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"Protection of Building Structures against Corrosion": The New Russian Codes

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ABSTRACT

The new Russian Building Codes "Protection of Building Structures against Corrosion" have been developed and approved. The Codes-2012 are aimed at replacing the out-of-date Codes-1987 in the field of corrosion protection. They incorporate the new experience accumulated in the last years and harmonize national and international approaches. The developed Codes set general principles of structural protection against corrosion in regard to concrete and reinforced concrete, stone, timber and steel structures for buildings and constructions intended for operation in hostile environments. In the Codes, detailed classifications of hostile environments and their corrosive action on structures are provided and requirements imposed on materials and structures are set. The Codes comprise a great number of informative annexes describing characteristics of the most important environmental conditions and frequently used protective materials. In general, the modern Russian Codes still follow the prescriptive concept but present a large range of design variables and design options.

Keywords: Codes, corrosion, durability, hostile environments, protection.

INTRODUCTION

Russia entered the process of creating new building regulations, revising building codes and standards, and reestablishing the corresponding enforcement mechanism to ensure regulatory compliance. This provides a unique opportunity to rebuild its regulatory framework on the premises of integration and interoperability.

The acting Russian normative base in construction includes 135 Building Codes (99 for mandatory application) and 779 National (Interstate) Standards for voluntary application.

It is obvious that the urge to update documents in the field of corrosion protection of building structures has emerged long ago. In the recent years the new domestic and foreign materials with high corrosion resistance have been developed and produced, the new techniques in manufacture of materials and structures as well as in execution of protective operations have emerged (Shilin, 2010). At the same time, a considerable part of domestic protective materials reflected in the current documents is not produced any more or being produced according to other Codes, while building companies and organizations often use materials that did not pass due testing.

The new Russian Building Codes SP 28.133.30.2012 “Protection of Building Structures against Corrosion” are intended to replace outdated Codes on corrosion protection and to take into account the new experience accumulated during the last years with a number of regional documents of Moscow and St. Petersburg, together with a system of building codes and regulations.

SP is a normative document included in the list of documents approved by the Russian Government for mandatory application. Its enforcement provides the implementation of the requirements of technical regulations in construction.

GENERAL COMMENTS

The new Codes regulate protection of concrete and reinforced concrete structures as well as metal, stone and timber structures against corrosion.

The Scope. The Codes establish the general framework for design of corrosion protection of building structures intended to be operated in corrosive environments at temperatures from -70 °C to +50 °C with a service life up to 100 years. With greater lifetimes of structures, the corrosion protection shall comply with special requirements.

The Codes do not extend to the design of protection of structures against corrosion caused by radioactive emission or radioactive substances as well as to the design of structures from special concretes (polymer concretes, acid- and heat-resisting concretes, etc.)

Features in Designs of Building and Structures in Corrosive Environments. The Codes determine that the initial data for the design of corrosion protection are:

- characteristics of the corrosive medium: substance type and concentration, aggressive action frequency and duration;
- service conditions: temperature and humidity conditions in spaces, probability of corrosive substance contact with building structures, presence and quantity of dust (particularly, saline dust), etc.
- climatic conditions on construction sites;
- site survey results;
- anticipated changes in the medium corrosiveness extent during service of a building or structure;
- mechanical effects on structures;
- thermal effects on structures.

Before designing individual building components and structural elements, it is important first of all to identify the necessity and feasibility of the primary corrosion protection. The engineering solutions shall provide a possibility of the efficient secondary corrosion protection of a building or a structure while it is in service. Implementing secondary corrosion protection requires that architectural and structural solutions as well as the indoor machinery and equipment arrangement provide full access to all structural elements both for periodic inspections and for protective coating renovation without production process breakups.

Engineering solutions in designs of buildings and structures in corrosive environments shall be focused on the elimination of corrosive effects and on the reduction of corrosive damage in building components.

Process solutions implemented the design shall provide:

- hermetic sealing of process equipment and selection of the appropriate methods of corrosive raw material transportation and batching as well as receipt and transportation of the produced semi finished products, ruling out the contact of corrosive substances with building components;
- grouping of process equipment and units that cannot be hermeticized and are intended for the processing of substances with similar corrosive impact on building components, and their placement in separate buildings or outdoors;
- neutralization of inevitable corrosive substance leakage and wastage;
- heating of spaces with high air humidity to prevent water vapor condensation;
- general ventilation of spaces or local exhaust of corrosive vapors and gases, dry air blasting under combined roofs and skylights as well as into ceiling voids.

Architectural solutions of buildings and structures shall be made with due regard to the topography, soil conditions, prevailing winds and locations of adjacent projects affecting the corrosive environment parameters.

Structural solutions shall provide for simple shapes of structural elements, their minimum surface area, and the absence of space for accumulation of corrosive dust, liquids or vapors. In buildings, it is preferable to provide crawl floors (tunnels) for utility services allowing to carry out periodic inspections and corrosion protection renovation, roof drainage, water removal after floor mopping, partitions for rooms with corrosive substances.

