Durability of suspension facade systems with air gap

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Abstract. Overhanging ventilated facade is a very important engineering structure, the experience of using which in construction engineering for a long time, especially in this country, is not so wide. Information available in foreign publications, mostly in special ones, is, as a rule, of the advertising type. Details of the design, which determine the corrosion resistance of the ventilated façade and consequently its durability, lack in these sources. Thus, the corrosion resistance of supporting structures in suspension façade systems (further SFS) is one of the main parameters influencing their reliable and safe operation.

The planned term of façade usage is not clear either. According to the data available, in foreign practice the term of exploiting ventilated facades is 25 years. In Russia [1, 2] the estimated term for ventilated façade operation varies from 25 to 50 years.

In Germany, scientific research has been made and the first modern design elements as well as technologies for mounting the ventilated façades have been developed since 1950-ies. The all-European Manual ETAG 034 is used now.

The analysis has shown that there is no enough regulation and technical documents of the federal level for designing, erecting and using SFS. In studying the documents it has been found that there is enough practical experience accumulated for using various SFS, on the basis of which it is possible to draw up national regulation documents for providing safe exploitation and durability of suspension facade systems.

The paper contains data on forecast terms of SFS operation in normal conditions of their usage, which have been determined after investigation of corrosion defects in bearing metal components of various SFS.

1. General information about suspension façade systems

Ventilated facade made on residential, public and administrative buildings, being both erected and reconstructed, is a very important engineering structure, the experience of using which in building engineering for a long time, especially in this country, has not been wide yet. Information contained in foreign, mostly special editions is as a rule of the advertising character. Details of design solutions which determine the corrosion resistance of ventilated façade and consequently its durability are not available in these publications. And, of course, the open, accessible press lacks data on corrosion of façade constructive components exploited in different atmospheric conditions and this on corrosion defects revealed during inspection of facades which have been used for a long time. Moreover,
corrosion resistance of bearing structures in suspension façade systems (further SFS) is one of the main parameters influencing their reliable and safe exploitation. This is connected with the fact that the framework being between the bearing wall or interior finishing of the building walls, on the one hand, and their facing, on the other hand, cannot be looked over from outside during its exploitation.

There is no clear information either about the designed time period of façade operation which depends on the durability of its components and on the method of their anti-corrosion protection chosen. According to the available data, in foreign practice, the term of ventilated façade service is fixed to be 25 years. In Russia [1, 2], the supposed term of ventilated façade operation vary from 25 to 50 years. This depends, in particular, on the fact that at the present level of their exploitation experience, façades possess uncertain actual durability.

SFS are designed for solving complex problems of facing and heating external walls of buildings and structures of various purposes. Such kind of heating provides for a system of bearing structures used – cantilevers, vertical and horizontal guide profiles, fastening components and anchors made of different materials: non-alloyed (or low-alloy) steels, aluminum alloys, corrosion-resistant steels. The bearing metal components (cantilevers) fastened with anchors to walls or ceilings of the building being heated support the facing façade plates with the help of horizontal and vertical profiles.

When mounting SFS, the necessary condition is an air gap between the façade plates and the heat-insulation layer adjoining close to the wall and providing moisture ventilation from the suspension façade zone. The upward air stream allows moisture to be removed from the insulator and carrying wall, providing maintenance of normal moisture mode, which, in turn, increases efficiency of the building heat-insulation [3].

When two heterogeneous materials i.e. possessing different electrochemical properties come in contact, such type of corrosion destruction as contact corrosion can arise. Besides the contact corrosion, the slit corrosion is also very dangerous for SFS, the one which appears in slits and gaps between metals, packing materials, etc., where corrosion develops faster than on open sites. To provide durability of load bearing structures in suspension façade systems it is necessary to take measures of eliminating contact corrosion and of minimizing the slit one. Because of this the cantilevers and guides of profiles should be made from the same materials.

For fastening cantilevers to their base (a building wall or a ceiling) anchors are used (opening, stop, with expansion, chemical, etc.), the choice of which depends on the base material. Also when choosing an anchor, it is important to take into account peculiarities of the environment where it will work. It is possible to prevent the anchor corrosion if you take the corresponding measures, for example use special protective coatings or stainless steels.

