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Investigation of durability of centrifuged reinforced concrete supports for overhead power lines

R. Kliukas, O. Lukoševičienė and A.Jaras

Department of Applied Mechanics, Vilnius Gediminas Technical University, Lithuania

Abstract

Rail transport is an important part of the logistics chains in the world. To make rail transport competitive, we need more investment in infrastructure and more efficient and innovative technological solutions. From an environmental point of view, the efficiency of rail transport is highly related on the electrification of the rail network. One of the elements required for electrification is the support poles of the overhead contact lines, which are usually made of reinforced concrete, produced by centrifugation. In this paper presented experimental studies have been performed to investigate the long-term physical effects of salts and multicycle temperature gradient on centrifuged concrete with chemical admixture.

Keywords: durability, centrifuged concrete, chemical admixtures.

1 Introduction

Rail transport is an important part of the logistics chains in the world. To make rail transport competitive, we need more investment in infrastructure and more efficient and innovative technological solutions. From an environmental point of view, the efficiency of rail transport is highly related on the electrification of the rail network. At present, Lithuanian railways are one of the least electrified (~ 9% of the total network).

One of the elements required for electrification is the support poles of the overhead contact lines, which are usually made of reinforced concrete, produced by centrifugation. Centrifuged reinforced concrete structural elements have a number of

advantages. Due to the special production technology, by centrifugation, the concrete in the rotating metal mold is subjected to centrifugal forces and pressed against the mold walls particularly well. Concrete compacted in this way is significantly stronger than concrete of the same composition compacted in other ways. Structural elements made of centrifuged reinforced concrete have significantly better bending and torsional strength properties, and their compressive strength is also significantly higher.

Centrifuged reinforced concrete elements of an annular cross-section are ideal for supports of overhead contact lines, as they are resistant to effects of atmosphere, and their resistance to mechanical impact in any direction of cross-section is the same.

The main reason why reinforced concrete structures do not last their service life is the corrosion of the protective concrete reinforcement layer, followed by the corrosion of the reinforcement. Special studies [1] have shown that the outer layers of the centrifuged element are the strongest and the inner layers from 16 to 20% weaker on average. The difference between the strength and deformability of centrifuged concrete through the wall thickness of the element can reach 30% and depends on the composition of the concrete and the centrifugation mode.

The durability of concrete depends on the quality of the concrete components, its degree of compaction, residual water-cement ratio, product hardening conditions, wetting and drying conditions, exposure to various chemicals, carbonation, etc. [2-4].

Studies on the technical condition of reinforced concrete overhead line supports operated in Lithuania have shown that centrifuged elements are significantly more durable and reliable compared to vibrated concrete elements [5].

2 Methods

The durability of reinforced concrete structures is determined by the resistance of concrete to physical, chemical or biological effects. One of the most aggressive factors is the corrosion of concrete caused by the physical effects of salt in saline groundwater. Salts in concrete cause a number of negative factors. Salt reduce pH of concrete, and the acidic reaction weakens the structure of the concrete. The salt shrink and retain water in the pores and capillaries of the concrete, which causes additional damaging crystallization pressure [6].

One way to increase the service life of reinforced concrete structures operated under physical salt attack is to use admixtures in the concrete mix to produce denser concrete. Experimental studies, by authors, have been performed to investigate the long-term physical effects of salts and multicycle temperature gradient on centrifuged concrete with chemical admixture [7]. During the research, 84 specimens of centrifuged concrete with an annular cross-section were produced in the construction factory. The specimens were prepared using a single-layer wheel centrifuge. Cement, sand, crushed stone and water were used for the production of the concrete mix. In order to select a rational chemical admixture that increases the durability of centrifuged concrete, three-quarters of the prototypes were fabricated using the

chemical admixtures superplasticizers C-3 and Dofen, as well as acetone-formaldehyde resin ACF-3M.

The compositions of the concrete mixes, including the chemical admixtures, are selected so that the slump of concrete cone of such mixes could corresponds to an analogous parameter of workability of the admixture-free concrete mix. This was ensured by changing the water to cement ratio.

A part of an annular cross-sectional specimens were cut into eight prisms with one side equal about 200mm and the other corresponding to the thickness (50-95mm) of the annular specimen. From prismatic specimen two were left to store under normal temperature and humidity conditions, and the other three were soaked for 25, 50 or 75 cycles in water and air-dried at 100°C, the other three soaked for 25, 50 or 75 cycles in saline and air dried at 100°C. This ensured the reliability and comparability of the experimental results.

In order to evaluate the degree of aggressive effect of the specimens on the mechanical properties of the centrifuged concrete, the main and control prismatic specimens were axially compressing in the dry state after 25, 50 and 75 cycles. Thus determining the mechanical properties of centrifuged concrete in compressive strength and modulus of elasticity.

3 Results

The resistance of concrete to the impact of the aggressive environment was assessed using the coefficients α and β: estimated prismatic compressive strength f_c and modulus of elasticity E, respectively. The resistance coefficients α are calculated using relation of the prismatic compressive strength of centrifuged concrete subjected to the cyclic action of drying in the air (100°C) and wetting (20°C) in water (Figure1, a) or salt solution (Figure 1, c), with prismatic compressive strength of centrifuged concrete cured in air of normal ambient temperature and humidity.

The experimental data have shown that admixtures actually produce the positive effect on the considered indicator of spun concrete resistance. In this case, the admixtures C-3 and ‘Dofen’ appeared to be most effective.

