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Concrete as a safe building material

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Abstract

Concrete is one of the most popular building materials of the present day with considerable prospects for further development. The possibility of modification with various substances makes it not only a multifunctional material, but above all durable and safe. It gives many new possibilities to contemporary architects and designers, thanks to which the surrounding architecture becomes more and more interesting, for example due to the construction of "green" or architectural concrete. The article describes the features and applications of oncreto in construction, treating it as a safe building material.

Keywords: construction, building materials, concrete, safety

1 Introduction

Concrete is widely known and used today. There are many variations of it and market applications. Its type and application are determined by the technical properties of concrete, which are determined by the basic characteristics of concrete. They include, first of all, compressive strength, water absorption and frost resistance as well as aggregate grain size. [10]

Compressive strength is the basic requirement for concrete, set at the design stage of the structure, concrete elements and the mixture itself. This property is closely related to the microstructure of the hardened cement grout and the strength of the aggregate and the aggregate-grout contact zone. The compressive strength of concrete is determined by its class. According to the PN-EN 206-1 standard, the concrete class is a symbol, eg C25 / 30. The numbers after the letter C denote the characteristic strength determined on cylindrical samples 300 mm high and 150 mm in diameter and cubic samples with the dimensions of 150x150x150 mm.

Water absorption and frost resistance are features that directly affect the analogous properties of concrete. Building standards define the permissible water absorption (up to 4%) and frost resistance (90%). The allowed values are quite large, as it is assumed that they will not be able to fully manifest themselves in concrete. This is mainly due to the fact that the grout coats the grains and prevents water penetration. Void spaces or only partially filled with water act as "buffers" against the effect of pressure increase when water freezes. In practice, however, the water absorption should not be higher than 1.5% (exceptionally 3%), and frost resistance should apply to at least 95% of the randomly selected grains tested. Both of these characteristics are defined only for grains larger than 4 mm.

The optimal graining of the aggregate is such a graining that ensures achieving the assumed properties of concrete and concrete mix of the required consistency, with the lowest possible consumption of cement and water. We can talk about the optimal aggregate only for the specific assumed properties that the concrete mix and concrete are to demonstrate, and not "at all" optimal. For example, a change in the method of compaction may require the use of aggregate with other, more favorable properties in a given case. It may also turn out that the use of specially composed aggregates with low cavity, for making lower strength concretes from them, significantly increases the price of concrete, and therefore it is economically unjustified and therefore it is not done in practice. Regardless of the type of aggregate and its physical properties, it is assumed with high probability that the aggregate with the optimal grain size is the aggregate with the smallest number of cavities between the grains of the pile, while the pile contains the coarsest possible grains of the aggregate. (W) plus the amount of vacuum (P), which is in the concrete mix after it has been prepared, i.e. from C / (W + P). The above dependence, which was formulated by Feret, means that it is

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irrelevant to the loss of concrete strength whether pores in the concrete were formed as a result of air bubbles entering the concrete mixture or due to evaporation of excess water.

Technical properties are important due to the use of concrete as a building material, which ensures broadly understood safety [3, 9]. Four main groups can be distinguished:

- Physical properties: specific and volumetric (apparent) density, porosity, water absorption, water resistance, frost resistance, thermal conductivity, shrinkage.
- Mechanical properties: compressive strength, tensile strength, shear strength, torsional strength, local pressure strength, biaxial compressive strength, triaxial compressive strength, impact resistance (impact strength), abrasion resistance, resistance to dynamic impact, modulus of elasticity.
- Rheological properties: deformability under the influence of permanently acting external stimuli, especially under the influence of: - force loading, - temperature changes, - humidity changes.
- Environmental resistance: - to high temperature, - to low temperature, - to chemical aggression.

Safety, generally defined as a state of no danger in various aspects of activity, is understood primarily as the lack of threat to life, health, property, environment, and civil law [3–5, 7, 9]. The right to security is seen as one of the most important among human rights. Given this fact, it should be provided by every democratic state. The protection of citizens in the form of ensuring their proper security is regulated by legal acts that all - the authorities and the population - must undoubtedly obey.