It should be noted that SFS application is due to the necessity for setting legal standard requirements for system design solutions and for materials and products used in them, first of all with bearing in mind the specific climate conditions in Russia where SFS will be exploited.

For protection against wind and moisture, various kinds of barriers are used, the main of them being:

- membranes put in liquid state;
- building membrane-films.

«Liquid» membranes are usually put on the outside surface of the carrying wall with a roller or sprayer. This polymer coating after drying blocks the penetration of air and water. The building membrane-films are films usually made of polyethylene which can be self-sticking or mechanically attached to the outside surface of the load bearing wall or heat-insulating layer. Both types of membranes can contain inflammable polymers which could influence the fire-prevention characteristics of the external facing system [4]. However, for example, in the British documents for fire-proof façades it is considered that contribution of membranes in fire spreading is negligible [5, 6].

Mounting of SFS heat-insulation [7] performed by using wind- and moisture-protective membrane applied over heat-insulator and fixed with dowels allows both the heat-insulation itself of the ventilated façade and the membrane to be attached simultaneously. The material for wind- and moisture-protective membrane is most often a film which protects the surface of the heat-insulator
against water and moisture, against mechanical damage and also prevents heat loss thanks to longitudinal filtration of air in the heat insulator. Such protection is especially actual at oblique rain when the heat-insulator gets heavily wet through slits between facing plates, and if there is no a ventilated gap which dries the surface quickly, there is the risk of the walls being frozen. The wet heat-insulator loses up to 90% of its energy-saving characteristics claimed by the producer. The vapour-insulating film should be laid with its smooth surface outward.

Wind-protective membrane for facing façades of buildings should correspond to the group of non-inflammable materials.

The necessity of using wind-protective membrane when assembling ventilated façades is under lively discussion now [8] as there are heat-insulators with a cash layer on the market, which can be used without wind- and moisture protective membrane.

One of the important problems in using these systems for facing façades of buildings is their fire safety [9-11].

In order to limit the spread of fire, anti-fire cuts-through – solid and punched ones – are used in suspension façade systems at present. When solid cuts-through are used, the role of air gap is reduced to zero, in which case it is necessary either to provide ventilation in the façade with extra facilities or to mount them in such a way that they overlap the ventilation gaps.

Another version of anti-fire cut-through is designed in such way that in order not to prevent the movement of air streams in an inner layer, it is punched.

In spite of a big amount of research made by different authors, there have been no works yet containing objective estimation of how anti-fire cuts-through influence the movement of air streams in an inner layer of suspension ventilated façades.

The offered ways of how to improve the design of cuts-through provide free flow of air stream in ordinary conditions and sharp reduction of air (oxygen) feed due to a cut-through on springs in case of emergency – fire.

In the scientific research made by the authors in 2019, the regulation and technical documentation has been examined and analyzed, containing statements and requirements for designing, mounting and exploiting the suspension façade systems with air gap:
- codes of regulations for designing steel thin-walled structures made from cold-bent zinc-coated profiles and corrugated sheets (Building Acts 260.1325800.2016), multistory buildings (Building Acts 267.1325800.2016), for designing heat-insulation in residential and public buildings (Building Acts 345.1325800.2017);
- international and national standards in the testing methods for fire danger of external walls from outside (GOST 31251-2008), building enclosing structures (GOST R 54851-2011), substructure materials for SFS (GOST R 58154-2018);
- standards of organizations, containing technical specifications for fastening steel components in SFS (STO 75298253-001-2006, STO 35305799-003-2008), methods of determining the load bearing capacity as a result of natural testing of anchor fasteners (STO 44416204-010-2010), requirements for work of designing and producing SFS (STO NOSTROY 2.14.67-2012, STO NOSTROY 2.14.96-2013);
- Albums of engineering solutions, Manuals, Recommendations, Regulations and Technical Certificates.

