European Proceedings of
Social and Behavioural Sciences
EpSBS
www.europeanproceedings.com
e-ISSN: 2357-1330

DOI: 10.15405/epsbs.2021.11.189

SCTCMG 2021
International Scientific Conference «Social and Cultural Transformations in the Context of Modern Globalism»

SYSTEMATIC APPROACH TO DESIGN OF PREFABRICATED BUILDINGS FOR EMERGENCY UNITS IN ARCTIC

Alexander Leonidovich Shidlovsky (a), Dmitry Nikolaevich Saratov (b),
Viktor Nikolaevich Gromov (c)*, Petimat Ramzanovna Tagirova (d),
Taisa Salmanovna Saydulaeva (d), Khadizhat Kurbanovna Butaeva (d),
Alikhan Akhmedovich Dzhankhotov (d), Raisa Salmanovna Erzhapova (d)
*Corresponding author

(a) Department of Practical Training of Employees of Fire and Rescue Units, St. Petersburg University, State Fire-Fighting Service of the EMERCOM of Russia, 149, Moskovsky Ave., St. Petersburg, 196105, Russia
(b) Department of Fire Safety of Buildings and Automated Fire Fighting Systems, St. Petersburg University, State Fire-Fighting Service of the EMERCOM of Russia, 149, Moskovsky Ave., St. Petersburg, 196105, Russia; Department of Special Information Technologies, St. Petersburg University, of the Ministry of Internal Affairs of the Russian Federation, 1, Pilot Pilyutov Str., St. Petersburg, 198206, Russia
(c) Higher School of Cyber Physical Systems and Management, Peter the Great St. Petersburg Polytechnic University, 29, Polytechnicheskaya Str., St. Petersburg, 195251, Russia, talirovskiy@igps.ru
(d) Grozny State Oil Technical University named after Academician M.D. Millionshchikov, 30, A. Kadyrov Ave., Grozny, 364902, Russia, t-petimat@mail.ru

Abstract

The relevance of the topic is caused by state tasks to protect against emergencies and develop the Northern borders of our homeland. The architectural design of the town made of prefabricated and mobile structures was developed on the Arctic coast to equip the units the EMERCOM of Russia. The issues of coordination of the Arctic development and security should be considered in strict compliance with the provisions stipulated in regulatory documents. The use of mobile complexes and buildings in the North makes it possible to quickly equip the units the EMERCOM of Russia in hard-to-reach areas of the North and create comfortable conditions for their life and readiness to eliminate emergencies. The paper discusses innovative additive technologies of design and construction using 3D printers, the use of which makes it possible to simplify the technological chain of building structures construction. The implementation of these proposals requires a systematic approach and the development of experimental architectural projects, a detailed study of all conceptual ideas in terms of structures, engineering networks, decoration, and technical equipment to ensure comfort of living in an artificial environment.

Keywords: Arctic, pre-fabricated buildings, extreme construction, additive technologies, ecology, industrial 3D printers

https://doi.org/10.15405/epsbs.2021.11.189
Corresponding Author: Viktor Nikolaevich Gromov
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

1. Introduction

The issues of coordination of the Arctic development and security should be considered in strict compliance with the provisions stipulated in such documents as the *Fundamentals of the State Policy of the Russian Federation in the Arctic for the Period until 2020 and the Future Perspective* and the *Environmental Doctrine of the Russian Federation*.

The geographical location of the Anzhu archipelago is strategically important to ensure the Russia's security in the north of the country.

It is located east of the Taimyr Peninsula, separating the Laptev Sea and the East Siberian Sea. The archipelago "covers" the eastern part of the Northern Sea Route and allows an aircraft operating from it controlling the vast adjacent zone located east of Taimyr and west of Chukotka (Fig. 01).

The archipelago will host coastal and air defense points, rescue units, material support, meteorological research, shipping support, as well as a contingent of facility protection. In addition to the Anzhu archipelago, similar bases will soon be created in the area of the Franz Josef Land and the Novaya Zemlya.

