Durability of reinforced concrete for transport constructions

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Abstract. Leaching corrosion by dissolving cement stone from ordinary Portland cement (cement stone from general construction (GCC)) and cement for transport construction in water and chloride solution was investigated. Stone from GCC in water dissolves on average 3 times faster than transport cement and in chloride solution under similar conditions – 2-4 times. The addition of silica fume to cement reduces the solubility of transport cement stone by 3-5 times, and impregnation with compounds that reduce the solubility of lime by 2-4 times.

1. Introduction

The durability of reinforced concrete structures for transport construction in Russia is ensured by the requirements of a number of regulatory documents that prescribe high strength, frost resistance, impermeability and other characteristics. At the same time, the real service life of reinforced concrete bridges and other transport structures in Russia does not exceed 25-30 years, instead of the standard 50-100 years. There are many different processes that can cause destruction of a concrete structure, including, for example, reinforcement corrosion, sulfate corrosion, and frost damage. [1]

Typically, the properties of the corrosion resistance of concrete, determined in laboratory conditions, differs from the actual work of structures under aggressive conditions, since during operation many factors act simultaneously on concrete. [2, 3]

In addition to design solutions, the service life of these structures depends on the corrosive effect of NaCl-based de-icers on concrete. The greatest destruction of reinforced concrete structures is noted during wetting and leaks, especially in combination with dynamic loads and when exposed to chloride solutions. At the same time, a synergistic negative effect is noted, including exposure to frost.

As is known, the porosity of cement stone affects to a greater extent the durability and corrosion resistance of concrete. [4] In this regard, to increase the durability of cement concrete working in aggressive environments, first of all, it is necessary to reduce porosity, increase density, in order to prevent the possibility of penetration of components of an aggressive environment into the concrete. Silica fume additive has long been known as a component that improves the properties of concrete [5, 6]. It is interesting to study the kinetics of corrosion of concrete obtained on the basis of special cement for transport construction in combination with silica fume.

2. Materials and methods

In this work, we investigated the comparative kinetics of leaching corrosion by the mass loss of cement stone from general construction (GCC) and cement for transport construction in water and...
NaCl solution, depending on the W/C and the composition of the cement composition. Both cements were of the same class CEM I/42.5 of one Iskitimcement factory. Samples 2x2x2 cm in size from the dough of the specified cements with W/C 0.29; 0.5 and 1.0 hardened at heat-moisture treatment (HMT) at 70 °C according to the regime of 3+6+3 hours and were additionally kept under normal conditions for 28 days. Silica fume was introduced into separate compositions based on transport cement, and some of the samples from transport cement were also impregnated with a lime dissolution inhibitor. The samples were water-saturated, weighed, placed in a flask with water or a 20 % NaCl solution with a constant ratio of Water:Solid = 30 (by volume) and were "dissolved" on a shaking table under constant conditions for 10 hours. The mass loss was used to evaluate the leaching kinetics every 2 hours.

3. Results and discussions

The generalized test results are shown in the figures. As can be seen from Fig. 1, the “dissolution” of the stone from the GCC in water shows that there is a high level of weight loss during leaching at high W/C. At low W/C, leaching does not exceed 0.5–1.0%. An increase in the leaching duration also leads to an increase in mass losses, which do not fade over time, but increase somewhat.

![Figure 1. Loss of mass during the leaching of general cement in water.](image-url)

The loss of mass by the GCC stone during leaching in a NaCl solution occurs almost linearly, without attenuation (Fig. 2). The mass loss in the chloride solution at low W/C is comparable to the loss in water, but already at W/C = 0.5 it exceeds water leaching by 3 times.
Figure 2. Loss of mass during the leaching of stone from building cement in a 20% solution of NaCl.

It can be seen from Figs. 3 and 4 that the mass loss by the samples of transport cement occurs with intense attenuation in time when processed in water and with less attenuation in a salt solution. Absolute values of mass loss are 2-4 times less compared to GCC in similar environment at a W/C of 0.5 or more.

Thus, it can be seen from the experiments that the leaching of the stone substantially depends on the W/C, as well as the type of cement. Loss of mass by stone at W/C 0.29 is low, not more than 0.5-1.0% and does not depend on the type of cement. And vice versa-leaching of cement at W/C 0.5–1.0 increases significantly and depends on the type of cement. Both in water and in salt solution, the stone from the GCC dissolves 2 to 4 times faster than stone from transport cement.

Figure 3. Loss of mass during leaching of stone from transport cement in water.
Figure 4. Weight loss during stone leaching from transport cement in a 20% NaCl solution.

To increase the resistance of cement stone to leaching corrosion, including in saline solution, microsilica was added to the transport cement. The addition of silica fume significantly increases the corrosion resistance of the stone (Figure 5), as well as surface impregnation with a lime dissolution inhibitor in the form of NaH$_2$PO$_4$×2H$_2$O. This additionally reduces the weight loss during leaching corrosion by 3–5 times, not exceeding the mass loss of 0.5% at W/C = 0.5.

Figure 5. Weight loss during stone leaching from transport cement with the addition of 10% silica fume in a 20% NaCl solution.

To put these results into practice, according to our proposals, at the Altaiavtdor Novoaltaysky Bridge Structures Plant, concrete blocks of dividing strips with silica fume were manufactured since 2000 (Figure 6) according to patent No. 2232144 and utility model certificate No. 29478 of 06/10/2002. For the repair of these blocks for 15 years, we have manufactured and supplied a dry repair mixture with
silica fume. As can be seen from the figure, products after 20 years of operation in aggressive solutions with NaCl look satisfactory.

![Figure 6. M52 federal highway in front of Novoaltaysk with concrete blocks of the dividing strip.](image)

Our proposal for the manufacture of span beams and other elements of the bridge, as well as culverts, did not find support from the plant's management due to an increase in the cost of raw materials. It should be noted that silica fume is 2.5 to 3 times more expensive than cement, although its consumption is only 7.5 - 10% by weight of the binder. At the same time, the durability of concrete structures increases significantly.

4. Conclusions
1. It is established that the water-cement ratio directly affects the corrosion resistance of cement stone
2. Special cements for transport construction are characterized by better indicators of corrosion resistance in comparison with ordinary ones.
3. The addition of silica fume to transport cement can reduce leaching with chloride solutions. The results are tested on structures for transport construction.

References
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