The analysis has shown that codes of regulations Building Acts 267.1325800.2016, Building Acts 345.1325800.2017 and GOST R 54851-2011 contain instructions and recommendations on the methods for thermal engineering calculations of external enclosing structures, including SFS, where the methods of thermal engineering calculations are given in the sufficient quantity.

Building Acts 260.1325800.2016 contains the basics of strength calculation and of designing the building structures made from steel zinc-coated thin-walled cold-bent profiles, which steel components of SFS are referred to, but it does not give recommendations on calculating the SFS components, the operation of which is rather specific.
As to the calculation of thin-walled aluminum profiles, Building Acts 128.13330.2012 «Aluminum structures» lacks the requirements of taking into account reduction of the compressed part in the profile cross-section [12,13] when making calculations of strength and deformation.

It should be noted that the SFS components are calculated in a special way, which should be reflected in a new code of regulations with methods of calculating the SFS frameworks, their components and assemblies, including fastening facilities. This code of regulations needs to be worked out because of the necessity to increase reliability and durability of structures under climatic influence exerted as a result of the SFS exploitation.

Code of regulations for the anti-fire protection systems Building Acts 2.13130.2012 contains requirements of how to provide the fire-resistance of the objects to be protected and to determine the class of fire danger for SFS. This code specifies only general requirements, but it does not give methods of how to solve problems of preventing the fire spread over the SFS. GOST 31251-2008 gives the method of testing the external wall structures and the protection & decoration systems for fire danger, the essence of which is to determine their characteristics under the influence of fire flame from a window of premises with the fire centre on the outside surface of external walls.

Our opinion is that it is necessary to examine the fire-resistance of the SFS structural components not only within a limited area of the fire flame influence from a window of the premises, but also along the total height of the façade, especially in multistory buildings. The temperature influence on the SFS structure should be investigated when the upper zones of the façade are burning. A method should be worked out, allowing the SFS structure characteristics to be determined in conditions of fire flame influence along the façade height.

In addition, the need has arisen to study the spread of fire over the SFS when a new type of facing is used – the punched façade cassettes (a decoration material designed for façade facing, which looks like punched metal plates), its advantages and disadvantages regarding fire-resistance, the possibility and sufficiency of making anti-fire cuts-through.

GOST R 58154-2018 contains general requirements for choosing building materials, fastening facilities and for selecting materials of protective coatings for metal components of SFS.

Nevertheless, there is a need in estimating durability and safety of SFS for different, particularly climatic conditions of their exploitation. These methods could be developed in the form of text-book for estimating durability and safety of different suspension façade systems during their exploitation.

Besides requirements for choosing materials of the SFS components, it is necessary to work out standard methods of testing the structure components, fastening facilities and facing parts of SFS. Development of standard testing methods is due to the necessity to use a unified approach to testing methods and to estimation of the results obtained. In this development, regulations from organizations’ standards could be used, which give methods of testing the SFS components: STO 44416204-012-2013, STO 35305799-003-2008.

Organizations’ standards STO NOSTROY 2.14.67-2012 and STO NOSTROY 2.14.96-2013, STO 0060-2008 define requirements for the processes of mounting and supervising how the work of constructing SFS has been done. It should be noted that the standards have been used in practice for more than 5 years and one may follow them when developing the national standard for performing the work processes of erecting SFS and for requirements how to control their execution.

In analyzing the technical certificates it has been found that they confirm the fact that new products correspond to the standard and are suitable for being used on the territory of the Russian Federation, and they are regularly included in The State Register of Technical Certificates made up on the web-site of The Construction Building Ministry of Russia.

In the technical documentation studied, the requirements are not defined for the materials of SFS foundations, namely whether they are strong enough to be fixed with anchors. It is necessary to work out a national document regulating the requirements for the SFS foundation materials and for the anchor materials and design.
2. **Peculiarities in operation of suspension façade system frameworks regarding to the analysis of the regulation-technical documents.**

For most kinds of facings with the mass no more than 30 kgf/m² the dead weight of the façade facing results in a small proportion of the stressed state in the SFS framework structure. The main load acting on the façade is wind load [14].