Figure 1. Geographical location of the Anzhu archipelago

The presence of rescue units is necessary to protect the national interests from emergencies in this critical point. The Northern Sea Route is being exploited more and more intensively, which will make it one of the most important transport corridors in the world in the foreseeable future. For Russia, the Northern Sea Route will also become more important because it will provide for the active development of the Arctic mainland and shelf mineral deposits. Today, their extraction is largely complicated by the difficulty of developing deposits and transporting extracted natural resources (Baryn, 1996; Izrailev, 1997).

In 2011, during the Novosibirsk Islands-2011 expedition, a reconnaissance survey of the Lyakhovsky and Kotelny islands was carried out with the aim of placing a base field camp on the archipelago. It was determined that the runway has almost not been destroyed in 20 years and is fully recoverable.

Thus, part of the infrastructure may be used in the reconstruction of the territory, which will allow equipping this territory with less cost.

2. Problem Statement

2.1. Architectural and planning solutions of residential, office and technical buildings

Frame heated tents and fast-moving mobile housing are used for temporary residence of personnel. Understanding the state significance of this territory, the staff of the department and the cadets of St. Petersburg University State Fire-Fighting Service of the EMERCOM of Russia developed preliminary designs for the arrangement of the EMERCOM units using pre-fabricated and mobile buildings and structures to accommodate personnel in the conditions of the Far North.

The use of these structural systems and the utilization of modern technologies for their construction will allow creating a full-fledged comfortable town on the Novosibirsk Islands for the EMERCOM units to accommodate not only the EMERCOM employees for their direct purpose, but also meteorologists, military staff, and other specialists of related fields.

The proposed architectural and planning solutions of residential, office and technical buildings are developed taking into account climatic conditions on an alternative basis.

The climate is Arctic, harsh. Snow lies 9–10 months a year. The average temperature in July is +0.3 °C, but at night the temperature drops to –6 °C. From November to March, thaws are excluded, in April the absolute maximum temperature is 0 °C. In terms of average monthly and minimum temperature the coldest month is February (–36.3 and –49.9 °C, respectively). Temperatures below –30 °C may be observed from October to April. Frequent high speed wind reaches up to 40 m/s. There is approximately 250–500 mm of rainfall per year.

3. Research Questions

The first draft of the military camp project in the Far North was developed using cylindrical unified blocks and cylindrical buildings for officers and technical means (Fig. 02) (Karasev, 1987).

Residential complexes using mobile cylindrical unified volumetric blocks are most effectively used for the accommodation of employees of the EMERCOM and other small units: managers of firefighting operations, meteorological service, polar stations, etc., totaling up to 100 people.

https://doi.org/10.15405/epsbs.2021.11.189
Corresponding Author: Viktor Nikolaevich Gromov
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

Figure 2. Sketch of the EMERCOM camp in the Far North using cylindrical unified blocks and cylindrical buildings

4. Purpose of the Study

The developed design of a residential complex for ordinary personnel using unified ready-to-operate cylindrical blocks is aimed for rapid and repeated deployment of towns in hard-to-reach areas. The complex includes the following: a sleeping block for 12 people (two-tier placement) and for 4–6 people (one-tier placement) (Fig. 03), a sanitary unit with a utility room, a dining room with dining hall, a utility service block with banya (bath), shower rooms, a laundry room, etc.

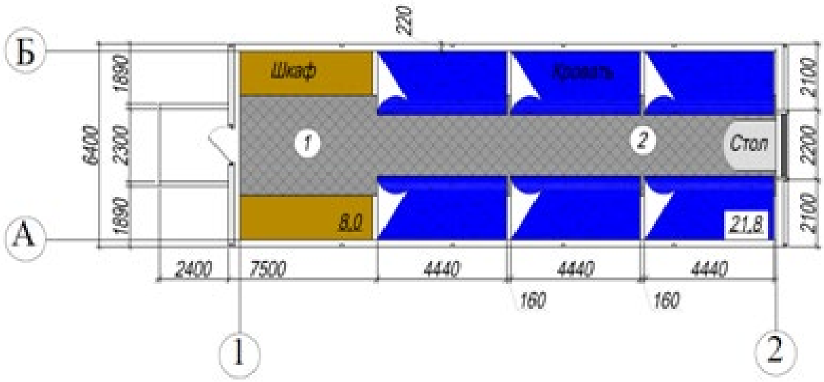


Figure 3. Sleeping block for 12-6 people: 1 – entrance hall with a wardrobe, 2 – bedroom for 12 people

5. Research Methods

The bedroom has beds with laths and wall back barriers, nightstands, a table and stools. The lighting in the bedroom is comfortable and electric (common and from individual luminaries above each bed).

