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Assessment of the Operational Safety of Roads and Transport Structures with Use of the Fracture Mechanics Methods

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Abstract

The study is aimed at revealing the correlation between the critical coefficient of stress intensity and slag alkaline cement-free concrete structure and strength. Based on the fracture mechanics methods, the comparative assessment of crack formation in concrete of transport structures based on traditional and cement-free slag alkaline binder is performed. The comparison of criteria of crack resistance of high strength slag alkaline concrete and portland-cement concrete has shown that the first one has the stress intensity coefficient 1.5 times higher, fracture energy value 2.4 times higher, a bigger crack size at the same level of loading. Thus, it is concluded that slag alkaline concrete is a perspective and durable material for road and transport structures.

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Keywords: road surface fracture; transport structures; slag alkaline (cement-free) binder; fracture mechanics methods; crack resistance; concrete deformability

1. Introduction

In recent years, the interest to the assessment of concrete fracture process upon various stress conditions has been growing. It is explained by raising the requirements to its quality, expansion of the application range and operational conditions, as well as by use of relatively new kinds of binder for its production such as cement-free slag alkaline binder.

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The study is aimed at revealing the correlation between the critical coefficient of stress intensity (K_{Ic}) and slag alkaline cement-free concrete structure and strength.

The phenomenon of concrete and reinforced concrete fracture is a complex multi-staged process of appearance, growth and development of cracks. In order to forecast the behavior and reliability of road surfaces and structures as well as their fracture parameters, it is required to know how fast cracks will grow in the material and, consequently, how fast the residual strength will decrease.

Based on the fracture mechanics provisions, the comparative assessment has been performed as to the crack formation in concretes of transport structures, based on traditional and cement-free slag alkaline binder.

The correlation between the critical coefficient of stress intensity (K_{Ic}) and slag alkaline concrete structure and strength is revealed. It is shown that high-strength slag alkaline concrete compared to portland-cement concrete has higher values of K_{Ic}, a bigger limiting crack size at the same level of loading, which predetermine its high performance.

2. Main text

2.1. Materials and methods

The study considers the use of slag alkaline concrete of various strength cured under normal conditions as well as being steamed, tempered with soluble glass with various silicate modules and density. Alkali-lime index of granulated blast furnace slag amounted to 1.04; specific post-grinding surface $S_{sp.} = 320 \div 340\ m^2/kg$.

In course of testing, standard test beams 4x4x16 cm were used when subjected to loadings as per the three-point bending scheme [National Committee for Construction and Investments (1991)].

Based on the obtained experimental data, the main crack resistance criteria were determined. The deviation of the curve “loading–deformation” from the rectilinear direction in the beginning of a loading process was considered to be the effect of the availability of a microcracking zone before the crack apex in a fragile material. It is proved by the measurement of the speed of ultra sound passing through a loaded test beam in course of testing. It has been noted that the moment of ultra sound wave speed slowdown in a material corresponds to the moment of the beginning of noticeable nonlinearity on the chart. This nonlinearity has nothing to do with the phenomenon of plasticity observed in materials of clear crystalline nature and stipulated by motion of dislocations when subjected to loading.

Critical crack length a_c is a derivative of fracture viscosity and it shows the crack size allowable in the structure material if it suffers these stresses. Maximum stretchability when bended ε_b was determined on the basis of differences in test indications before and after loading.

For greater certainty of the experimental method, the assessment of notch effect on the value of above-specified crack resistance criteria has been performed.

The data on the influence of an artificial crack on the strength of mortar and concrete are conflicting [Muravin and Guriev (1987)]. It is assumed that the ratio of the strength of notched test beams to the strength of similar unnotched test beams decreases following the notch depth increase and, passing the minimum, grows when the notch depth increases.

In course of the experiments, to the part of test beams, at the depth equal to 1/3 of the height, a triggering crack was applied with use of a diamond blade 0.8 mm thick. The depth of a triggering notch was specified after testing.

2.2. Results of the study

Table 1 shows the results of test beams’ bending tests with and without notches at the age of 28 days [Petrova (1999, 2000)].

Table 1. Notch effect as to the slag alkaline based concrete crack resistance criteria value.

Testing method	R_{bt}, MPa	K_{Ic}, MPa $\cdot m^{0.5}$	a_c	$\varepsilon_{st.}^{b.} \cdot 10^4$	$R_{c.}$, MPa