INFLUENCE OF STRUCTURAL PARAMETERS ON ABRASION IN MULTIPHASE MATRIX–CEMENT MATERIALS

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Summar. The concrete surfaces after abrasion wear test have been characterized by structural parameters, such as mean inter-particle distance; mean coast aggregates diameter, its area fraction, and matrix hardness. The specific method to obtain the inter-particle distances was developed. From regression analyses it has become evident that wear effects arising from coast aggregate fraction and their geometrical parameters surpass the influence of matrix hardness.

INTRODUCTION

In the modern projects of hydraulic engineering and transport reinforced concrete structures, sufficient attention should be given to the abrasion durability of concrete. Such abrasion causes loss of effective thickness and of constructive elements. Another very important problem is how to provide requirements to abrasion strength characteristics of constructional building materials for maintenance of reliability and safety of engineering constructions during the whole exploitation period. The mechanics of friction interaction enables the analysis of wear failure process and phenomena which occur in friction interaction of moving components resulting in the energy and material losses in constructions. It allows determining serviceability of a construction during its destruction. Application of theoretical and experimental contact mechanics methods to an estimation of strength and durability of concrete constructions is hampered as against designs from metal, ceramics and other materials because of concrete structure singularities. Concrete is a stochastically heterogeneous material with brittle cement stone matrix. Thus the softening near-surface layer zone attains the considerably size. Different models can predicts that its abrasion strength depend on technological, physical and geometrical characteristics of concrete mix. But only experimental researches support and specify these theoretical predictions.

MODELLING FOR WEAR FAILURE OF CONCRETE

Let's consider wear process of a concrete surface at various structural levels. The following hypotheses are accepted: mechanical forces of friction are considered only; adhesive is ignored, and erosive deterioration is ignored too. As the choice of criteria of destruction is difficult; therefore the wear can be divided into the following stages [1,2]:

Stage 0 - the new stage. Near-surface layer is submitted by the following structural components: a surface of concrete; a grain of a coarse aggregate; solvation sphere of a coarse aggregate; a fine grain; solvation sphere of a fine grain; the hardened cement paste.

Stage I - the initial stage. In this stage of the wear process: the abrasion of solvation sphere of fine grains; the destruction of solvation sphere of fine grains; the abrasion of a surface of fine grains. At a micro-level only the cement-sand stone is wear out by break of bonding between cement paste and a fine grain.

Stage II - the normal operating stage. In this stage of the wear process: the abrasion of coarse aggregates surface; the abrasion of a cement-sand stone surface. In meso-level the grains surface of a coarse aggregates and the cement-sandy stone between them is abraded. As soon as volumetric degradation (softening) of near-surface layer zone of concrete is beginning, the stage II is finished.

Stage III - the destruction stage. Two cases of destruction near-surface layer zone of concrete are possible. The case 1 is characteristic for concrete which includes a fragile cement-sandy stone. In this stage of the wear process: the volumetric degradation (softening) of cement-sand stone; the shaking and falling of coarse aggregates grains. The case 2 is characteristic for concrete which includes a strong cement-sandy stone. In this stage of the wear process: the fatigue macrocrack propagates on border between a coarse aggregates grains and a cement-sand stone.

In a stage I modeling is not difficult; concrete can be accepted as homogeneous solid. The wear rate can be presented as dW/dt , which depends from speed V, pressure p, materials hardness H and also from the parameters having certain value for each mechanism of wear process and used for its studying model.

Stage I is finished, when a grains of coast aggregates is exposed on surface. The materials hardness H is different for coarse aggregate and a cement-cand stone, therefore the application of previous model to stage II incorrectly. In a stage II the wear process should be considered simultaneously on micro- and meso-levels. At a meso-level there is a abrasion of coarse aggregates surface. At a micro-level there is a destruction of a cement-sand matrix, it results in change of the form of a surface.