Before 2011 the building standards did not take into account the peculiar influence of the wind load on façade systems, and only when Building Acts 20.13330.2011 was issued, the term «peak load» appeared [15]. This type of wind influence takes into account even negligible sizes of areas under load when collecting wind load for calculation of framework components in ventilated façade systems.

The peculiarity of the wind influence is in heterogeneous intensiveness of the wind stream acting over the surface of the building structure [16]. This unevenness leads to separate pressure peaks over a small area from 2 to 20 m², which can considerably exceed an average value of the rapid wind flow. The wider the surface area under load due to wind influence on the structure is, the less local peaks act on an average value of the wind pressure.

Small areas under the load influence also determine sizes of the load bearing components in the framework of façade system. The façade systems that are mounted on the carrying and self-carrying walls in buildings and structures usually have spans of 1200 mm and less, and guide spacing – no more than 1000 mm. In this case the cross-sections of the framework components are negligible. In particular, the supporting base of the support L-shape cantilever is usually 45-60 mm wide and from 55 to 70 mm high with the heel bracket 3.5 – 5 mm thick, at the same time the diameter which the anchor bolt head 10 – 12 mm in diameter fits is correspondingly 17.6 and 19.9 mm, which is commensurable with the cantilever sizes.

3. **General principles and purpose of suspension ventilated façades in EU**

Since 1950-ies scientific research has been made and first modern structural components and technologies of mounting ventilated façades have been developed in Germany.

At present The Association of Materials and Component Parts for Ventilated Façades (FVHF) operates in Germany.

SFS in Europe is known to mean «suspension ventilated façade» or «suspension ventilated complete set». It is a system consisting of facing parts fixed on a steel zinc-coated, stainless steel or aluminum framework to a carrying layer of the wall or to a monolith ceiling. Over the gap between the facing and the wall or the heat-insulator, air circulates freely, which removes condensate and moisture from the structures. For additional heat-insulation of the building walls, a heat-insulator is fixed to the wall with plate dowels or flexible ties. In order to prevent the air blowing out from the heat-insulator it is covered with a moisture- and wind-protective, vapour-permeable membrane (film).

To interrupt the capillary mechanism of moisture transfer inside the wall and to drain water from melted snow over the inner surface of the facing, an air gap is used between the external facing and the layer of heat-insulator. Ventilation of the air gap is necessary to reduce the moisture content inside and outside the materials, and to drain a part of rain or snow which happens to be behind the facing.

Foreign regulation documents give the following recommendations for the width of air gap in suspension ventilated façades. The requirements for suspension ventilated façades have been set according to German standard DIN 18615-1 [17] as long as since 1970-s. However, at present a later document is used – all-European Manual ETAG 034 [18] which is the main regulation document for European certification of suspension ventilated façades.

According to these documents:
- the distance between the facing components and the heat-insulator or the carrying wall – the air gap – should be no less than 20 mm (at some places the air gap can get narrow to 5-10 mm if this does not prevent drainage and ventilation);
- there should be ventilation holes, at least in the socle part of the façade and near the roof or parapet so that air could enter the ventilation gap and come out of it, with the cross-section no less than 50 cm$^2$ per linear meter.

Standard **DIN 18516-1** considers only the SFS, the ventilation gap in which is no more than 150 mm.

When designing a façade, one should pay special attention to metal structures that become inaccessible for inspection later. They should be protected against corrosion during the whole period of the façade operation.

The choice of steel or aluminum alloy brands for façade structures is determined by corrosion conditions of their application. In extremely aggressive environments contaminated chemically very much (for example, near sulfur cleaning plants) it is necessary to take extra measures of protection against corrosion.

There is a procedure in EU for voluntary certification of new or innovative building products, for which there is no harmonized European standard for some reasons. Complete sets of materials, parts and facilities for mounting suspension ventilated façades, among others, are referred to these products. Certification of suspension ventilated façade systems in Europe is performed by The European Organization of Technical Assessment — EOTA.

Suspension ventilated façade systems are certified according to guideline ETAG 034 «Guideline for European Technical Approval of Kit for External Wall Claddings». The approval is confirmed with document ETA (European Technical Assessment) which is an analogue of the Russian Technical certificate.

