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The importance of the resistance of reinforced concrete remediation bunds, improvement options

Vasbeton felfogóterek ellenállóképességének jelentősége, fejlesztési lehetőségek

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Bevezetés

A veszélyes anyagok tárolása során bekövetkező rendkívüli események megelőzése és kezelése tervezői, kivitelezői, üzemeltetői és hatósági szempontból is kiemelt jelentőségű feladat. Feltételezem, hogy ez a kritikus pontok feltárásával, elemzésével és a releváns következtetések megfogalmazásával, valamint a fejlesztési irányok meghatározásával hatékonyan megvalósítható. Jelen publikáció célkitűzése elemző és laboratóriumi vizsgálatok útján képet alkotni a veszélyes anyagot tároló tartályok felfogótereinek veszélyeztetettségről, valamint azok ellenállóképességének fejlesztési lehetőségeiről. A publikációban a tárolt veszélyes anyag tulajdonságainak megfelelő betonkeverék megválasztásának jelentősége kerül bemutatásra, valamint az elvégzett laboratóriumi vizsgálatok részeredményeinek közlése történik meg.

Introduction

The prevention and management of incidents during the storage of hazardous substances is a priority for designers, contractors, operators and authorities. I assume that this can be effectively achieved by identifying and analysing critical points, drawing the relevant conclusions and defining the directions for improvement. The objective of this publication is to provide a picture of the vulnerability of the remediation bunds of tanks storing hazardous substances and the possibilities for improving their resistance by means of analytical and laboratory tests. The importance of choosing the right concrete mix for the properties of the stored hazardous material is presented and the partial results of the laboratory tests carried out are reported.

Kulcsszavak: vasbeton felfogótér, veszélyes anyag, kémiai korrózió, ellenállóképesség fokozása, fejlesztési lehetőségek

Keywords: reinforced concrete remediation bund, dangerous substance, chemical corrosion, increasing resistance, improvement options

1. Introduction of scientific problem

Social growth and technological progress are a natural consequence of the continuous expansion of industry. Literature sources show that world chemical sales are growing year on year. As a result, a large number of hazardous materials plants have been set up around the world and are expected to expand (due to increased demand for raw materials and a wider range of chemicals) and to be expanded in the future [1]. Concrete and reinforced concrete structures (in addition to steel) are used in very large quantities in these plants and their installations. Concrete mixtures and structures made using them must meet a number of quality and safety criteria and tests during design, manufacture and construction.

At the same time, the complexity of the concrete technology process means that the designer, contractor, operator and authority have to take into account a multitude of risk factors in their activities. These risk factors may be exacerbated by the meteorological anomalies experienced in recent years and their extreme nature. This is because radical changes in the weather over a short period of time can put concrete structures under increased stress. This may reduce their resistance to further external influences. The conclusion to be drawn from this line of thought is that there is a need to review standards based on technological elements that are becoming obsolete as a result of rapid technological progress and to formulate and systematise recommendations for new technological elements [2].

The reinforced concrete structures of plants handling hazardous materials, and thus the reinforced concrete remediation bunds, may be subject to irreversible effects that may cause damage and possibly short-term failure. Thus, serious accidents involving hazardous materials may occur as a result of a reduction in the stability and resistance of the structures. These accidents can result in natural, built environment and human health, local and permanent damage. In order to perform their function to the extent required, bunds facilities need to be designed, constructed, operated, monitored and maintained to the appropriate level.

2. The importance of the resistance and improvement options – laboratory testing

Chemically aggressive substances can cause swelling or dissolution corrosion of concrete, possibly both at the same time. The first signs of swelling corrosion of concrete occur on reinforced concrete structures in contact with natural water. Dissolution corrosion has come to the fore with the spread of industrial and municipal technologies. It should be noted that protection against swelling corrosion has a history going back 80 years, whereas protection against dissolution corrosion is recent. However, it is important to stress that dissolving corrosion of concrete is a multifaceted phenomenon, which makes it more difficult to treat and its methods are not yet fully developed [3].

Practical experience shows that the resistance of concrete to chemical attack is poor, but can be improved, for example by improving the internal structure of the concrete. Typical concrete technology methods to improve the resistance to chemical attack include:

- use of cement admixtures (e.g. fly ash, silica, metakaolin),
- use of low water/cement ratio,
- use of nanotechnology materials (e.g.: nanocomposite, nano-titania),
- and the use of acid-resistant coatings, which can be considered as secondary protection [4-5].

In the laboratory test, the formulation used was determined on the basis of a concrete mix commonly used in industrial practice and the criteria for environmental classes according to MSZ

4798:2016. Based on these criteria, the standard concrete properties of the mix are as follows: C35/45-XC4-XA5(H)-XK2(H)-XV2(H)-16-F4-100 year MSZ 4798. The concrete composition used in the laboratory test is illustrated in Table 1.