There is a table, soft sofas, a built-in closet for clean dress and linen in the hall. A TV or radio may be installed on the shelves of the built-in cabinet. The lighting is natural and electric from a ceiling light.

https://doi.org/10.15405/epsbs.2021.11.189
Corresponding Author: Viktor Nikolaevich Gromov
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

The developed life support systems make it possible to create comfortable conditions for personnel in buildings from cylindrical unified blocks.

The advantages of towns from cylindrical unified blocks for the EMERCOM units are as follows:

1. Operational mobility and possibility of deploying different numbers of personnel;
2. Multiplicity of assembly and installation of different complexes;
3. Use of a cylindrical unified unit allows solving the problem of snow drifts;
4. It has good thermal characteristics, heat losses are reduced by a quarter compared to rectangular containers;
5. There is no need to erect foundations to place cylindrical unified blocks on the ground, telescopic supports make it possible to install them on a relief base.

6. Findings

Residential buildings for officers designed from metal cylindrical blocks located in the residential zone of the town give certain expressiveness to the general view of the town. The layout of the building reduces snow deposition around buildings and heat loss.

The residential block is two-story, designed to accommodate 32 people (Fig. 04) Officers are housed in residential rooms of two people with sanitary facilities. The rooms have all necessary conditions for the rest of officers.

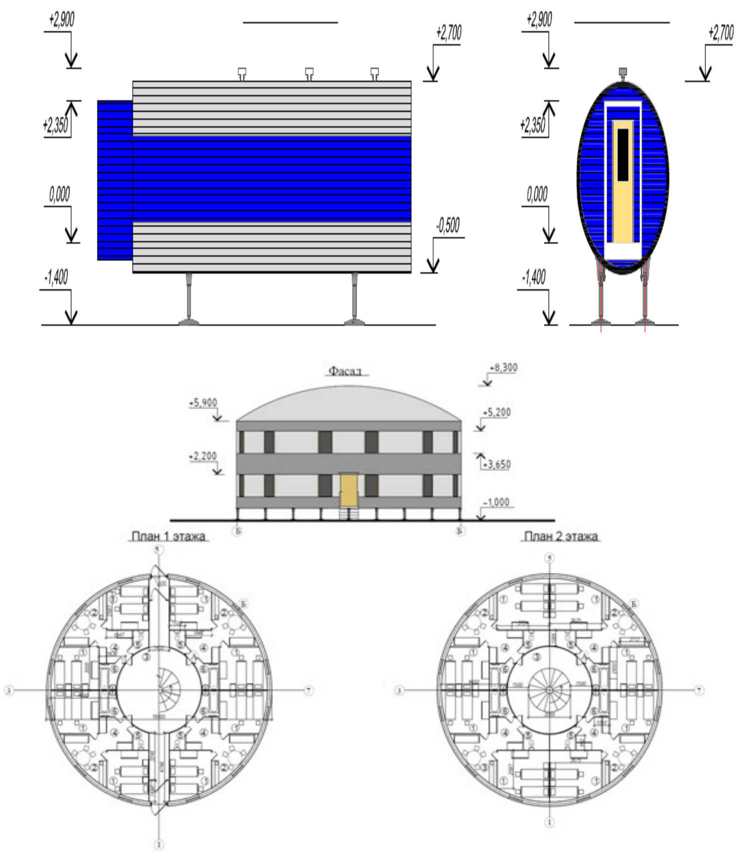


Figure 4. Residential complex for officers: 1 – bedroom, 2 – kitchen, 3 – corridor, 4 – entrance hall, 5 – toilet, 6 – bathroom

https://doi.org/10.15405/epsbs.2021.11.189
Corresponding Author: Viktor Nikolaevich Gromov
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

Modern materials used for the decoration of premises and equipment, engineering life support systems create comfortable living conditions for the EMERCOM staff (Figure 05).