4. **The results of investigating durability for bearing structures of suspension façade kits in urban air environment**

Three groups of building materials and their combinations are mainly used in suspension façade systems:
- corrosion-resistant steels;
- carbon steels with anti-corrosion coatings;
- aluminum alloys.

By the order from The Ministry of Building Engineering the joint-stock company «TSNIIPromzdaniy» and SRTU «MIS&A» in cooperation examined buildings with SFS.

Assessment was made, of the extent, in which the environment influences, depending on the general aggressiveness of it, the distance from highways and the height of buildings in Moscow, the rate of corrosion and durability of bearing structures in ventilated SFS made from corrosion-resistant steels. The term of their exploitation was 10-15 years.

All systems approved to be applied on the territory of Moscow have technical certificates issued by FAI «FCC». All in all, the catalogue includes 22 systems produced on the territory of the Russian Federation.

By types of cladding materials used the SFS approved for application in the building complex are distributed as follows:
- from ceramic granite and ceramic plates – 19 systems;
- from fiber cement, metal cassettes and other forms of cladding – 3 systems.

4.1. **The results of investigating corrosion-resistance of steel in SFS structures**

Parts of building structures made from corrosion-resistant steels were selected from objects situated in the centre of Moscow near highways and from buildings of different heights.

The parts of load bearing structures were made from corrosion-resistant steels of ferrite 12Cr17 (AISI 430) and austenitic 08Cr18Ni10Ti (AISI 321) classes. Corrosion state of the parts was assessed by the visual and metallographic methods.
Signs of local corrosion in the material of the parts from steels AISI 321 were not noticed, the rate of overall corrosion was low, being no more than 0.1 mc/year, which allows a long term, no less than 50 years, to be forecast for exploitation of bearing structures in suspension façade systems.

A distinctive feature of steels AISI 430 (12Cr17) is their susceptibility to local ulcerous (pitting) corrosion, which is connected with local breach in passivity of the metal as a result of action of corrosion-aggressive components from the environment.

The type of corrosion defects in steels of the ferrite class is characteristic of medium-aggressive environments: built areas of cities, high gas concentration because of increased transport traffic and exhaust wastes from industrial enterprises. Most corrosion defects were found on the parts exploited in the socle section of the buildings.

When assessing durability of ferrite steels, the rate of local (pitting) corrosion was considered. After 10 years of exploitation the depth of pitting is no more than 15 microns; the rate of local corrosion – 1.0-1.5 mc/year with the rate of general corrosion of steel not more than 0.5 mc/year.

The rate of general corrosion for parts from steels AISI 321 and AISI 430 is no more than 0.1 mc/year, which allows a long term of exploitation, not less than 50 years, to be forecast for load bearing structures in SFS.

4.2. The results of investigating zinc-coated painted low-carbon steels in SFS structures

The research has been made, of corrosion-resistance and durability of parts in load bearing structures after their having been exploited in the Moscow city environment for 7 years, made from sheet zinc-coated steel of 18-20 microns with additional polymer coatings not less than 45 microns thick.

After its exploitation for 7 years in the Moscow city (ceramic granite cladding) the coating has remained almost intact; local corrosion points have been revealed on the surface of the parts, which is probably connected with the lack of coating in some zones. The coating has strong adhesion to the metal base, which corresponds to the highest zero mark in the ISO classification.

The term of work for steel structures depends on their coating. The term of operation for zinc coating 18-20 microns thick in low- and medium-aggressive (under a tent) environments is about 20 and 12 years correspondingly. The term of service for polymer coatings no less than 45 microns thick is about 14-16 years in low-aggressive environments and 10-14 years in medium-aggressive ones if their decorative appearance is not important. The term of service for bearing structures with combined coatings (zinc-coating with additional coating of a polymer material) in low-aggressive environments is approximately 40-50 years, in medium-aggressive ones – 30-35 years.

4.3. The results of investigating aluminum alloys in the SFS structures

In addition to alloys on the ferrite base (corrosion-resistant and low-carbon steels), the building industry uses alloys of aluminum with manganese and silicon. In general, aluminum alloys for building purposes for enclosing structures of type 6060; 6063; AD31 are used in façade building. 