Table 1: The concrete formula used. Source: own editing

Name of raw material				**Weight kg/m³**	**Volume l/m³**
Cement	CEM III/B 32.5 N LH/SR			351	129
Water	mains			155	155
V/C				0.40	
Additive	1	**OHK 0/4**	42%	775	290
	2	**OK 4/8**	20%	369	135
	3	**OK 8/16**	38%	701	262
Total additives			100%	1 846	687
Other agents	1	**DenBraven**	1.3 l to 100 kg cement	5.07	5.07
	2	**Metaver**	10%	39	14
Air			1%		10
Designed body density and volume, kg/m³, litre				2 396	1 000

Given that the criteria for the environmental classes defined by the MSZ 4798 standard required a low water/cement ratio, a flow agent was used to improve workability. Literature sources indicate that various cement admixtures can significantly increase the chemical resistance of concrete. For this reason, metakaolin was added to the formulation. [6-9]

During the test, 10 to 10 concrete test cubes with an edge length of 150*150*150 mm were prepared in three measuring cycles according to the recipe shown in Table 1. For each measuring cycle, the test blocks were stored in water for 7 days after desalting and then in laboratory air for 28 days. Coating of 3 to 3 test cubes per measurement cycle was carried out using a two-component epoxy resin protective coating as the coating material. In each case, the protective coating was applied to the specimens in 2 layers. A waiting period of 10 days was determined for the complete curing of the coatings, after which 6-6 test blocks were exposed to aggressive chemical attack (20% hydrochloric acid) (Figure 1), and 3-3 blocks were stored in laboratory air as controls.

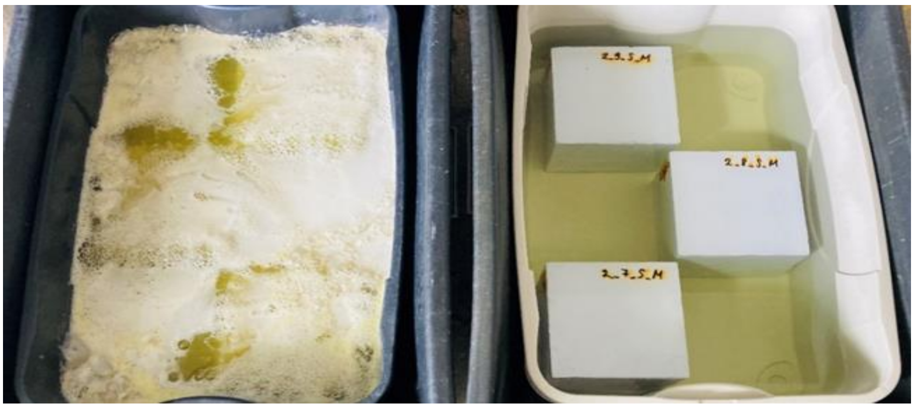

Figure 1: Test cubes immediately after placing in 20% hydrochloric acid (left side: uncoated; right side: coated). Source: own editing

Figure 1 clearly shows that the surface of the uncoated test cubes reacted with the hydrochloric acid immediately after insertion, while no visible reaction was observed in the coated cubes. At the end of the exposure time, the test specimens were cleaned and then dried in a drying oven at 50°C for 4 hours, after which they were ventilated in laboratory air. The exposure time was 24 hours for the first measurement cycle, 72 hours for the second and 144 hours for the third.

For the test specimens, the first number in their identifier indicates the measurement cycle, the second number indicates the number of frames in the measurement cycle, "k" indicates the control frame, "s" indicates the uncoated frame in acid and "s_m" indicates the coated frame in acid.

The measurements carried out during the test can be divided into three groups. In the first group, the size and mass of the test cubes were measured, in the second group, the compressive strength values of the test cubes were determined using a non-destructive test (Schmidt hammer) and in the third group, the compressive strength values were determined using a destructive test (concrete crusher).

3. The laboratory test results and their analysis

The results of the tests carried out during the experiment are briefly presented below. From the values obtained after back-measuring the mass of the specimens, it can be seen that the protective epoxy resin coating applied in two layers only slightly increases the mass of the specimens, but that the mass of the specimens without protective coating is significantly reduced by the 20% hydrochloric acid, through dissolution corrosion. (Figure 2)