Given the severity of the climate and a lot of time spent by the EMERCOM staff in the premises of a residential complex, the military camp includes a sports complex with simulators and a psychological unloading complex, which includes halls with various training facilities and recreation rooms, a billiard room, a cinema hall, a classroom and a library (Figure 06, 07). These rooms make it possible to relieve the psychological discomfort associated with continuous stay in buildings during service and rest, since all residential and service blocks are connected with each other by warm passages.

Figure 5. Interiors of the residential complex

Figure 6. Interiors and equipment of sports complex

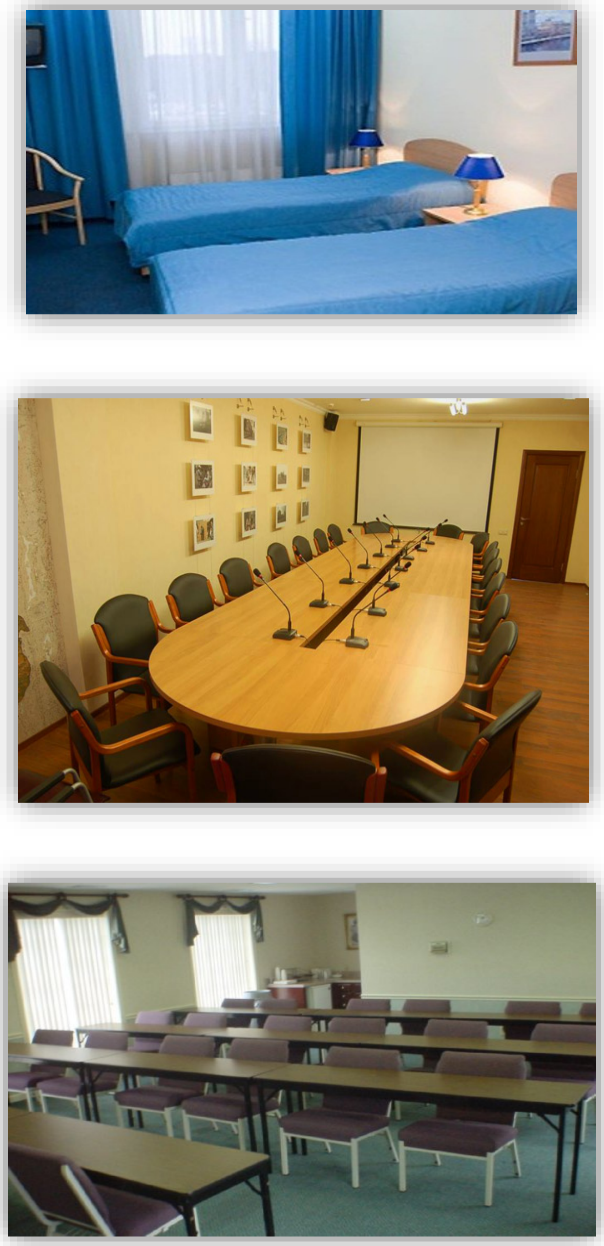


Figure 7. Office interiors and equipment

Having studied the foreign experience of arranging polar stations in the extreme North, a preliminary design was developed for rescue units in a harsh climate using a volumetric octagon block. The proposed volumetric block can be used both for residential and public buildings, as well as for technical (boiler houses, technical workshops, etc.), as well as mobile medical centers and canteen complexes.

A residential complex from a volumetric octagon block allows accommodating organizations and divisions of various numbers – 100, 200, 300, 500 or more people (Fig. 08, 09).

https://doi.org/10.15405/epsbs.2021.11.189
Corresponding Author: Viktor Nikolaevich Gromov
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

Figure 8. Draft design of the housing and administrative complex from octagon blocks

