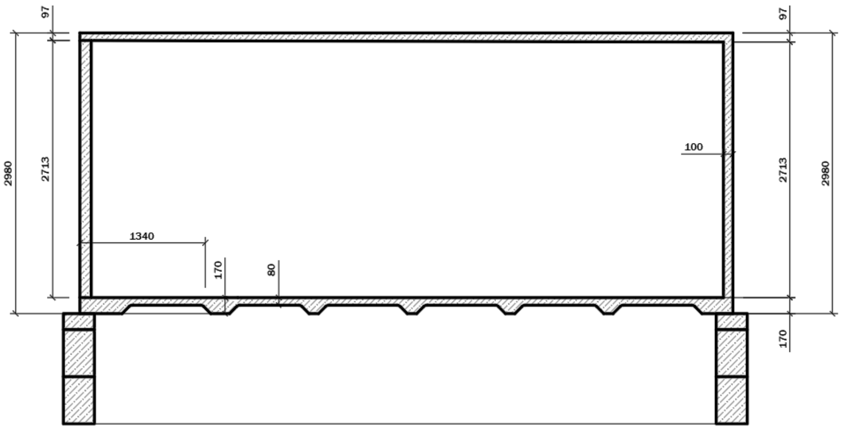

Figure 1. Scheme of the volume block on the pedestal

The volume block with dimensions 6980x3480x2980 mm is made of expanded clay concrete of strength class LC 20/22 (B20) density class ρ = 800 kg/m3. Inside the volume block, there is a reinforced concrete partition 70 mm thick of heavy concrete and two brick partitions 120 mm thick each. The floor slab is a coffered slab with an 80 mm thick shelf and 170 mm high ribs. The floor slab is reinforced with a mesh of reinforcing wire Ø4 S200C (Vr200) with 200x200 mm cells.

Figure 2. General view of the volumetric block on the pedestal

The longitudinal ribs of the floor slab with a width of 260 mm, 277 mm, and 330 mm are reinforced by vertical frames with longitudinal reinforcement of periodic profile 2Ø8 S500 (A-500C) and transverse bars Ø4 S400C (Vr40).

Transverse ribs with widths of 100 mm and 200 mm were reinforced with longitudinal reinforcement 3Ø8 S500 (A-500C) and transverse V-shaped bars Ø4 S200C (Vr200) with a spacing of 200 mm. The floor slab was loaded with small piece weights (bricks), the columns of which with dimensions of 500x500 mm were placed on a layer of sand in such a way as to exclude their mutual touching and formation of vaults (Figures 3, 4).

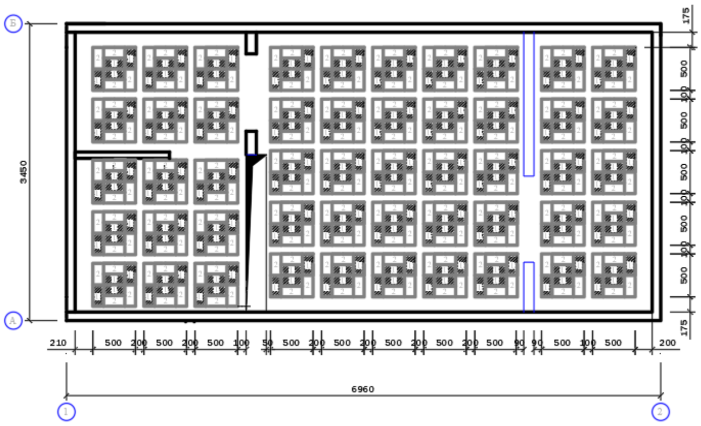

Figure 3. Scheme of brick columns on the floor slab

Figure 4. View of loading the floor slab with bricks

The floor slab was loaded in steps with a step size of not more than 5-10 % of the design vertical load. At variable (normative) vertical load, a soaking period of 1-2 hours (variable vertical load of 2 kN/m2) was performed. Thereafter, the increase in vertical load was continued until slab failure or undamped increase in deflections and excessive crack opening. In the process of loading, we measured vertical displacements with the help of deflection meters PAO-6 with the division value of 0.01 mm in the middle part of the span and on the supports and also recorded the picture of crack development with the measurement of crack opening width with the help of microscope MPB-3 with the division value of 0.02 mm (Figure 5). Figure 6 shows a fragment of a concrete pedestal with deflection gauges and safety supports made of bricks [12].