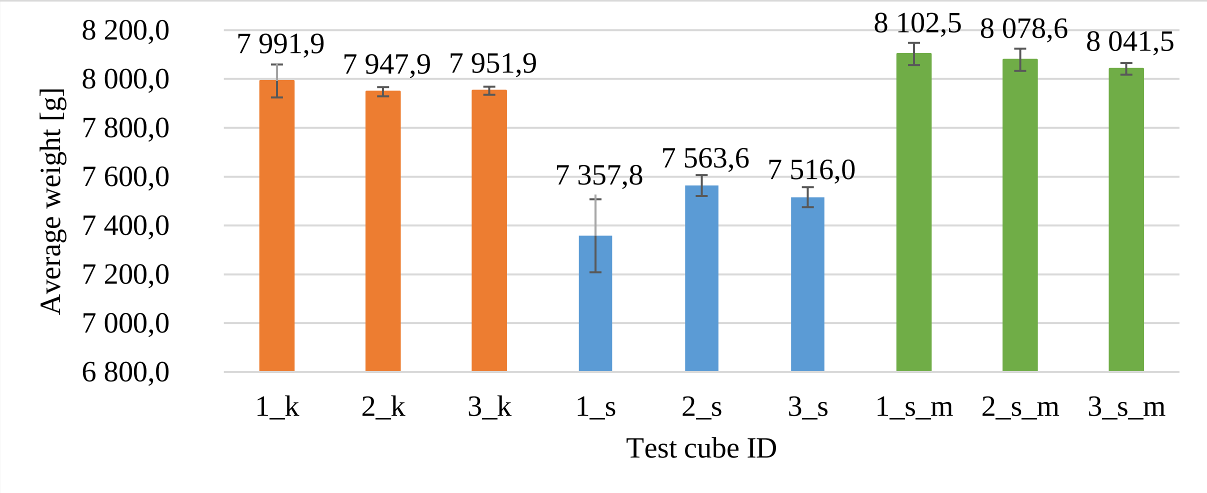

Figure 2: Evolution of the average mass of test cubes compared by measurement cycles. Source: own editing

Figure 3 illustrates the evolution of the average compressive strength of the test specimens in comparison with the coating and the exposure medium.

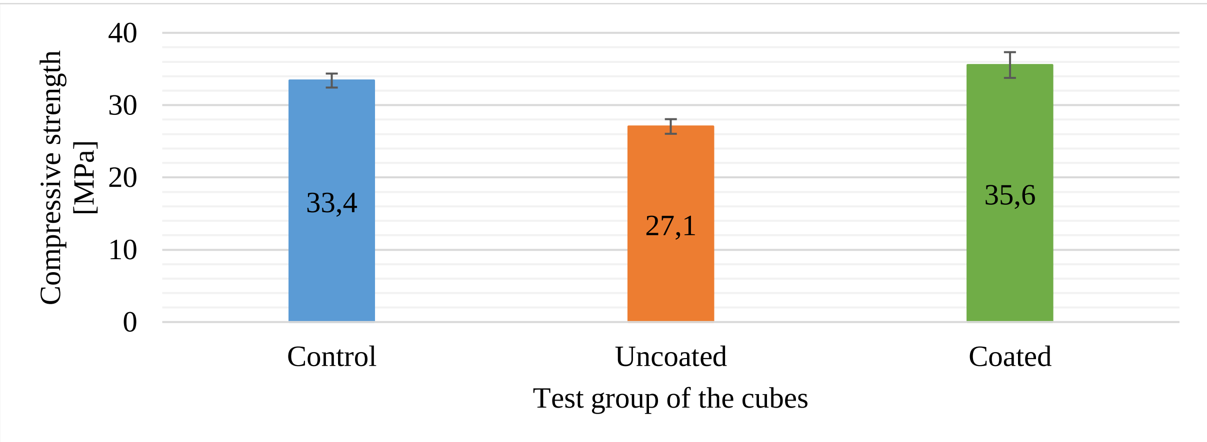

Figure 3: Evolution of the average compressive strength of test cubes compared by media and coating. Source: own editing

Figure 3 shows that the epoxy resin protective coating increased the average compressive strength of the test specimens slightly (2.2, MPa), but only to a negligible extent. However, the fact that the average compressive strength of the uncoated test specimens was 6.3 MPa lower than that of the control test specimens is of greater significance. Figure 4 illustrates the evolution of the average compressive strength of the test cubes in comparison with the coating and the exposure medium.