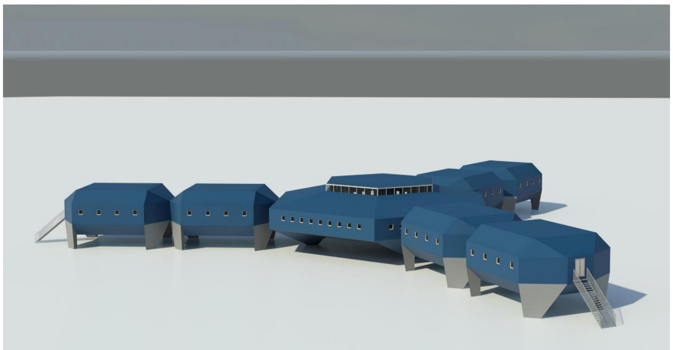


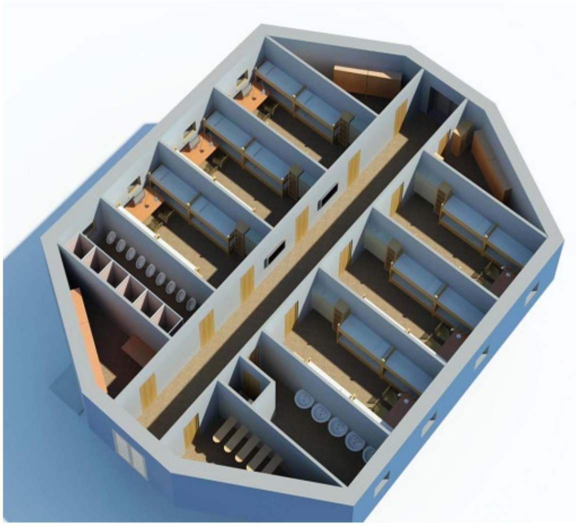
Figure 9. Administrative-residential complex for 100 people

The architectural and planning arrangement of the residential complex consists of an octagon-shaped residential unit, which houses 24 or 48 people, an administrative and maintenance unit. Towns of various numbers may be built from these block modules.

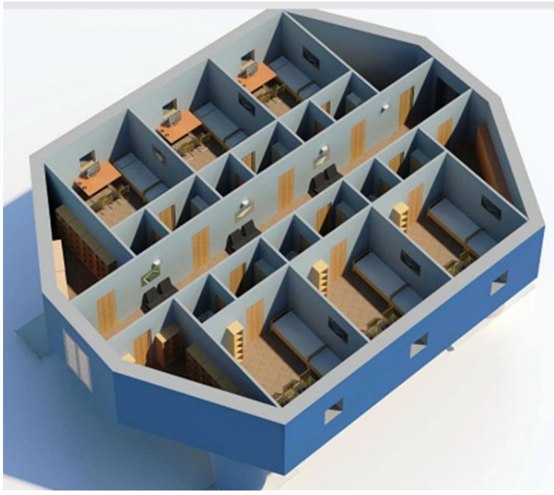
The architectural and planning solution of the residential block for 24 people provides for the placement of personnel in separate residential cells of four people with sanitary facilities (Fig. 10, a).

In a residential block for 48 people the personnel is accommodated in residential cells with two-tier sleeping places. Sanitary facilities are located in a separate block (Fig. 10, b).

The interior creates a calm habitat in the extreme North, which positively affects the psychological state of people.



a



b

Figure 10. Layout of residential blocks: a) for 24 people, b) for 48 people

Due to unique shape and design features, the residential complex can be effectively used in cramped conditions. The technical characteristics of modern materials and architectural and planning solutions of the complex make it possible to reduce the problems of snow drifts, heat and technical losses, increase the level of living comfort.

Engineering support (autonomous, centralized and mixed) corresponds to mobile conditions. Engineering networks are made of progressive materials, structural and connecting parts allow repeated assembly and disassembly depending on tasks (Denisova, 2011).

The unified block modules make it possible to quickly solve the issues on the arrangement of the EMERCOM units and other civilian units of various numbers depending on tasks (Fig. 11).

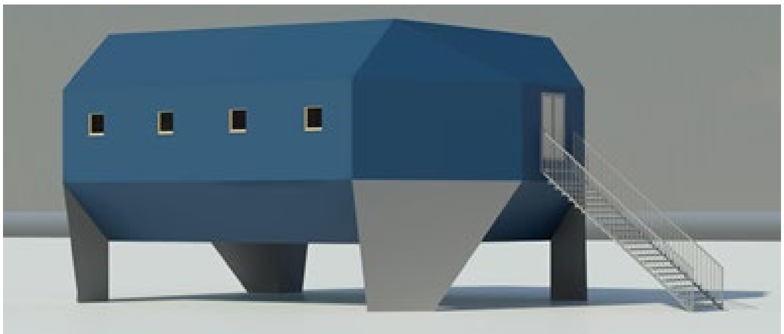


Figure 11. Octagon modular unit (Layout)

The maximum comfort and modern housing in the extreme North allow solving operational and tactical tasks and ensuring the reliable operation of technical means to protect the borders from emergencies.

https://doi.org/10.15405/epsbs.2021.11.189
Corresponding Author: Viktor Nikolaevich Gromov
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

6.1. Problems of construction in extreme conditions of the Far North and their solution

The relevance of the developed design solutions for the arrangement of rescue units reveals a number of architectural and construction problems that require further study for the construction in the Far North.