The broadly understood meaning of the term safety in construction is regulated primarily by the construction law. The currently binding provisions of the Act of July 7, 1994 - Construction Law, as amended, clearly define the requirements for safe design, construction, maintenance and demolition of buildings. The technical conditions to be met by buildings and their location, construction standards and generally accepted principles of construction art are also important.

When considering the field of activity which is construction, in terms of safety, two components can be distinguished: the safety of people and the safety of the structure. The first one is mainly related to occupational health and safety and the development of a health and safety at work plan, the purpose of which is to identify threats to the safety of employees and to define effective preventive measures at the stage of investment implementation. The safety of the structure, in turn, is primarily related to the fulfillment of the limit states of the bearing capacity and suitability for use, including fire safety [1, 11, 13].

2 Concrete in construction

Concrete, known as artificial stone, is a material that has been known in the construction industry for centuries. Nowadays it is a composite made by mixing cement, fine and coarse aggregate, water and possible additives, admixtures or fibers. However, as a combination of rock crumbs with a mineral binder, it was used already in antiquity and was perfect for erecting the most famous buildings from that period. An example is the Roman Pantheon - a temple on a circular plan crowned with a huge dome made of monolithic unreinforced concrete, which is still the largest structure of this type in the world (Fig. 1). However, the dynamic development of this material took place only in the 19th century, when Joseph Aspdin obtained a patent for an artificial binder called Portland cement in 1824 [8]. It is since then that significant progress has been made both in the field of reinforced concrete and concrete technology. Consequently, this material is today the most widely used raw material for erecting all kinds of engineering structures.

The safety of the structure is primarily the high quality of the material used to make it. In the case of concrete structures, the necessary requirements, limitations and specifications for concrete used both for monolithic structures and prefabricated elements are included in the European standard PN-EN 206 Concrete. Requirements, properties, production and compliance and its national supplement PN-B-06265. These standards are peculiar mines of knowledge about concrete, its properties and technology. Moreover, PN-EN 206 implements a new approach to designing the composition and production of concrete, and its main assumption is to guarantee the appropriate durability of the structure and its individual elements [2, 3]. Considering the fact that all erected structures have always been exposed to the harmful effects of the surrounding environment (e.g. freezing or aggressive effects of water and polluted air), and with the progress of civilization, the threat seems to increase due to the production of a much more aggressive environment by industry , it is the durability of concrete that becomes its most important property. It is defined as ensuring the safe operating condition of the structure under specific conditions and the expected service life, which, in accordance with the European standard, is at least 50 years (when the structure is made according to the standard's

Figure 1. The dome of the Pantheon in Rome with a visible oculus - a central opening with a diameter of approx. 7.9 m [4]

recommendations). In order to systematize the issue, the environmental conditions in which concrete may be present are defined by exposure classes (Fig. 2). In turn, ensuring adequate durability of concrete working in unfavorable environmental conditions is possible thanks to the selection of the appropriate composition of the concrete mix to the conditions of use.