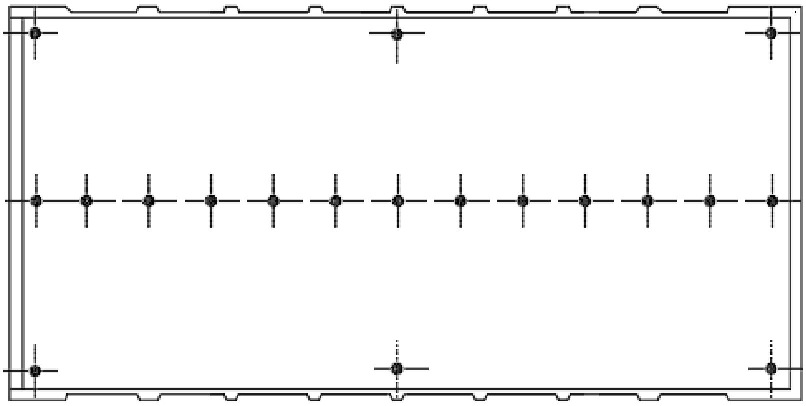

Figure 5. Layout of vertical deflection gauges

Figure 6. Fragment of a concrete pedestal

Findings/Discussion

Figure 7 shows a picture of the change in deflections of the middle part of the floor slab in the process of increasing the vertical load from 100 kgf/m2 to 900 kgf/m2, which has the form of a convex curve and illustrates the accelerated increase in deflections with increasing vertical load. The largest deflection of the slab at variable load qk = 200 kgf/m2 was 0.6 mm, which is significantly less than the allowable deflection (at f/l=1/200 the allowable deflection is 15.6 mm).

Figure 8 shows the deflection diagram of the middle part of the floor slab, which confirms the accelerated increase in deflections with increasing vertical load, which indicates the flattening of the vertical displacement curve.

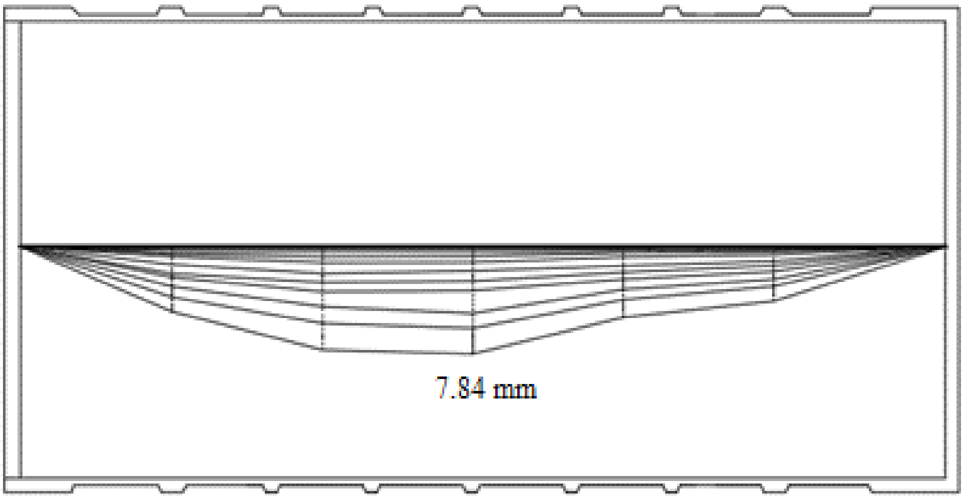

Figure 7. Vertical deflections of the middle part of the floor slab

At vertical load qk = 927 kgf/m2 further loading of the floor slab was stopped and the slab rested on the safety support. Cracks in the floor slab appeared during the construction of brick partitions in the volume block and their opening width was 0.05-0.25 mm (Figure 9). At a vertical load value of 160 kg/m2, their opening width increased to 0.10-0.35 mm. Thus, the floor slab of the volume block has sufficient crack resistance. At the last stage of loading, normal cracks appeared in the middle ribs of the floor slab with an opening width of 0.10-0.20 mm and the floor slab fell on the safety support.

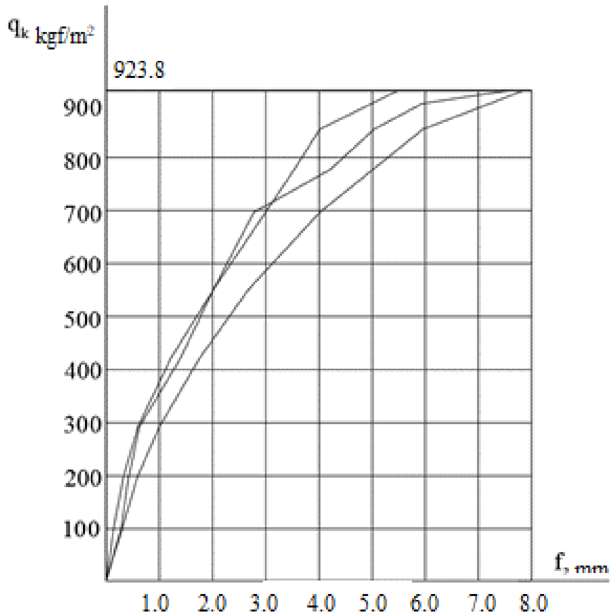

Figure 8. Diagrams of vertical displacements of the middle part of the floor slab