Extreme conditions and natural and man-made emergencies require new technologies for design and construction of fast-moving structures.

In this regard, in recent years we are no longer talking about solving individual construction problems, but about a systemic approach that can lead to truly creative innovative solutions.

The system approach to the tasks of automated design requires the joint design of the facility and its automated construction management system, i.e. management of these two related technological processes.

The traditional separate consideration of tasks related to the design and production of construction facilities no longer meets the needs of today, as it cannot guarantee either high quality of design or the proper level of organization of production processes that ensure their implementation.

The implementation of modern innovative methods for the construction of fast-production protected structures in extreme conditions and emergencies requires the use of an additive method for the construction of objects, which allows, by gradually adding materials, increasing the necessary shape for the production of something using 3D industrial printers.

Many facilities and engineering structures that support the life of campuses for the EMERCOM units have typical architectural shape. Such structures should be built at a high pace, with a minimum cost and with high reliability.

Developing digital additive technologies can change the existing technological chain required for the construction of complex and simple facilities.

Additive 3D technologies allow creating full-size forms of small architectural structures using construction 3D printers (Maksimov, 2018).

The process of creating an object is as follows: special software forms a virtual solid 3D model of designed structures, then the information is transmitted into a 3D printer code, which in the on-line mode forms building elements by extrusion printing with semi-liquid material.

One of the important trends of the fourth industrial revolution will be the ubiquitous penetration of industrial 3D printing. 3D printing and digital manufacturing may become key drivers in many spheres and, especially in the construction industry.

The main advantages of construction printers are the minimum (compared to traditional methods of work) time and efficiency of logistics.

According to Technavio Research, the volume of the global 3D printer market from 2020 to 2024 will increase by $14.49 billion and will grow by 39 % annually.

The US Marine Corps uses 3D printing technology to build concrete barracks.

Additive on-line technologies allow implementing various modern methods of accelerated construction of objects (Karimova, 2019) based on the following:

- Fused Deposition Modeling (FDM);

https://doi.org/10.15405/epsbs.2021.11.189
Corresponding Author: Viktor Nikolaevich Gromov
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

- Laser Stereolithography (SLA) – layer-by-layer hardening of liquid polymer with ultraviolet radiation;
- Selective Laser Sintering (SLS).

On-line construction technologies continue to be constantly developed and improved.

The most common and accessible is FDM technology, which does not require special conditions for work, additional complex infrastructure and long-term preparation for 3D printers.

This is especially important in the application of additive on-line manufacturing technology in extreme conditions and in areas of the Far North where it is required to use mobile 3D printers that can be easily delivered to the construction site, quickly installed, launch the system and start manufacturing the facility.

The main types of modern building printers (Karimova, 2019) include the following:

- portal;
- delta printers;
- manipulator printers;
- printers for building blocks.

Currently, the Russian printer Apis Cor (Karimova, 2019) that prints entire buildings, including multi-storey buildings, deserves special attention. Apis Cor resembles a crane boom in shape (Fig. 01) and ensures the following:

- erection of structures with the area of 132 m^2 or more;
- positioning accuracy: ±0.5 mm;
- maximum speed of printing unit movement: up to 10 m/min;
- printing technology: FDM;
- use of various working materials for printing: fiberconcrete, geopolymer, etc.

Geopolymer concrete may be based on inorganic industrial wastes (fly ash, slag, etc.), natural minerals.

Properly selected fillers make the material highly fire resistance. So geoconcrete is able to withstand up to 1200 °C.

On the other hand, geoconcrete has high frost resistance and can be used at negative temperatures without additional heating to –40...–50 °C.

The reagent, an aqueous alkaline solution, acts as an electrolyte, which also lowers the freezing point of the liquid in the concrete structure.