Comparing the data given in Figure 1, it can be observed that in the case of a complex cyclic effect of temperature changes and a salt attack (c, d), the decrease in the mechanical indicators’ values of ordinary centrifuged concrete is not faster than that found under the condition of a particular aggressive effect of temperature changes on the considered concrete. In the case of a complex effect of a salt solution and temperature changes, the negative effect of the latter, shown by the formation of micro cracks in concrete, is smoothed by a positive effect of new formations of salt crystals in micro cracks and pores on the strength and deformability of concrete.

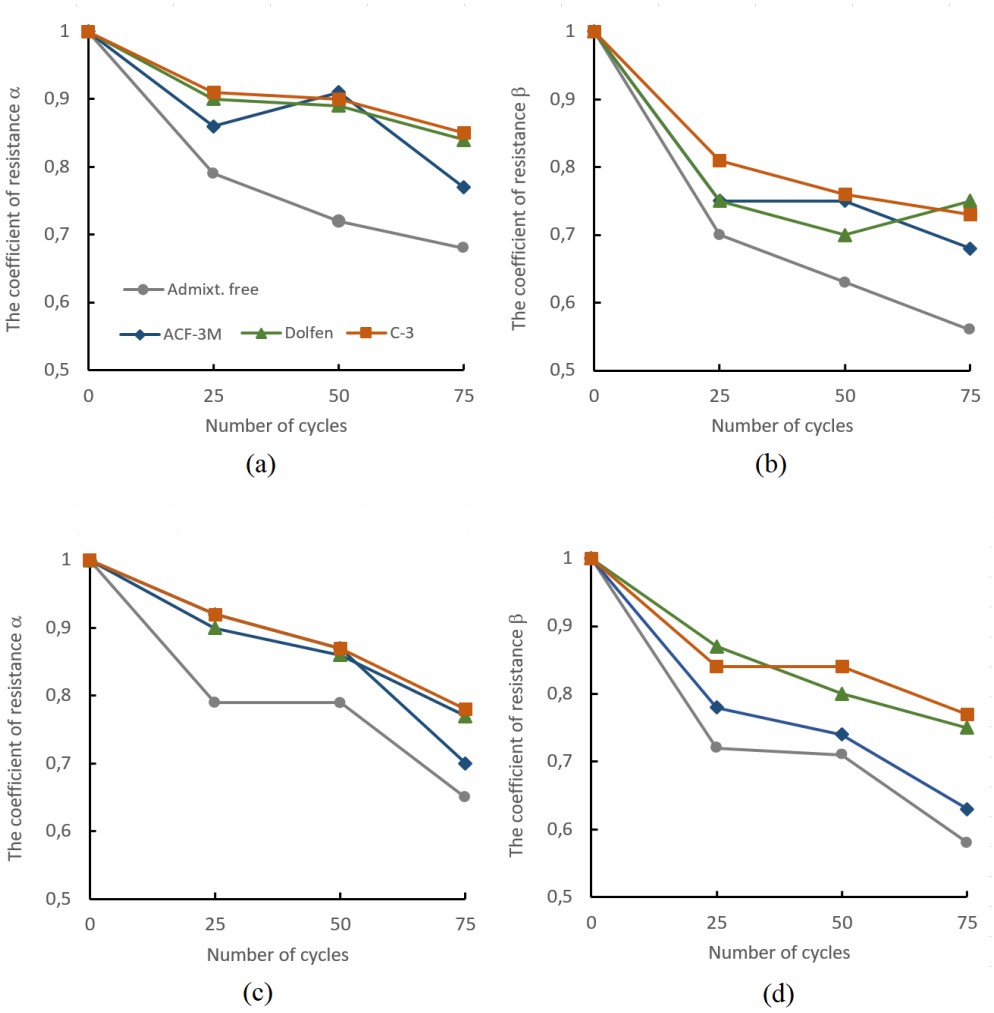

Figure 1. Diagrams of the relation of the resistance coefficient of centrifuged concrete α and β based on the number of cycles of its drying in the air and wetting in water (a, b) or salt solution (c, d)

4 Conclusions and Contributions

The rational content of chemical admixtures for centrifuged concrete is 0.15% by weight of cement using formaldehyde resin ACF-3M and 1% by weight of cement using superplasticizers C-3 and Dofen, respectively. This is explained by the fact that about 25% -30% of the admixtures are washed out together with the free water during centrifugation.

It was found that the chemical admixtures C-3, Dofen and ACF-3M have a significant positive effect on the mechanical properties of centrifuged concrete operated in dry and hot climatic conditions. Taking into account the factors of temperature changes and corrosion of concrete of the third type, it was found that the most effective chemical admixtures improving the durability of centrifuged concrete

operated in these extreme environmental conditions, superplasticizers C-3 and Dofen can be recommended.

It has been established that a cyclic temperature changes from 100°C to 20°C has a significant negative effect on the mechanical properties and durability of centrifuged concrete. At the same time, the decrease of the mechanical properties of this concrete, observed with an increase in the duration of exposure to a cyclic temperature changes, weakens over time, i.e. over time, concrete "adapts" to these aggressive environmental conditions. It was revealed that under the combined effect of temperature changes and salt solution, corresponding in composition to groundwater in the deserts and semi-deserts, complex and significant processes flow in the structure of centrifuged concrete. First, the process of destruction of the concrete structure is caused by cyclic temperature changes. Second, the presence of the effect of a salt solution helps to improve the structure of concrete in the initial period of this complex effect of the environment. This is due to the fact that over time, the process of crystallization of salts in the pores, as well as in concrete micro-cracks, which have a different prehistory of appearance, including those that have appeared from a cyclic temperature changes, takes place. With a long-term complex effect on concrete of temperature changes and salt solution, this positive effect of corrosion of concrete of the third type on its strength and deformation properties turns into a negative one, as the effect of the pressure of surfaces, growing salt crystals on the wall of pores and micro-cracks of concrete is more noticeable.

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