Parts of load bearing structures in SFS, made from aluminum alloy EN 6063 dismantled in Moscow after 10 years of its exploitation (siding cladding) have been investigated.

As a result of the analysis it has been found that there are numerous ulcerous defects on the cantilevers examined, located in the zone contiguous to the heat-insulator. Inter-cry stallite corrosion more than 250 microns deep has also been revealed beyond the zone of contact with the heat-insulator. In the heat-insulator contact zone the stratifying corrosion not less than 150 microns deep has been discovered.

As a result of the research it has been found that the stratifying corrosion can lead to appearance of plastic (residual) deformation under the influence of the working loads and cause mechanical damage of aluminum parts.

Unlike carbon steels, aluminum alloys are characterized with negligible overall corrosion. Aluminum oxidizes quickly: the Al₂O₃ film is formed very fast on the surface of aluminum alloy without additional treatment. The parts remain smooth, shining for quite a long period of time.
However, under the influence of atmospheric conditions the internal brittleness develops in the alloy volume, the so called local corrosion, because of which the strength of constructive parts becomes much less, and the term of the system operation is sure to become shorter [19].

Aluminum alloys of the AD31 type in the non-anodized form should not be used for long-term exploitation. Anodizing i.e. formation of the protective oxide on purpose is a very effective method for protecting aluminum structures against many types of corrosion, allowing their durability to be increased at least by 50%. On the structures made from the AD31 alloy, if they are used in the non-anodized form, considerable centers of defects could appear as soon as in 25 years. Destruction of the anodized alloy, however, will start approximately in 25 years and more often as long as after 35-40 years of its exploitation. It is possible to extend the term of aluminum framework operation for 50 years by using two-stage protection system: anodizing with subsequent application of varnish-paint coating [19].

A disadvantage of aluminum alloys is dependence of their quality on a producer and raw materials. It often happens that though the regulation requirements are observed in producing an aluminum alloy with the right proportion of the main components, the concentration of harmful additives is rather high: Fe, Cu, Zn, Pb. For example, because of increased content of iron or copper the alloy falls under the category of non-resistant to corrosion.

The service terms of materials for load bearing structures in suspension façade systems, according to research data from SRTU «MUS&A», are given in Table 1.

Table 1. Durability of materials for bearing structures in ventilated suspension façade systems

| № | Material | Durability, years | With heat-insulator influence | Without heat-insulator influence |
|---|---------|-----------------|-----------------------------|---------------------------------|
| 1 | Aluminum alloy **/ AD31 | 18-25 | 25-30 |
| 2 | Aluminum alloy**/ 6063 | 30-35 | 35-50 |
| 3 | Aluminum alloy 6060 containing Fe < 0.2 % | 40-50 | 50 |
| 4 | Aluminum alloy **/ 6060 containing Fe > 0.2 % | 35-50 | 50 |
| 5 | Aluminum alloy AMr2 | 50 | 50 |
| 6 | Zinc-coated steel, 18-20 microns | 8-10 | 15-30 |
| 7 | Painted zinc-coated steel***/ | 20-50 | 35-50 |
| 8 | Corrosion-resistant steels (CRS) of the ferrite class | 50 | 50 |
| 9 | Corrosion-resistant steels of the austenite class | 50 | 50 |

**/ In the contact zone of heterogeneous materials (CRS rivets – aluminum cantilevers, CRS clammers – aluminum guides etc) the durability of structure can be reduced by 10-15% at minimum;

**/ Use of additional anti-corrosion protection for aluminum alloys will increase the operation term of structures by 10-15 years.

***/ Scattered of the durability data is connected with quality of the polymer coatings and thickness of the zinc layer.

The analysis of the examination results allows the following conclusions to be made:
- alloy 6060 is recommended for long exploitation as the purest by its alloy components;
- alloy 6063 is recommended for exploitation in low-aggressive environments;
- alloy AD 31 is not recommended for long exploitation without additional anti-corrosion coatings (anode or polymer).