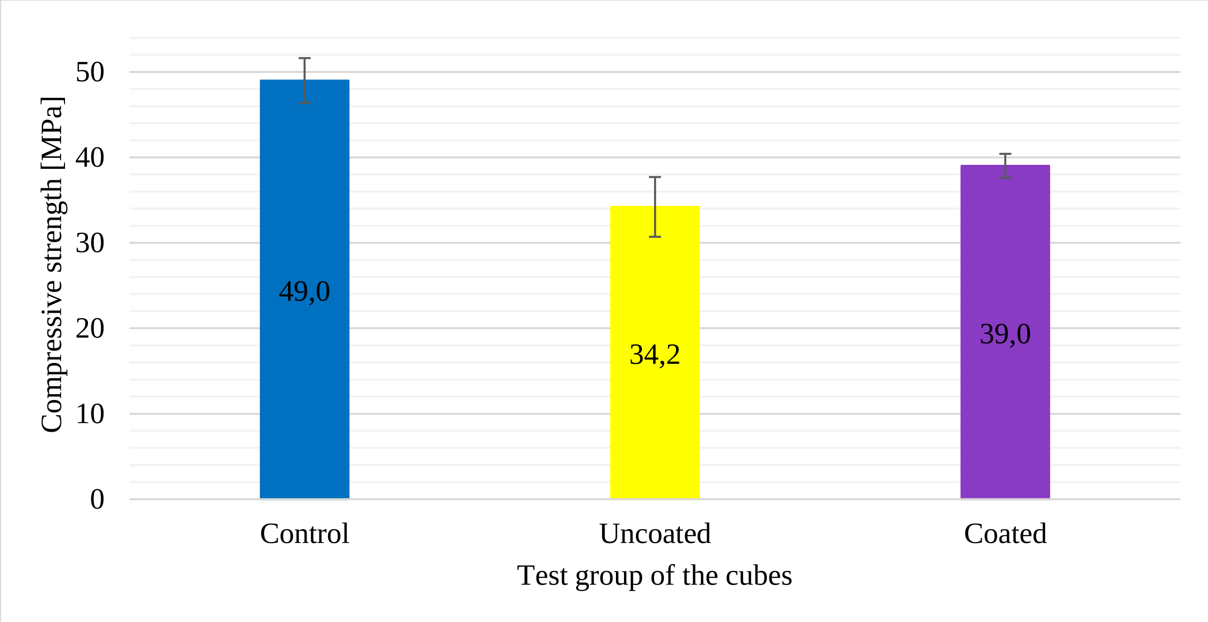

Figure 4: Evolution of the average compressive strength of test cubes compared by media and coating. Source: own editing

As shown in Figure 4, the average compressive strength of the uncoated test cubes is 14.8 MPa lower than that of the control test cubes. While for the test specimens with protective coating this difference is much smaller (10,0 MPa).

3. Safety aspects of emergency planning

Remediation bunds are one of the most important defense locks in internal defense design. However, there are additional defense design considerations that can be summarized as follows. One of the important areas of prevention of dangerous goods logistics accidents is the prevention of the release of flammable dangerous substances into the open air, the most important technical basis of which is the installation of signaling systems [10, 11]. In addition to property protection systems, fire protection signaling systems installed for fire prevention purposes [12], which perform their assignments together with widely used fire protection extinguishing systems [13]. In addition to fire protection signaling systems, it is also particularly important the application of monitoring systems for the detection of dangerous substances that are primarily flammable and toxic in industrial environments. These systems can be installed inside buildings, such in the case of commercial and logistics warehouses, or outside the building in the technological and natural environment [14]. In recent years, as a result of technological development, the simplification of these systems and the harmonization of their application with systems serving other purposes have come to the fore. The latter supporting technical system can also be camera systems installed for property and occupational safety purposes [15]. Finally, we can learn important practical lessons for the development of fire protection authority activity when dealing with the policing issues of event order security [16].

5. Summary

To summarise the literature and this publication, the design of the remediation bund structures should take into account not only the forces acting on the structure but also the environmental effects that may occur under the operating conditions of the structure.

Among the most important causes of concrete deterioration are the various corrosion effects. Chemically aggressive substances can cause swelling or dissolution corrosion of concrete, possibly with a simultaneous effect. Since both can lead to damage to the reinforced concrete structure, and in severe cases to its destruction, the study of this area is of particular importance for plants dealing with hazardous substances.

In the event of damage to a storage tank, the leaking, chemically aggressive liquid can damage the concrete surface of the reinforced concrete remediation bund and, depending on the depth of the impact, the inner parts of the concrete, and in severe cases even destroy it. Based on the results of the laboratory tests carried out, it can be concluded that, after the damage event has been remedied and the affected concrete surfaces have been cleaned, the compressive strength of the concrete surface can be approximated well using a non-destructive method (Schmidt hammer). Therefore, it is recommended to perform a compressive strength test with a Schmidt hammer after the damage event. Based on this and the results of further tests, it is then decided whether the necessary step is to dismantle the remediation bund or to repair or renovate it.

However, it is recommended to apply a protective coating to reinforced concrete remediation bunds during the construction phase, for which chemical-resistant epoxy resin is an excellent choice. In addition, for existing bunds, it is recommended that the application of a protective coating is included in the maintenance schedule.

It should be noted, however, that there are limitations to the use of epoxy resin, which need to be assessed on a case-by-case basis. These include, for example, site, environmental and use restrictions and the issue of a suitable surface condition. It is therefore recommended that the substrate is carefully inspected and prepared prior to the application of the epoxy resin protective coating, which is a key task following a damage event.

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