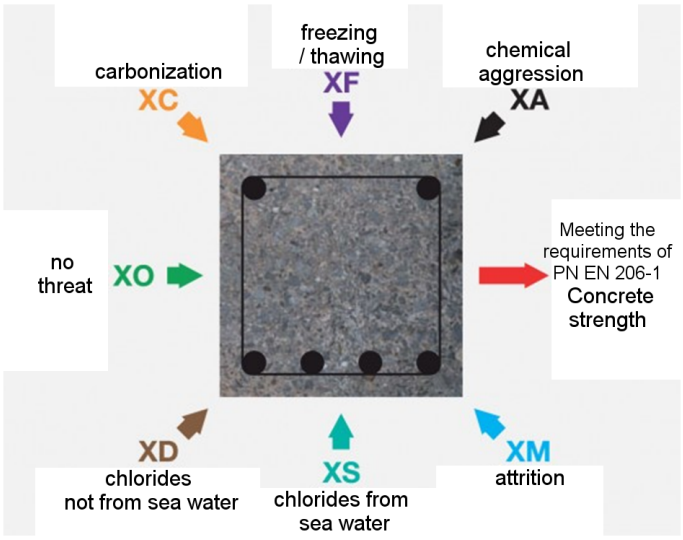

Figure 2. Structure exposure classes according to PN-EN 206 [5] of the appropriate composition of the concrete mix to the conditions of use

Further analyzing the content of the PN-EN 206 standard and taking into account those factors that significantly affect the quality of concrete produced for construction purposes, the most important are:

- density,
- production method,

- use of additives / admixtures.

Concrete covered by PN-EN 206 in terms of density can be:

- light - with a dry density of not less than 800 kg / m3 and not more than 2000 kg / m3,
- regular - with a dry density greater than 2000 kg / m3 and less than 2600 kg / m3,
- heavy - with a dry density of more than 2600 kg / m3.

The density of concrete, as well as its durability in difficult environmental conditions, is closely related to its composition. Therefore, each of the components of the concrete mix is assigned separate standards with guidelines and recommendations for their use, such as PN-EN 197 Cement or PN-EN 1008 Mixing water. In construction practice, the structural concrete, i.e. the one from which the load-bearing elements of buildings are made, is plain concrete. Its quality is determined by the compressive strength - the main parameter taken into account when designing concrete structures. This strength is determined to the greatest extent by the water-cement ratio (w / c), defined as the ratio of the effective water content to the cement content in the concrete mix. The lower it is, the lower the porosity of the mixture becomes, which results in higher strength, durability, and resistance to shrinkage and corrosion. Therefore, it is advisable to try to reduce the w / c ratio in the produced concrete as much as possible. The guaranteed strength value is determined by the concrete class. Currently, with the introduction of European standards, concrete classes are used from C8 / 10 to C100 / 115, which have replaced the Polish scale with markings from B10 to B60, still found at construction sites.

Due to the method of production, concrete is distinguished:

- freight - delivered as a concrete mix by a person or entity who is not the contractor, as well as concrete produced by the contractor outside the construction site or concrete produced on the construction site but not by the contractor,
- performed at the construction site - concrete produced at the construction site by the contractor for his own use,
- produced in a prefabrication plant - concrete produced by a manufacturer of prefabricated concrete elements in the production plant,

In the era of modern construction and the implementation of more and more complex investments, there is no doubt that the most common is ready-mixed concrete in the form of a concrete mix delivered to the construction site from the production plant by means of concrete trucks. Concrete precast elements are also frequently used, e.g. lintel beams or ready-made stairs (Fig. 3), which do not require formwork or reinforcement, and thus facilitate construction works and shorten their duration. Such elements only need to be properly integrated into the structure of the object. On the scale in which the construction industry is developing nowadays, it is rather abandoning self-made concrete mix on the construction site. This activity is practiced only for the implementation of small investments, for example for concreting the fence foundation. This solution is understandable, because concrete from the factory has a much better quality, and thus is a better, safer building material.

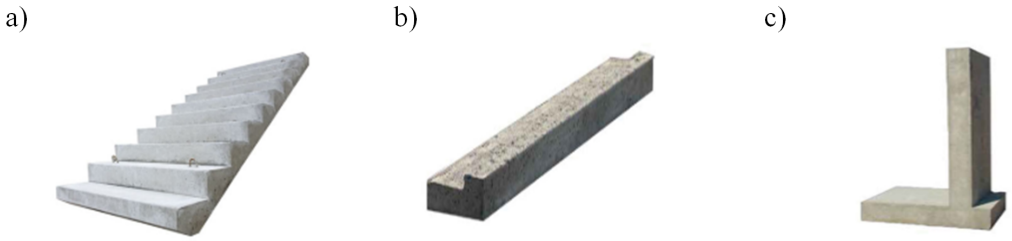

Figure 3. Examples of precast concrete elements: a) stairs, b) lintel, c) retaining wall [12]

