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Definition of organizational and technological parameters for residential buildings of large–sized volumetric blocks

The article summarizes the progressive experience of volumetric block buildings construc-tion, starting from the first series and its further development in the factories construction to man-ufacture volumetric blocks. The turn of development of three-dimensional block buildings idea towards a new technical basis providing for the maximum transfer of the volume of construction and installation work from a construction site to industrial enterprises sphere is revealed. At the same time, the parallel development of modular construction is shown. Long-term development, as well as accumulated domestic and foreign experience, has led to a new direction in residential construction. Residential buildings construction of large-sized volumetric blocks is the most im-portant promising direction. A considerable experiment in this area is being conducted by the MonArch Group of companies (Moscow), which currently manufactures such blocks and carries out the construction of residential buildings of the fifth industrial generation. In this experiment, the issues of designing blocks, materials consumption for their manufacture, the selection of mounting and transport means, organization and technology of mounting blocks and their installa-tion in the design position are worked out. This article describes an approach to defining the organizational and technological parameters of residential buildings made of large blocks. Its main stages, their content and the results obtained are disclosed. At the same time, the difficulties asso-ciated with the lack of an appropriate regulatory framework, the necessary installation and transport means, as well as technological equipment are pointed out. The article argues for the need to expand scientific research and design and experimental developments aimed at reasoning and creating effective organizational, technological and managerial solutions in this urgent direc-tion of country's residential fund development.

Keywords: *large-sized blocks (modules), blocks type, types of space-planning solutions, installation cranes, installation processes*

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INTRODUCTION

Continuous enhancement of high-quality comfortable housing construction and well-balanced development of all types of social services, provided to local residents, community infrastructure and environmental improvements are the most important urban planning tasks. For this purpose, mass construction of high- and medium-rise residential building is underway in large cities and towns, while low-rise houses are built in suburbs and rural areas.

Ever-growing residential construction is inextricably linked with expanding and more efficient research stud-ies and their faster application to production.

SUMMARIZED ADVANCED EXPERIENCE

Residential buildings of the fifth industrial generation are built nowadays. This generation, or stage, is characterized by universal and flexible space-planning and structural solutions, developed for prefabricated, cast-in-situ and industrialized construction systems, and a rise in modular residential construction [1–4].

Standard prefab residential buildings were initially designed in 1931, and in 1969 several enterprises launched production of volumetric blocks. Unfortunately, due to the limited access to erection equipment and means of transport, as well as the underdeveloped transport infrastructure, this niche of residential construction could not develop fast enough. However, this idea was adopted by other industries. Back then, major tasks of the national economy were solved to ensure its breakthrough development on the back of consolidated local production facilities, fuel and energy complexes. The fuel and energy sector, located in Western Siberia, was one of the most important drivers of the national economy, and its intensive development triggered the emergence of prefab construction method applied to oil and gas facilities.

It is noteworthy that the vast territory of the Tyumen Region is characterized by extremely harsh climate and complex geological conditions. In addition, its major portion was sparsely populated and difficult to access. Against this background, traditional construction methods were useless. As a result, the workflow was rearranged to relocate the maximum amount of construction and assembly work from construction sites to industrial enterprises to ensure the continuous assembly of standard blocks, joints and structures [5–10].

Meanwhile, the innovative technology of modular construction was successfully applied to the production of mobile service buildings and structures for employees of construction companies. For example, by 1975, domestic enterprises had manufactured more than 400 thousand sets of mobile buildings, and by 1985 their total floor area had exceeded 30 million square meters, or more than six square meters per employee. Presently, these mobile buildings are manufactured by LLC RPK Module, Bytprom, Kraus, KMD, etc. [3, 6, 7].

Modular housing construction was developing thanks to the experience, accumulated by domestic and for-eign enterprises. For example, reinforced concrete blocks weighing up to 20 tons, having the length of 6–8 m and the width of 2.4–3.6 m, were manufactured by the concrete plant in Krasnodar and Vybor LLC in Voronezh. Their use boosted the workability of construction products, substantially increased the degree of prefabrication, reduced the construction time and onsite labour intensity [8–14].