A building’s (structure’s) layout and structural system as well as structural details shall be selected so that possible corrosive damage does not cause the failure of the whole building. Besides, one shall provide a possibility to replace structural elements mostly exposed to corrosive environment.

When designing reconstruction projects for buildings and structures, the Codes request the analysis of the corrosion state of structures and protective coatings with account of the medium corrosiveness type and degree in new service conditions.

When designing structures with protective coatings to be used at variable temperatures, one should consider various thermal deformations of materials and ensure reliability of protection.

The surface corrosion protection for building components shall be provided in conformance with the requirements of Codes for fire-resistance rating and structural fire safety. Selection of anti-corrosion materials shall be carried out with account of their fire engineering characteristics (fire hazard) and compatibility with fire-resistant materials.

In this paper, the approach to concrete and reinforced concrete structures will be outlined to some detail, as implemented in the Russian Building Codes SP 28.133.30.2012.

CONCRETE AND REINFORCED CONCRETE STRUCTURES

It is well known that concretes have changed significantly in the past years (Bazhenov, 2007). In 1986 the world scientific community formulated for the first time a concept of high-performance concretes (HPC) that defined basic requirements to quality of concretes with a long projected lifetime reaching 500 years. Appearance of such concretes has opened an era of skyscrapers with cast-in-place concrete frames, offshore oil platforms on oceanic shelves, large-span prestressed concrete bridges and tunnels between islands and continents, underground “mini-towns” and architectural concrete (Gousev et al, 2012).

Extensive research have been conducted on the concrete corrosion in gaseous, liquid and solid severe environments, in biologically active media, and studies of “internal” concrete corrosion, in particular, caused by ASR, and of modern HPC corrosion. Diagnostic experience of a corrosion processes in building structures of various application in buildings and constructions, together with the experience of corrosion protection of building structures, has been accumulated as well.

Classification of Corrosive Media. When designing corrosion protection of concrete and reinforced concrete structures, it is important to clearly define characteristics of a corrosive medium, in which one or another corrosion damage occurs.

The Codes subdivide corrosive media into gaseous, liquid and solid ones with regard to their physical state. Besides, depending on intensity of the corrosive action on building structures, the media are subdivided into classes for each specific material unprotected against corrosion. The environments affecting concrete and reinforced concrete structures are subdivided into non-corrosive, low-corrosive, medium-corrosive and highly corrosive.

With regard to the nature of corrosive media impact on a building material, they are subdivided into chemical (e.g. sulfate, magnesia, acidic, alkali, etc.) and biological.

Corrosive severity is proposed to be classified similarly to that in EN 206 (2000) and in a number of other foreign codes with account for the current practice.

Concrete may be exposed to corrosive effects in a media combination. The classification provided in the Codes does not rule out other corrosive effects on concrete in any media that require special protective measures for concrete and reinforcement, e.g. use of stainless steel or special protective coatings; these shall be specified in the design.

The Codes define various levels of the severity of exposure to corrosive effects on structures made of concrete and reinforced concrete. When a building or structure is affected by several various corrosive media, it is proposed to determine the appropriate zones of specific corrosive effects and corrosiveness degree in these zones. With simultaneous action of corrosive media the requirements are applied relating to the medium with higher corrosiveness indices, unless specified otherwise in the design.

Requirements to Concrete and Structural Concrete Durability. The requirements to concrete durability for each class of the service environment shall comprise:

- allowed types and grades (classes) of concrete components;
- maximum permissible W/C ratio;
- minimum required cement content;
- minimum concrete class by compression strength;
- minimum air-entrainment (when necessary).

The document referentially provides limit values of some concrete mix parameters for various classes of service environments relating to cement class CEM I 32,5 according to GOST 30515 (1997). This part of the Codes is also harmonized with EN 206 (2000).

If the concrete is proportioned according to the boundary values of requirements for the given service conditions, then no troubles occur in the course of service, given that:

- a concrete mix is placed and compacted carefully as well as the due treatment is provided in compliance with the current Codes and other documents taking into account the climatic conditions;
- a structure is used in those environments, for which the boundary values of characteristics were recommended;
- the required concrete covers are provided to reinforcement in compliance with the present Codes requirements;
- routine maintenance of a structure is carried out.

As is stipulated by the current documents, the concrete in components of buildings and structures with corrosive media is recommended to be assumed as having W4 water permeability grade (maximal water pressure, at which on four of six cylindrical samples the water percolation was not observed) and higher.

Higher frost-resistance requirements (rated in the Codes' special annex) shall be imposed on concrete in structures exposed to corrosive liquid media (chlorides, sulfates, nitrates and other salts) and simultaneously to alternate freezing and thawing.

Besides specified above, new Codes include:

- the estimation of aggressiveness of different environmental conditions for HPC with impermeability up to W20 (in former Codes - to W8 only);
- parameters of permeability of concrete, including diffusive permeability of concrete for carbon dioxide and chloride.