Due to the continuous development in the field of concrete technology and the desire to optimize expenditure while improving quality, the issue of using concrete additives and admixtures has become a matter of course and has also been regulated by additional regulations, including PN-EN 934-1 and 2 Concrete admixtures, PN-EN -EN 450 Fly ash for concrete, PN-EN 14889 Fibers for concrete and many others. It often happens that the terms additive and admixture are incorrectly used interchangeably, and the main difference is that the admixture is a substance added

during the preparation of concrete mix in an amount not exceeding 5% of the cement mass, and the additive is a substance whose content exceeds 5% of the cement mass [6]. Admixtures currently constitute a very wide range of products with various properties aimed at improving the properties of the concrete mix and / or hardened concrete, and they may modify one or more features (so-called multifunctional admixtures). However, it should be remembered that they do not always bring only positive effects, because it is possible that by improving one property they worsen another. Hence, appropriate technical knowledge and reference to standard recommendations is necessary. There is no doubt, however, that such a modified concrete has improved features and gives greater design possibilities. Among the numerous admixtures, depending on what they determine the effect, the following groups are distinguished:

- plasticizing,
- liquefying,
- aerating,
- sealing,
- accelerating / delaying the bond,
- accelerating hardening.

As previously mentioned, the main development direction in which the production of concrete is heading is increasing its strength and durability. It is possible thanks to the use of admixtures with different properties and their continuous improvement. For example, plasticizers, i.e. plasticizing admixtures, are able, without changing the consistency of the mixture, to reduce the amount of water contained in it, and thus reduce the w / c ratio. Air-entraining admixtures, in turn, guarantee greater resistance to frost, but cause a decrease in strength. For concrete exposed to unfavorable environmental conditions, sealing admixtures are used, which reduce its water absorption, and thus improve its durability.

When it comes to additives, their main task is to save cement, supplement dusty aggregate fractions and, as with admixtures, improve selected properties of concrete. They mainly take the form of crumbs, dust or fibers. Among them, there are fly ash, blast furnace slag and silica dust. In order to obtain better results, it is possible to use concrete additives together with admixtures, e.g. plasticizers, which is a common construction practice.

3 Summary

Concrete is undoubtedly the most popular building material of the present time, with a significant prospect for further development. The possibility of modification with various substances makes it not only a multi-functional material, but above all durable and safe. It gives many new possibilities to contemporary architects and designers, thanks to which the surrounding architecture becomes more and more interesting, for example due to the construction of "green" or architectural concrete.

Properly designed concrete structures meet the limit states even in the most extreme conditions, such as the effects of seismic events. However, it should be remembered that when designing, choosing, among others, the class of concrete or its exposure class, the values given in the standards are based on a number of years of research and improvement of the composition of the concrete mix, so that it guarantees the highest level of safety for the structure. It is also important that each building be used correctly, i.e. according to its intended purpose, and the role of reinforcement that works with concrete in transferring tensile loads.

The quality of the material, and in this case the concrete, should always be of paramount importance in the process of designing and implementing the investment. Saving on cheaper solutions with lower strength parameters is an unacceptable practice and may result in a construction disaster on a larger or smaller scale, and supervision over compliance with the guidelines contained in the project is the absolute responsibility of the site manager. It would seem that age structures, such as the previously mentioned Pantheon or many other temples and monuments have survived for so many years, despite the lack of guidelines such as standards and the use of special accessories or production techniques. However, it should be remembered that these objects are usually redesigned - their durability and strength is possible thanks to their extremely large size and weight. In modern, balanced and, above all, safe construction, it is necessary to optimize the dimensions while ensuring the appropriate load-bearing capacity of the structure. Especially when the world of science and technology offers so many new possibilities.

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