MonArch Group, Moscow, has improved its modular construction skills and conducted an experiment to confirm the efficiency of large-sized volumetric blocks as a replacement for small-sized ones [3, 10, 15, 16]. Maximum dimensions of volumetric blocks reached 15.5 × 7.5 × 3.75 m, and their maximum weight reached 65 tons. The degree of prefabrication went up to 98 %. As a result, residential buildings could be swiftly assembled on construction sites at minimal costs (Fig.).

MATERIALS AND METHODS

Several studies, each having five interrelated stages, were conducted to simulate processes of construction of residential buildings from large-sized blocks.

Stage 1. At this stage, characteristics of large-sized blocks (modules), that are most likely to be used in modular residential construction projects, are determined and analyzed. When volumetric blocks are designed, the increment step is assumed as 0.3 in terms of length, and 0.1 in terms of width. Each block has a number indicating its weight (Table 1). The height of each block is 3.5 m. In general, there are 1,008 types of volumetric blocks . The maximum block weight is 65 tons, and its volume is 341.3 m^3.

Stage 2. Designs of standard building sections, developed by Parametrica and AMC Project architectural workshops, St. Petersburg, were used as the basis for architectural planning solutions for residential buildings. As a result, over 100 space-planning solutions were developed for residential buildings assembled from large-sized volumetric blocks, given that one large-sized volumetric block was an apartment with an average total floor area of 100 m^2 (for blocks No. 1). Five most characteristic options, whose sections had the shapes of a square, a rectangle, Г and П – letters, were selected for further research. Table 2 shows three types of solutions and their technical charac-teristics.

Stage 3. A large-sized block installation method was developed at this stage. Basic operations, including block preparation for unloading, block unloading and installation, were predesigned. For example, the block installation process includes such operations as the capture of blocks using specialized machinery, the lifting (relocation) and installation of blocks, as well as their fixing in the appropriate position. In turn, process arrangements, machinery used, all installation operations, as well

Installation of a large-sized volumetric block (a module)

Table 1. Sets of large-sized blocks, their ordinal number and weight, tons (extract)

Width, m	Length, m						
	15.0	**14.7**	**14.4**	**14.1**	**13.8**	**13.5**	**13.2**
6.5	1–65 t	2–63.7 t	3–62.4 t	4–61.1 t	5–59.8 t	6–58.5 t	7–57.2 t
6.4	29–64 t	30–62.7 t	31–61.4 t	32–60.2 t	33–58.9 t	34–57.6 t	35–56.3 t
6.3	57–63 t	58–61.7 t	59–60.5 t	60–59.2 t	61–58 t	62–56.7 t	63–55.4 t
6.2	85–62 t	86–60.8 t	87–59.5 t	88–58.3 t	89–57 t	90–55.8 t	91–54.6 t
6.1	113–61 t	114–59.8 t	115–58.6 t	116–57.3 t	117–56.1 t	118–54.9 t	119–53.7 t
6.0	141–60 t	142–58.8 t	143–57.6 t	144–56.4 t	145–55.2 t	146–54 t	147–52.8 t
5.9	169–59 t	170–57.8 t	171–56.6 t	172–55.5 t	173–54.3 t	174–53.1 t	175–51.9 t
5.8	197–58 t	198–56.8 t	199–55.7 t	200–54.5 t	201–53.4 t	202–52.2 t	203–51 t
5.7	225–57 t	226–55.9 t	227–54.7 t	228–53.6 t	229–52.4 t	230–51.3 t	231–50.2 t
5.6	253–56 t	254–54.9 t	255–53.8 t	256–52.6 t	257–51.5 t	258–50.4 t	259–49.3 t
5.5	281–55 t	282–53.9 t	283–52.8 t	284–51.7 t	285–50.6 t	286–49.5 t	287–48.4 t
5.4	309–54 t	310–52.9 t	311–51.8 t	312–50.8 t	313–49.7 t	314–48.6 t	315–47.5 t
5.3	337–53 t	338–51.9 t	339–50.9 t	340–49.8 t	341–48.8 t	342–47.7 t	343–46.6 t
5.2	365–52 t	366–51 t	367–49.9 t	368–48.9 t	369–47.8 t	370–46.8 t	371–45.8 t
5.1	393–51 t	394–50 t	395–49 t	396–47.9 t	397–46.9 t	398–45.9 t	399–44.9 t
5.0	421–50 t	422–49 t	423–48 t	424–47 t	425–46 t	426–45 t	427–44 t
4.9	449–49 t	450–48 t	451–47 t	452–46.1 t	453–45.1 t	454–44.1 t	455–43.1 t
4.8	477–48 t	478–47 t	479–46.1 t	480–45.1 t	481–44.2 t	482–43.2 t	483–42.2 t
4.7	505–47 t	506–46.1 t	507–45.1 t	508–44.2 t	509–43.2 t	510–42.3 t	511–41.4 t
4.6	533–46 t	534–45.1 t	535–44.2 t	536–43.2 t	537–42.3 t	538–41.4 t	539–40.5 t

