

DOI 10.15826/rjcsst.2021.2.003

УДК 69.059

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QUALITY ASSESSMENT OF RETAILABLE AND MODULAR BUILDINGS SUBJECT TO DIFFERENT OPERATING CONDITIONS

Abstract. Ensuring the reliability of prefabricated buildings is not only based on force factors, but is also considering the influence of sudden unforeseen non-force and force factors associated with extreme conditions and operating characteristics. The authors of the article analyzed three prefabricated buildings under different operating conditions: an industrial building with a service life of 10 years and several cycles of assembly and disassembly; a modular building in the Far North and the modular prefabricated building "warehouse for sulfuric acid". Based on the data obtained, as a result of the quality assessment, recommendations were formed to avoid such problems in the operation of modular and prefabricated buildings.

Keywords: prefabricated modular buildings, extreme working conditions.

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ОЦЕНКА КАЧЕСТВА БЫСТРОВЗВОДИМЫХ И МОДУЛЬНЫХ ЗДАНИЙ, ПОДВЕРЖЕННЫХ РАЗЛИЧНЫМ УСЛОВИЯМ ЭКСПЛУАТАЦИИ

Аннотация. Обеспечение надежности быстровозводимых зданий основано не только на силовых факторах, но и учитывает влияние внезапных непредвиденных несиловых и силовых факторов, связанных с экстремальными условиями эксплуатации. Авторы статьи проанализировали три быстровозводимых здания в разных условиях эксплуатации: промышленное здание со сроком службы 10 лет и несколькими циклами сборки и разборки; модульное здание на Крайнем Севере и модульное быстровозводимое здание "склад серной кислоты". На основании полученных данных в результате оценки качества были сформированы рекомендации, позволяющие избежать подобных проблем при эксплуатации модульных и быстровозводимых зданий.

Ключевые слова: модульное здание, быстровозводимое здание, экстремальные условия эксплуатации

1. Introduction

One of the most important construction industry tasks is to ensure the reliability of buildings and structures, that is, their ability to perform the required functions for the estimated life of the construction project [1, 2]. It is necessary to ensure normal operation

of the facility during its life cycle with proper maintenance.

As is known, the main criterion is the reliability of the construction site with a distance exceeding their inability to limit states by the action of most unfavorable combinations of design loads for a predetermined lifetime [3]. In addition, the reliability of building structures should also be

ensured under extreme conditions (by choosing materials and design solutions that, under extreme conditions, do not lead to progressive collapse of the structure, or through other measures).

To ensure the required durability of the construction is necessary to consider (in its design, the development of technical solutions, etc.) applied material properties, measures to protect them from the negative impacts of air pollution, degradation of their operational properties for the service, as well as operating conditions for the intended purpose.

For prefabricated buildings of a collapsible type, belonging to the group of mobile buildings, the design service life should be, in accordance with [4], 25 years (or less when reaching five times the relocation). However, these buildings are generally used as permanent buildings with a permanent site of operation. In this case, the service life and other requirements should be established as for ordinary buildings.

The authors of the article assessed the quality of several objects with different conditions and operating time. The results are summarized in Table 1. Based on the results obtained, recommendations were made to further avoid the identified problems.

2. Object 1 – manufacturing modular building with a long service life

2.1 Technical description

The building, a single-span one-storey rectangular in plan with a span of 18 meters and a height to the bottom of the rafters of 7.2 meters, has a span layout with a frame-braced steel frame.

Erection connections are mainly carried out on ordinary bolts of accuracy class B. The proportion of connections in field welding is insignificant.

All supporting structures are solid steel from low-carbon steels of various classes and are made of thin-walled cold-formed C-shaped profiles with a wall thickness of 3 ... 5 mm.

Wall fencing and coverings are made of three-layer insulated metal panels.

The joints between the elements of the wall fencing are covered with strips and insulated with a soft mineral wool insulation.

The frame of the panel consists only of transverse ribs made of Z-shaped profiles with a thickness of 3 mm, to which the enclosing cladding of steel galvanized profiled sheets with a thickness of 0.7 mm is attached. In this case, the inner lining is fastened with combined rivets, and the outer one - with self-tapping screws through tape heat-insulating polyvinyl chloride gaskets.

2.2 Terms

The technical condition of the structures was influenced by the fact that the building was already in operation, while the operating conditions are unknown. Thus, bearing and enclosing structures have been influenced by force and non-force effects (atmospheric moisture, weight of snow cover, daily and seasonal temperature changes, solar radiation, chemical aggression, water vapor flow through the fence, etc.) for several years. As a result, they, have received physical wear and tear to varying degrees. Additional wear was obtained during dismantling of structures (up to damage to individual elements), transportation to a new place of operation, rigging, as well as their storage for some time in an open area without conservation.