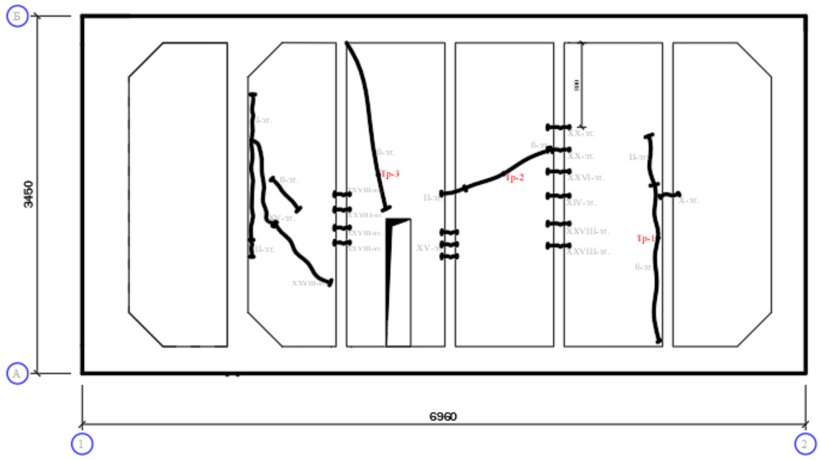

Figure 9. Crack location diagram along the bottom edge of the floor slab

In general, the results of the conducted tests of the volume block floor slab confirmed its sufficient strength, stiffness, and crack resistance.

Figures 10 show characteristic cracks in the slab and cross-ribs of the floor slab.

Figure 10. Cracks in floor slab and floor slab ribs

Conclusion

Rigorous control tests to assess the actual performance of volumetric blocks in real-world conditions is one of the main aspects of use. This empirical approach provides valuable data on factors such as load distribution, material behavior, and structural integrity, further informing the refinement of design principles and construction methodologies. The performed control tests of elements and assemblies of volumetric blocks allow us to draw the following conclusions:

1. Floor slabs of the volume block perceive variable vertical load and unite the walls of the volume block in a single system.

2. The floor slab under the action of vertical loads is damaged as a rectangular caisson reinforced concrete slab, pinched along the contour. The cracks in the floor slab are concentrated in the middle part, but the width of their opening as well as the deflections under alternating load are significantly smaller than the permissible values.

3. The failure of the expanded clay concrete floor slab is caused by cracking and damage to the transverse reinforced concrete ribs. The experimental failure load exceeded the control failure load by 11%. Vertical deflections of the slab before failure did not exceed 8 mm, which characterizes the floor slab as having high stiffness.

The contribution of the authors:

Altigenov U. – concept, analysis, writing.
Bespaev A. – methodology, resources, testing.
Tulebekova A. – visualization, data collection.
Zharkenov Ye. – interpretation, editing

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13. АО КазНИИСА, Технический отчет по контрольным испытаниям элементов и узлов объемных в г. Нур-Султан, Алматы, 2020 г.

У.Алтигенов[1], А.Беспаев[2], А. Тулебекова[1]*, Е.Жаркенов[1]

[1]Л.Н. Гумилев атындағы Еуразия ұлттық университеті, Астана, Қазақстан

2Қазақ құрылыс және сәулет ғылыми-зерттеу және жобалау институты» «ҚазҚСҒЗИ» АҚ, Алматы, Қазақстан

Көлемді блоктың еден плитасының беріктігін эксперименттік бағалау

Аңдатпа. Модульдік құрылыс – бұл ғимараттарды тез және тиімді тұрғызу үшін стандартталған блоктарды қолданатын жаңа әдіс. Бұл тәсіл құрылыстың уақыты мен құнын едәуір қысқартуға, сондай-ақ жұмыстың дәлдігі мен сапасын арттыруға мүмкіндік береді. Модульдік құрылыстың негізгі аспектілерінің бірі-құрылымдардың беріктігі мен қауіпсіздігін қамтамасыз ету үшін материалдарды мұқият жобалау және таңдау. Жұмыста көлемді блоктың еден плитасының беріктігін эксперименттік бағалау ұсынылған. Зерттеу әдістемесі нақты пайдалану жағдайларын қалпына келтіретін зертханалық жағдайларды жасауды, сондай-ақ деректерді өлшеу мен талдаудың заманауи әдістерін қолдануды қамтиды. Нәтижелер еден плитасының беріктік сипаттамалары туралы қорытынды жасауға мүмкіндік береді, бұл эксперименттік деструктивті жүктеме бақылау жүктемесінен 11% - ға асып түскенін көрсетті. Плитаның бұзылу алдындағы тік ауытқулары 8 мм-ден аспады, бұл еден плитасын жоғары қаттылық ретінде сипаттайды. Алынған ақпарат көлемді блокты пайдаланатын ғимараттарды жобалау және салу үшін маңызды негіз болып табылады. Жұмыс құрылыс процестерінің тиімділігін арттыруға елеулі үлес қосады және құрылыс индустриясы мен инженерлік шешімдер саласында өте маңызды болып табылатын конструкциялардың неғұрлым сенімді пайдалану сипаттамаларын қамтамасыз етеді.