In the near future, the printing of buildings will become 19 % cheaper than the construction from common materials.

A printer manufactured by Apis Cor in 2018 printed a house in Stupino near Moscow.

It took one day to print the walls of a one-story concrete house with an area of 38 square meters. The costs amounted to 593,568 rubles.

The life of the device itself is 12 years.

The cost of additive construction of a ready-to-operate house amounted to about 16 thousand rubles per 1 square meter, which is cheaper than the standard construction.

https://doi.org/10.15405/epsbs.2021.11.189
Corresponding Author: Viktor Nikolaevich Gromov
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

The estimated cost of Apis Cor printer is $150 thousand, and initial investments in its development amounted to about 10 million rubles (Fig. 12).

The printer does not require special materials or parts: the necessary parts and components can be ordered in Russia.

In the future, this technology may occupy up to 30 % of the world market for the construction of low-rise buildings, which is now estimated at $68 billion.

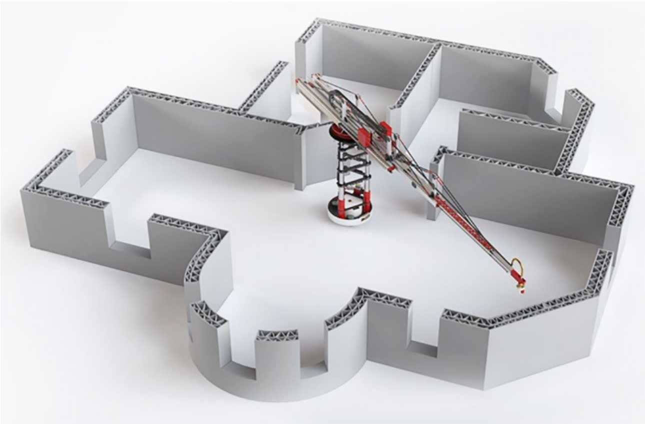


Figure 12. Apis Cor Printer, Russia

Due to the active development of the Arctic territories, the interest in ice has been increasing, which has long and effectively been used by the peoples of the Far North as construction material due to its availability and low cost of artificial ice.

Ice refers to environmentally friendly building materials and its properties allow its components to be reused or processed without any loss.

Fast-moving arched structures for economic and military purposes can be created from ice.

Ice is used for the construction of ice crossings, isothermal warehouses and ice reservoirs, ice piers and islands.

Successful ice construction requires preliminary scientific and experimental studies for the development of technologies to create ice massifs during the construction of structures, including the following:

- criteria ensuring the production of ice with certain mechanical properties;
- physical models of ice cover properties with specific types of ice composite materials;
- additive methods of application and optimization of thickness of created ice layers.

7. Conclusion

The implementation of these proposals requires a systematic approach and the development of experimental architectural projects, a detailed study of all conceptual ideas in terms of structures, engineering networks, decoration, and technical equipment to ensure comfort of living in an artificial environment.

https://doi.org/10.15405/epsbs.2021.11.189
Corresponding Author: Viktor Nikolaevich Gromov
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

Referring to the prospects of additive technologies in construction, we are often forced to refer to the achievements of Chinese, European and American scientists.

To promote 3D printing in Russia, it is necessary to train qualified engineers who have a wide range of knowledge in the fields of programming, materials science, robotics, etc.

References

Baryn, V. M. (1996). Problems of the development of military architecture in the interests of military conflicts. *Military thought, 3*, 22–28.

Denisova, T. A. (2011). Mobile and pre-fabricated facilities as a necessary component of rapid response complexes. *Industrial and civil construction, 8*, 49–50.

Izrailev, E. M. (1997). *Mobile architecture yesterday, today ... tomorrow.* Stroyizdat.

Karasev, N. N. (1987). *Mobile buildings and complexes based on open structural systems*. Stroyizdat.

Karimova, O. S. (2019). An overview of additive technologies in construction online. In *Actual problems of military scientific research. Collection of articles of the interuniversity scientific-practical conference "Development of life support systems, energy conservation and environmental protection"* (pp. 161–166). Polytechnic University.

Maksimov, N. M. (2018). Additive technologies in construction. *Additive technologies, 1*, 36–42.