5. Conclusions

The analysis of the world and national practice of using suspension ventilated façade systems has shown that in spite of the practical experience in this field already available in different countries of the world, there are a number of problems that should be worked at thoroughly.

The authors have looked into and analyzed the regulation and technical documentation containing statements and requirements for designing, mounting and exploiting suspension façade systems with air gap. The analysis has shown that there are not enough regulation and technical documents of the federal level in the field of designing, erecting and exploiting SFS. After studying the documents it has been found that there is enough practical experience of using various SFS, on the basis of which it is possible to work out the national regulation documents for providing safe exploitation and durability of suspension façade systems.

The analysis of the research results has allowed us to set the main problems of corrosion-resistance and strength characteristics for thin-walled metal structures made from various materials.

As a result of complete testing the framework components (guides, cross-bars, cantilevers) made from steel, corrosion-resistance steel and aluminum alloys, the corresponding to norm and the rated strengths of the parts tested and the permissible loads have been obtained. The primary results of the experimental research are the basis for further improvement of components, assemblies and fixing facilities for suspension façade systems. The results are also used for developing methods of calculating and designing SFS from steel, corrosion-resistance steel and aluminum alloys in order to include them later in the regulation documents.

The investigation made, of corrosion defects in the load bearing metal parts of SFS allows us to forecast, in conditions of normal exploitation, the following service terms:
- for bearing structures of SFS from steels AISI 321 and AISI 430 not less than 50 years;
- for bearing structures with combined coatings (zinc-coating with polymer coating) in low-aggressive environments approximately 40-50 years, in medium-aggressive environments – 30-35 years;
- for bearing structures from aluminum alloy 6060 -35-50 years;
- for bearing structures from aluminum alloy 6063 -30-35 years;
- aluminum alloy AD 31 is not recommended for long exploitation without additional anti-corrosion coatings (anode or polymer).

References

[1] Kalinin A Yu 2003 Building materials 7 19-21
[2] Antonov O S 2003 Building materials 7 26-28
[3] Sinitsyna A S 2017 Bulletin of the Siberian state University of Railways 1(40) 46-50
[4] Evaluation of the Fire Performance of Aluminum Composite Material (ACM) Assembles using ANSI/FM 4880 /FM Global, 2017 (USA).
[5] 2016 Performance of modern building facades in fire: a comprehensive rev. E. J. of Structural Eng. 16(1)
[6] Technical Note 98 – Fire performance of facades – Guide to the requirements of UK Building Regulations, CWCT 2017 (Britain)
[7] Ershov M N, Babiy I N and Meneylyuk I A 2015 Technology and organization of construction production 4-1 43-47
[8] Gagarin V G and Kozlov V V 2008 Stroyprofil 1(63) 29-33
[9] Elfimova M V and Elfimov N V 2017 Scientific and analytical journal Vestnik of the St. Petersburg University of The state fire service of EMERCOM of Russia 4 50-57
[10] Merkulov S I and Polyakova N V 2017 AUDITORIUM 1(13) 143-148
[11] Bushmanova A V, Mikhailova M K, Dalinchuk V S and Dobrogorskaya L V 2016 Construction of unique buildings and structures 9(48) 34-51
[12] Airumyan E L 2009 Stroyprofile 8(78) 12-14
[13] Kuznetsov I L, Dymolazov M A and Guimranov L R 2018 Light metal structures. Examples of calculation: Educational text-book of methods (Kazan: Publishing house of the Kazan State Architectural and Building Engineering University)
[14] Tusnina V M 2017 Scientific review 5 20-27
[15] Gagarin V G and Guvernyuk S V 2018 Building materials 6 8-12
[16] Gagarin V G, Guvernyuk S V, Kozlov V V, Ledenev P V and Tsykanovsky E Yu 2010 ACADEMIA. ARCHITECTURE AND CONSTRUCTION 3 261-278
[17] DIN 18615-1:2010 Cladding for external walls, ventilated at rear — Part 1: Requirements, principles of testing
[18] ETAG 034 Guideline for European technical approval of kits for external wall cladding, 2014
[19] Kazakevich A V 2006 Building technologies 7