Түйін сөздер: көлемді блоктар, еден плитасы, жарыққа төзімділік, қаттылық, беріктік, жүктеме

У.Алтигенов[1], А.Беспаев[2], А. Тулебекова[1]*, Е.Жаркенов[1]

[1]Евразийский национальный университет им. Л.Н. Гумилева, Астана, Казахстан

[1]Казахский научно-исследовательский и проектный институт строительства и архитектуры АО «КазНИИСА, Алматы, Казахстан

Экспериментальная оценка прочности плиты пола объемного блока

Аннотация. Модульное строительство – это новый метод, при котором для быстрого и эффективного возведения зданий используются стандартизированные блоки. Такой подход позволяет значительно сократить сроки и стоимость строительства, а также повысить точность и качество работ. Одним из ключевых аспектов модульного строительства является тщательное проектирование и выбор материалов для обеспечения долговечности и безопасности конструкций. В работе представлена экспериментальная оценка прочности плиты перекрытия объемного блока. Методика исследования включает создание лабораторных условий, воссоздающих реальные эксплуатационные ситуации, а также применение современных методов измерений и анализа данных. Полученные результаты позволяют сделать выводы о прочностных характеристиках плиты перекрытия, которые показали, что экспериментальная разрушающая нагрузка превысила контрольную на 11 %. Вертикальные прогибы плиты перед разрушением не превышали 8 мм, что характеризует плиту перекрытия как обладающую высокой жесткостью. Полученная информация является важной основой для проектирования и строительства зданий, в которых используется объемный блок. Работа способствует повышению эффективности строительных процессов и обеспечивает более надежные конструктивные характеристики, что важно в области строительной индустрии и инженерных решений.

Ключевые слова: объемные блоки, плита перекрытия, трещиностойкость, жесткость, прочность, нагрузка.

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Information about authors:

Altigenov Ulan **–** PhD student of Civil Engineering department, L.N. Gumilyov Eurasian National University, Astana, Kazakhstan, ulanbek_666@mail.ru
Bespaev Aliy **–** Dr.Tech.Sc., Professor, Kazakh Research and Design Institute of Construction and Architecture Investment (JSC "KazNIISA"), Almaty, Kazakhstan, aliy40@mail.ru
Tulebekova Assel **–** PhD, Professor of Civil Engineering, L.N. Gumilyov Eurasian National University, Astana, Kazakhstan, krasavka5@mail.ru,
Zharkenov Yerkebulan – PhD, Associate Professor of Civil Engineering, L.N. Gumilyov Eurasian National University, Astana, Kazakhstan, berdenovich@gmail.com
Алтигенов Улан **–** «Құрылыс» кафедрасының Ph.D студенті, Л.Н. Гумилев атындағы Еуразия ұлттық университеті, Астана, Қазақстан, ulanbek_666@mail.ru
Беспаев Али **–** т.ғ.д., профессор, Қазақ құрылыс және сәулет ғылыми-зерттеу және жобалау институты» «ҚазҚСҒЗИ» АҚ, Алматы, Қазақстан,aliy40@mail.ru
Тулебекова Әсел Серікқызы **–** «Құрылыс» кафедрасының профессорі, Ph.D., Л.Н. Гумилев атындағы Еуразия ұлттық университеті, Астана, Қазақстан, krasavka5@mail.ru
Жаркенов Еркебулан Берденович **–** «Құрылыс» кафедрасының доценті, Ph.D., Л.Н. Гумилев атындағы Еуразия ұлттық университеті, Астана, Қазақстан, berdenovich@gmail.com

Алтигенов Улан **–** докторант кафедры «Строительство», Евразийский национальный университет им. Л.Н. Гумилева, Астана, Казахстан, ulanbek_666@mail.ru
Беспаев Али **–** доктор технических наук, профессор, Казахский научно-исследовательский и проектный институт строительства и архитектуры, Алматы, Казахстан, aliy40@mail.ru
Тулебекова Асель Сериковна **–** PhD, профессор кафедры «Строительство», Евразийский национальный университет им. Л.Н. Гумилева, Астана, Казахстан, krasavka5@mail.ru,
Жаркенов Еркебулан **–** PhD, доцент кафедры «Строительство», Евразийский национальный университет им. Л.Н. Гумилева, Астана, Казахстан, berdenovich@gmail.com