2.3 Defects

Based on the results of a full-scale examination of the building structures, the following main defects were revealed.

Defects in the structure of the main and auxiliary frames are deterioration of the anticorrosive coating and surface corrosion (pitting and local) of steel in an area of 10...100% of the total surface area, as well as local pitting corrosion of steel; loss of structural elements; separation of fastening parts; burn through oval holes; cuts of the profile walls with a circular saw; destruction of steel in small areas.

Defects of coating panels and walls are violation of anticorrosive coating and surface corrosion (pitting and local) of steel on an area of 0.5...100% of the total surface area; rotation of the transverse edges of the coating panels

around their own longitudinal axis by an angle of 0.5...60 degrees; general curvature of panel elements; damage to sealing and heat-insulating gaskets; damage to the plastic film; wetting of insulation; separation of the mounting plates from the panel skins.

The most serious defects of the panels are destruction of the joints of the elements of the panels with each other (mainly when joining on combined rivets); destruction of steel skins; bending of the ribs of the frame of wall panels (mainly panels with a width of 2 m); destruction of the insulation of wall panels due to its systematic moistening due to the lack of vapor barrier.

At the same time, it was established by the method of ultrasonic thickness measurement that the degree of corrosion wear is insignificant, and its consideration when carrying out verification calculations is not required.

2.4 Survey result

In view of the identified defects and conducted testing calculations technical condition of the examined building structures,

which was estimated by outward signs, is following:

- The supporting structures of the main frame and ties are generally satisfactory, some structures are not entirely satisfactory, one element is unsatisfactory.
- The design of the auxiliary frame is generally satisfactory, some designs are not entirely satisfactory.
- Panel coverage is generally not entirely satisfactory, some panels are not satisfactory.
- Wall panels are generally unsatisfactory, some elements are not entirely satisfactory.
- Windows in general - not entirely satisfactory.

3. Object 2 – modular building in the far north and maritime climate

3.1 Technical description

The building is modular, one-storey rectangular in plan with a width of 3 meters, a length of 7.2 meters and a height of 2.5 meters (Fig. 1).



Fig. 1. Object 2 before the start of operation

The metal frame is made of channel, angle and pipe.

Wall panels, cover panels, three-layer frame-type panels with embedded mineral wool insulation with a total thickness of 120 mm without polyethylene film. The outer and inner cladding is made of steel galvanized profiled sheets with a thickness of 0.7 mm.

The roof is pitched with a slope of "2".

The joints between the elements of the wall fencing are covered with strips and insulated with a soft mineral wool insulation.

The connections are mainly made using assembly welding.

3.2 Terms

The technical condition of the structures was influenced by the fact that the building was operated in places where hydrogen sulfide evaporated, as well as maritime climate of the Arctic Ocean prevailed.

3.3 Defects

Based on the results of a full-scale examination of the building structures (Fig. 2), the following main defects were revealed.

Defects in the structure of the lower supporting frame are violation of the anti-corrosion coating and surface corrosion (pitting and local) steel on an area of 10...100 % of the total surface area, as well as local pitting corrosion of steel

Defects of coating panels and walls are violation of anticorrosive coating and surface corrosion (pitting and local) of steel on an area of 0.5...100% of the total surface area.

Violation of the heat-insulating floor layer is up to 50%.

Destruction of mineral wool insulation from low temperatures is to 50%.



Fig. 2. Corrosion destruction field of object 2

3.4 Survey result

In view of the identified defects and conducted testing calculations technical condition of the examined building structures,

which was estimated by outward signs, is following:

- The load-bearing structures of the lower frame and ties are generally not entirely satisfactory, some structures are satisfactory, one element is

- unsatisfactory.
- Floor panels - unsatisfactory, emergency.
 - Wall panels and roofs are generally satisfactory.
 - The windows are generally satisfactory.

4. Object 3: Rapidly erected modular building "Pumping station of acid warehouse"

4.1 Technical description

The building is a modular container type, one-storey rectangular in plan with a width of 6 meters, a length of 13.5 meters and a height of 3.4 meters. The installation was planned from three blocks and subsequent screed and sealing of joints.

The building envelope was designed to protect against sulfuric acid vapors.

Metal frame is made from channel, angle and pipe.

Wall panels, cover panels, three-layer frame-type panels with embedded mineral wool insulation with a total thickness of 120 mm without polyethylene film. The outer and inner cladding is made of 2 mm thick galvanized steel profiled sheets.

The roof is pitched with a slope of "2".

The thermal insulation material is non-flammable, resistant to chemical influences.

Floor covering sheet metal is 4 mm thick, steel grade is St.08-12X18H10T.

The joints between the elements of the wall fencing are covered with strips and insulated with a soft mineral wool insulation.

The connections are mainly made using assembly welding.