as the management quality determine large-sized block installation methods.

Stage 4. At this stage, selection and arrangement of construction machinery are a complex procedure that ensures rational and safe construction of residential buildings. Towards this end, engineering parameters are identi-fied, using characteristics of particular types of buildings, to formulate the requirements applicable to the main instal-lation machine. The unique nature of the process of making buildings from large-sized blocks limits the choice of installation machines. The following construction machines may be applied:

- a crane on a special chassis with a lifting capacity of 650 tons with the use of removable cargo-grabbing devices – an automatic traverse (patent RU 2749677 C1);
- a tracked crane in a tower-boom design for the use of an automatic traverse with a lifting capacity of 800 tons (patent RU 2749677 C1);

Table 2. Characteristics of space-planning solutions for residential buildings made of large-sized volumetric blocks

Space-planning solutions	Basic parameters		Number of large-sized blocks		
	total area, thousand m^2	number of floors	ground floor	standard floor	engineering floor
Type 1. Single-section square	7.5	16	8	120	8
Type 2. Single-section rectangle	5.3	9	9	72	9
Type 3. Three-section П-shaped solution	10.9	5	38	152	38

• portal system using an automatic traverse (patent RU 2749677 C1).

The time study has identified the following process characteristics:

- block preparation for unloading: 0.157 persons · hour/m^2;
- block unloading: 0.222 persons · hour/m^2;
- block installation: 0.211 persons · hour/m^2.

As a result, due to the uniqueness and high cost of cranes, another parameter, or the average daily number of blocks installed, must be determined in addition to the engineering parameters, such as the lifting capacity, the crane arm length, and the hook lifting height. The studies have proven that the distribution of this parameter over time is in line with the hyperbolic law.

Hence, one can accurately calculate the crane time on the construction site:

$$T = t_a + r_1 + r_2 + r_3 + r_4,$$

where T is the crane time on the construction site, days;
t_a is the installation of the superstructure of a residential building, days;
r_1 is the installation and dismantling of the crane, days;
r_2 is the maintenance and repair of the crane, days;
r_3 is the time lost due to bad weather, days;
r_4 is weekends and holidays, days.

RESULT

Stage 5. At this stage final documents are developed, including work schedules, a construction master plan, a crane operation schedule, an integrated machinery operation schedule, etc.

The construction schedule consolidates the above processes, the sequence and time of their implementation, while the construction master plan encompasses the arrangement of construction machines, including the location of parking lots and the unloading area for large-sized blocks.

CONCLUSION

The construction of residential buildings from large-sized volumetric blocks has the strongest potential in terms of development of industrial housing construction.

The storied domestic history of prefab construction can serve as the basis for standardization and unifica-tion of blocks, further conversion of material resources into blocks, choosing special assembly and transport ma-chines to make sure that the construction process remains continuous.

Growing numbers of residential buildings, made from large-sized volumetric blocks, substantiate the need to expand scientific research, design and experimental developments to devise effective organizational, engineering and management solutions.