The model of a surface with the strengthened areas [3] is used for modeling of concrete surfaces wear process in [4]. The surface of concrete can be presented as elastic half-space with the area, in which strengthened inside circular areas of the radius r, in nodes of a square mesh with step l. The parameter m characterizes a strengthening of surface as hardness relations between cement-sand stone and coarse aggregates grains. The parameter $a = r/l$ characterizes geometrical parameters of strengthening of a surface. By varying parameters m and a it is possible to optimize the concrete structure. However, only experimental researches will allow estimating the degree of idealization of the accepted modeling parameters.

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EXPERIMENTAL PROCEDURE

Dependencies of concrete abrasion strength on technological parameters of a concrete mix are experimentally established. As varied factors are chosen: the volume fraction of coarse aggregate, volume fraction of silica and superplasticizer (4 series of samples). The maximal size of coarse aggregate, the water-cement ratio and the charge of cement were used for manufacturing of the testing specimens as a constant.
The test method meets the requirements of GOST 13087-81. Abrasion resistant is estimated as loss of weight at abrasion of concrete cubes on a rotating circle. The total way of the sample - 600 m, consists of 20 cycles on 30 m everyone. In addition the height of deterioration was determined.
After test the received surfaces of samples were investigated. Hardness of coarse aggregates and of each sample hardness of a cement-sand matrix was experimentally determined by use of Poldi device. The parameter of surface strengthening m has been certain as relation between average diameters of imprints on a reference bar at test accordingly matrixes and coast aggregate.
For definition of geometrical parameters the received surfaces have been photographed after tests. Quantitative image parameters (maximum and minimum diameter, area fraction and centroid coordinates) were determined by using the standard method of GetData.Graph.Digitizer software and used for further statistical analysis. Statistical calculations were done with Statgraphics statistical package. In the described way, all relevant material parameters for wear loss in abrasive environment could be defined for each received surface. Correlation between abrasion (loss of weight and height of deterioration) and relevant structural parameters of received surfaces were investigated using multiple regression analysis.

RESULTS AND DISCUSSION

Macrostructure analyses of typical concrete surface after abrasion test were carried out. Predominantly, the almost spherical sand particles are homogeneously distributed within the surface, but the distribution of polygonal coast aggregates particles is inhomogeneous. Quantitative wear rates on weight and height loss for the four series of samples are shown that the hardness of cement matrix depends from silica and superplasticizer volume fractions.
Statistical analysis was used in this study to determine linear effects and regressions coefficients of the quantitative image parameters on the abrasive wear resistance predicted by model [4]. Two dependent parameter models (loss of weight and height of deterioration) were considered for the fourteen variables (hardness, area fraction, diameter, inter-particle distance and their parities). It has to be pointed out that these variables are not independent; however, for simplification of modeling they were set independent. Variance and regression coefficients for any of the linear functions are documented.
The parameter model based on total area fraction shows with p-value = 0,029 higher correlation than the model based on equivalent particle diameter with p-value = 0,10. It means that wear resistance can be much more addressed to particle area fraction than to equivalent diameter. The model based hardness shows the low fitting with p-value = 0,126. The model based on inter-particle distance shows the lowest fitting with p-value = 0,51. Nevertheless the model based on relation between equivalent particle diameter and inter-particle distance shows the best fitting with p-value = 0,024.and low-standard error compared with the other models. This leads to the conclusion that the area fraction, inter-particle distance and its relations are significant parameters for characterization of materials when resistance to abrasion is important.

CONCLUSIONS

Wear rates of four different series of cement-matrix composites samples were investigated for their connection with structural parameters of these materials. Quantitative methods were used for determination of relevant abrasive behavior material parameters describing the volumetric participant distribution and additives in concrete. The particle area fraction has exhibited stronger effect on wear rate than or equivalent diameter and inter-particle distance, but relation between equivalent particle diameter and inter-particle distance shows the best influence on wear rate. Hardness of the matrix has minor influence on abrasive wear. The multiple regression analyses done for different models on a synergetic effect from parameter combination have revealed the highest interaction.
The results of the present work indicate the high influence of structural parameters distribution on wear performance of cement-matrix systems for constructions that have to withstand abrasive processes. The knowledge on the effect of volumetric aggregate particles distribution characteristics allows making the selection of the required technological parameters in order to achieve the highest wear resistance of selected particulate reinforced composite materials.

References

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