Concrete proportioning with account of the service environment effects is mandatory to ensure concrete corrosion and frost resistance. The service environment effects should be considered in concrete mix proportioning, when:

- a structure's target lifetime essentially exceeds 100 years;
- a structure shall have high reliability and minimum risk of failure;
- a service environment is corrosive, but the nature of its corrosiveness is not quire clear;
- it is necessary to ensure improved workmanship;
- a structure service implies special monitoring, with probable future rehabilitation of the structure;
- mass-scale erection of single-type structures is planned;
- new materials are used;
- mix proportioning methods were used with consideration of the current normative and technical documents, but the practical experience turned to be unsuccessful.

The Codes detail the requirements to cements, aggregates, water, admixtures, and reinforcement used for manufacture of concrete and reinforced concrete elements of buildings and structures with corrosive media, as well as the requirements to their surface corrosion protection with regard to the type and degree of the corrosive medium effects. Different cement types are organized into tables, depending on the exposure conditions.

Requirements to structural concrete with new types of reinforcement steel bar and FRP bar (steel specification, crack resistance, the maximum admissible width of crack opening displacement, a thickness of protection layer, etc.) are given in special section of Codes.

Types of Protection against Corrosion. To prevent corrosion failure of concrete and reinforced concrete structures, the Codes provide the following types of protection:

- primary protection: structural concrete choice and the organization of its structure that would ensure resistance of this concrete to the appropriate corrosive medium;
- secondary protection: application of a protective coating that will limit or rule out corrosive failure of structural concrete when exposed to a corrosive medium;
- special protection: other technical measures.

According to the Codes, *the primary protection* measures include:

- use of concretes resisting corrosive environments;
- use of admixtures improving corrosion resistance of concretes and their protective capacity in relation to steel reinforcement, embedded steel parts and connecting pieces;
- reduction of concrete permeability;
- compliance with the additional design and structural requirements in the design of structures.

The secondary protection measures imply protection of reinforced concrete surfaces with:

- paint coatings, including heavy (mastic) coverings;
- membrane waterproofing;
- insulating plaster coatings;
- thin crack-resisting polymer cement protective coatings – when exposed to gaseous media and occasionally exposed to liquid media, under occasional watering or precipitation wetting, and sweating (also for structures with deformations accompanied by crack opening);
- thick polymer cement coatings – when exposed to liquid media;
- piecework or block revetment;
- sealing treatment of a surface layer with chemically resistant materials;
- treatment with hydrophobic compounds;
- treatment with biocidal and antiseptic agents, etc.

The secondary protection is used when corrosion protection cannot be ensured by the primary protection measures. It should be emphasized that the secondary protection, as a rule, requires renewal.

With regard to the extent of the environment corrosiveness, the Codes recommend to use the following protection types or their combinations:

- in low corrosive environments – either primary or secondary protection;
- in medium-corrosive environment – both primary and secondary protection, while implementing the latter by applying a protective coating that limits the contact of the corrosive medium with the structural material;
- in high-corrosive environment – both primary and secondary protection, while implementing the latter by applying a protective coating that prevents the contacts of the corrosive medium with the structural material.

For buildings and structures in the particular economically justified cases of service one may use special corrosion protection.

A final decision on the type and materials of corrosion protection for concrete and reinforced concrete structures should be made on the basis of comparison of performance indicators for alternative solutions. Technical and economic analyses shall take account of capital investments, the average annual cost of protection, and the cost of its periodic renovation as well as the value of forced losses caused by the necessity of disruption in the production process for the time of corrosion protection renovation.

The lifetime of the corrosion protection for concrete and reinforced concrete structures shall correspond to the service life of a building or structure taking into account the necessity of its regular renovation. Selection of the protective measures shall be carried out on the basis of performance option comparison considering the predicted service life and costs including expenses for secondary protection renovation, running repairs and overhauls and other expenses associated with structures' operation costs.

The Codes' separate sections establish the requirements to protection of reinforced concrete components against electro corrosion, the requirements to corrosion protection for embedded parts and connecting pieces as well as safety and environmental requirements.

The Codes comprise a great number of reference annexes describing characteristics of the most important environmental conditions and frequently used protective materials.

CONCLUSIONS

In general, the modern Russian Codes still follow the prescriptive concept, but present a large range of design variables and design options.

The Codes, together with the Interstate Standard of CIS GOST 31384-2008 "Structural Concrete Protection against Corrosion. General Requirements", set the durability requirements for various concrete exposed in different environmental conditions. Essential test methods have been described in Interstate Standard of CIS GOST 31383-2008 named "Structural Concrete Protection against Corrosion. Test Methods".

It is expected that the requirements of the Codes and the above-mentioned Standards will be taken into account in layout designs, specifications and other normative documents regulating manufacture and erection of specific type of structures. The requirements shall establish specified quality measures ensuring technical and process efficiency. They shall also be used in development of process flow and design documentation. In this regard the engineering solutions for corrosion protection of concrete and reinforced concrete structures as well as their connecting elements shall be an independent part of designs for buildings and structures.

The service life design of structures will be one of the most important research and standardization fields for Russia in the near future.

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