REFERENCES

1. Gurov E.P. Prefabricated building construction. Development strategy. Stroyprofile. 2010. URL: http://stroyprofile.com/archive/4111 (rus.).
2. Kazachun G.U. Types of residential buildings. Rostov-on-Don, Phoenix Publ., 2011; 398. (rus.).
3. Oleynik P.P., Pakhomova L.A. Experience in construction of residential buildings from volumetric modules and prospects for the organization of large-modular construction. Actual problems of the construction industry and education : Collection of Reports of the First National Conference. Moscow, September 30, 2020. Moscow, 2020; 349-352. (rus.).
4. Gao Yu., Tian H.-L. Policy in the field of factory manufacturing and efficiency of the construction industry in China. Journal of Clean Production. 2020; 253:120042. DOI: 10.1016/j.jclepro.2020.120042
5. Andrienko V.G., Batalin Y.P., Shmal G.I. Industrialization of the construction of oil and gas industry facilities. Y.P. Batalin (Ed.). Moscow, Nedra Publ., 1985; 342. (rus.).
6. Oleynik P.P. Industrial-mobile methods of construction of enterprises, buildings and structures : monograph. Moscow, Publishing House DIA, 2021; 488. (rus.).
7. Oleinik P.P., Shirshikov B.F. Complete-block method of construction of objects : Textbook. Moscow, MGSU, 2008; 85. (rus.).
8. Zavrazhnov S.I., Rachkov D.S., Novikov M.A., Yudin S.V. Production technologies in construction: modular systems. Vestnik MGSU [Proceedings of Moscow State University of Civil Engineering]. 2010; 3:185-190. URL: https://www.elibrary.ru/item.asp?id=15273405 (rus.).
9. Shepeleva E.A., Shepelev A.L. Organization of construction of production facilities by the complete-block method. Arkhangelsk, CPI SAFU, 2013; 139. (rus.).
10. Arashpour M., Kamat V., Bai Yu., Vakefield R., Abbasi B. Optimization modeling of resources with multiple pans during assembly: a theoretical analysis of the costs of integrating processes in off-site construction. Automation in Construction. 2018; 95:1-9. DOI: 10.1016/j.autcon.2018.07.027
11. Sychev S.A., Shevtsov D.V. Robotic installation of prefabricated high–rise buildings from modular transformable building systems of increased factory readiness. Bulletin of Civil Engineers. 2017; 2(61):140-147. (rus.).
12. Sychev S.A. Methodology of variant design of technologies for the construction of buildings and structures from factory-ready modules. Bulletin of Civil Engineers. 2015; 5(52):119-125. (rus.).
13. Pittau F., Malighetti L.E., Lannaccone G., Masera G. Prefabricated production as a large-scale effective strategy for energy modernization of housing stock: on the example of Italy. Procedia Engineering. 2017; 180:1160-1169. DOI: 10.1016/j.proeng.2017.04.276
14. Gao Yu., Tian H.-L. Policy in the field of factory manufacturing and efficiency of the construction industry in China. Journal of Clean Production. 2020; 253:120042. DOI: 10.1016/ j.jclepro.2020.120042
15. Gokh M., Gokh Ya.M. Modeling of modular construction processes based on the theory of lean production. Automation in Construction. 2019; 101:227-244. DOI: 10.1016/s0926-5805(02)00086-9
16. Oleynik P., Pakhomova L. A new stage in the development of housing construction. E3S Web conference. 2021; 09060. DOI: 10.1051/e3sconf/202125809060

Определение организационно-технологических параметров жилых зданий из крупногабаритных объемных блоков

В статье дано обобщение прогрессивного опыта строительства объемно-блочных зданий, начиная с первых серий, и дальнейшее его развитие по строительству предприятий по изготовлению объемных блоков. Раскрыт поворот развития идеи объемно-блочных зданий в сторону новой технической основы, предусматривающий максимальный перенос объемов строительно-монтажных работ со строительной площадки в сферу промышленных предприятий. Одновременно показывается параллельное развитие модульного строительства. Многолетние развитие, а также накопленный отечественный и зарубежный опыт привели к новому направлению в жилищном строительстве. Возведение жилых зданий из крупногабаритных объемных блоков является важнейшим перспективным направлением. Масштабный эксперимент в этой области проводит группа компаний «МонАрх» (г. Москва), которая к настоящему времени изготавливает такие блоки и осуществляет строительство жилых зданий пятого индустриального поколения. В этом эксперименте отрабатываются вопросы проектирования блоков, расхода материалов на их изготовление, выбора монтажных и транспортных средств, организации и технологии монтажа блоков и их установки в проектное положение. В данной статье изложен подход к определению организационно-технологических параметров жилых зданий из крупногабаритных блоков. Раскрыты основные его этапы, их содержание и полученные результаты. Одновременно указывается на трудности, связанные с отсутствием соответствующей нормативной базы, необходимых монтажных и транспортных средств, а также технологической оснастки. В статье аргументирована необходимость расширения научных исследований и проектно-экспериментальных разработок, направленных на обоснование и создание эффективных организационно-технологических и управленческих решений в этом актуальном направлении развития жилищного фонда страны.