4.2 Terms

3 container-type blocks were delivered to the construction site for the purpose of subsequent installation. They were exhibited without sealing close to the design position (Fig. 3). Due to the fact that at this time the foundation was being installed, the blocks spent a month under the influence of sulfuric acid vapors in the pumping station in a leaky state.

4.3 Defects

Based on the results of a full-scale examination of the building structures, the following main defects were revealed.

Corrosion of the inner surface of containers: doors, floors, walls from 10 to 100% of the surface (Fig. 4).

Corrosion of all metal fasteners and equipment locks inside the blocks up to 100% of the area (Fig. 5).



Fig. 3. Storage conditions for prefabricated parts



Fig. 4. Corrosion of paint coating of doors and walls



Fig. 5. Corrosion of internal fittings

4.4 Survey result

In view of the identified defects and conducted testing calculations technical condition of the examined building structures, which was estimated by outward signs, is following:

- The condition of the supporting structures of the frame and ties is

completely satisfactory.

- Internal elements of the filling, including door and window cladding panels, are in an unsatisfactory condition.
- The condition of the fasteners and metal elements inside is unsatisfactory.

Table 1

Results of the object study

The main characteristics of the object	Conditions and service life	Types of defects and reasons for their appearance	Assessment of the accident rate of the object
One-span one-storey rectangular building. The span is 18 meters, the height to the bottom of the rafters is 7.2 meters.	10 years of operation, conditions unknown	<ol style="list-style-type: none"> 1. Incomplete completeness of shipping marks (a consequence of installation and dismantling) 2. Corrosion, local and superficial 10-100% of the total area. Corrosion is negligible. (wobbling of non-force factors) 3. Rotation of cover panels (application of Z- shaped profiles) 4. Destruction of riveted elements. (application of rivets) 5. Destruction of the insulation of wall panels (lack of vapor barrier) 	The condition of the supporting and auxiliary frame is generally satisfactory, with the exception of one element of the supporting frame. The condition of the panels and windows is not entirely satisfactory.
The building is modular, one-storey rectangular in plan with a width of 3 m, a length of 7.2 m and a height of 2.5 m.	2 years in the far north, 70 km from the Arctic Ocean, presence of hydrogen sulfide vapors	<ol style="list-style-type: none"> 1. Corrosion of the lower frame structure and floor sheathing up to 20% of the material area. 2. Corrosion of the coating in places where the paintwork is damaged by 10% of the material area 3. Corrosion of the floor sheathing sheet up to 70% 4. Violation of the heat insulating layer to the floor 3 0% <p>Reason: non-violent environmental influences</p> <ol style="list-style-type: none"> 5. Destruction of mineral wool insulation in the joints due to the influence of low temperatures. 	The condition of the lower supporting frame is unsatisfactory and requires reinforcement. Complete replacement of floor panels is required, as well as restoration of the heat-shielding layer.
Modular container-type building 13.5x6x3.4 m	1 month in a state of readiness for installation on the territory of the plant under the influence of sulfuric acid vapors	<p>Corrosion of the inner surface of containers: doors, floors, walls from 10 to 100% of the surface.</p> <p>Corrosion of all metal fasteners and equipment locks inside the blocks up to 100% of the area.</p> <p>Reason: Incorrect exploded view.</p>	The state of the supporting structures of the frame and ties is generally completely satisfactory. Internal elements of the filling, including door cladding panels and windows, are in an unsatisfactory condition. The condition of the fasteners and metal elements inside is unsatisfactory.

5. Conclusion

By combining the results of the studies carried out, we can come to the following conclusions.

The main destructive factor for prefabricated buildings is corrosion of metal structures, regardless of the reasons for its occurrence, therefore, it is necessary to provide a protective layer for all structures.

Harmful non-force environmental factors may appear unexpectedly, for example, when the structure is re-placed in the place of accumulation of hydrogen sulfide vapors, which will require a higher class of chemical protection from the structure, which requires unification of the types of modular buildings for protection from aggressive environments.

It is necessary to make unification and interchangeability of individual elements and structures of modular buildings, which creates the need to form a series of structural elements.

It is required to unify the calculation of elements for unforeseen power and non-power factors that may arise during the installation and dismantling of structures. This is especially true for lightweight fences made of panels with metal sheathing.

It is necessary to presence of longitudinal ribs in the panel frame system to eliminate rotation transverse ribs around its straight panels about longitudinal axis. Application of Z-shaped profiles is undesirable because of their ability to turn and in some cases even twisting around the longitudinal axis.

The joints of the profiled sheets with the frame of the panels must be carried out only with self-tapping screws. The use of combined or electric rivets is not permitted.

It is required to limit the use of mineral wool insulation in the Far North. It is possible to use it only in sandwich panels.

Considering the above recommendations will improve the operational character and sticks of collapsible buildings.

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