Ключевые слова: *крупногабаритные блоки (модули), типаж блоков, типы объемно-планировочных решений, монтажные краны, монтажные процессы*

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СПИСОК ИСТОЧНИКОВ

1. Гуров Е.П. Сборное домостроение. Стратегия развития // СтройПРОФИль. 2010. URL: http://stroyprofile.com/archive/4111
2. Казачун Г.У. Типы жилых зданий. Ростов н/Д : Феникс, 2011. 398 с.
3. Олейник П.П., Пахомова Л.А. Опыт строительства жилых зданий из объемных модулей и перспективы организации строительства крупномодульного домостроения // Актуальные проблемы строительной отрасли и образования : сб. докл. Первой Национальной конф. Москва, 30 сентября 2020 г. М., 2020. С. 349–352.
4. Gao Y., Tian X.-L. Prefabrication policies and the performance of construction industry in China // Journal of Cleaner Production. 2020. Vol. 253. P. 120042. DOI: 10.1016/j.jclepro.2020.120042
5. Андриенко В.Г., Баталин Ю.П., Шмаль Г.И. и др. Индустриализация строительства объектов нефтяной и газовой промышленности / под ред. Ю.П. Баталина. М. : Недра, 1985. 342 с.
6. Олейник П.П. Индустриально-мобильные методы возведения предприятий, зданий и сооружений : монография. М. : Изд-во АСВ, 2021. 488 с.
7. Олейник П.П., Ширшиков Б.Ф. Комплектно-блочный метод возведения объектов : учеб. пособие. М. : МГСУ, 2008. 85 с.
8. Завражнов С.И., Рачков Д.С., Новиков М.А., Юдин С.В. Технологии производства в строительстве: модульные системы // Вестник МГСУ. 2010. № 3. С. 185–190. URL: https://www.elibrary.ru/item.asp?id=15273405
9. Шепелева Е.А., Шепелев А.Л. Организация строительства производственных объектов комплектно-блочным методом. Архангельск : ИПЦ САФУ, 2013. 139 с.
10. Arashpour M., Kamat V., Bai Yu., Wakefield R., Abbasi B. Optimization modeling of multi-skillet resources in prefabrication: Theorizing cost analysis of process integration in off-site construction // Automation in Construction. 2018. Vol. 95. Pp. 1–9. DOI: 10.1016/j.autcon.2018.07.027
11. Сычев С.А., Шевцов Д.В. Роботизированный монтаж быстровозводимых высотных зданий из модульных трансформируемых строительных систем повышенной заводской готовности // Вестник гражданских инженеров. 2017. № 2 (61). С. 140–147.
12. Сычев С.А. Методика вариантного проектирования технологий возведения зданий и сооружений из модулей заводской готовности // Вестник гражданских инженеров. 2015. № 5 (52). С. 119–125.
13. Pittau F., Malighetti L.E., Lannaccone G., Masera G.Prefabricated production as a large-scale effective strategy for energy modernization of housing stock: on the example of Italy // Procedia Engineering. 2017. Vol. 180. Pp. 1160–1169. DOI: 10.1016/j.proeng.2017.04.276
14. Gao Y., Tian X.-L. Prefabrication policies and the performance of construction industry in China // Journal of Cleaner Production. 2020. Vol. 253. P. 120042. DOI: 10.1016/ j.jclepro.2020.120042
15. Goh M., Goh Ya.M. Lean production theory-based simulation of modular construction processes // Automation in Construction. 2019. Vol. 101. Pp. 227–244. DOI: 10.1016/s0926-5805(02)00086-9
16. Oleynik P., Pakhomova L. A new stage in the development of housing construction // E3S Web of Conferences art. 2021. № 09060. DOI: 10.1051/e3sconf/202125809060

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