Improved alkali resistance of basalt fibers with zirconia and titania coatings

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Construction that is performed in extreme climate such as polar climate gives a rise to develop strength, resistant and sustainable materials for building. Reinforcement of a concrete by a fiber is an important step to increase the fracture toughness, water and frost resistance, bending and tensile strength of concrete. Basalt fiber is one of widespread types of such fiber. Due to some of its characteristics such as operating temperature, elastic modulus, tensile strength, basalt fiber is superior compared to most kinds of glass fiber. A disadvantage of the basalt fiber is its degradation in an alkaline medium such as a hardening concrete mass. The most promising way to solve this problem is the application of barrier coatings to basalt fiber that could slow the degradation process. The advantages of this method are targeting (maximum concentration in the reaction zone), cost (material cost reduction compared with other methods) and high adaptability. Also such technique can be easily scaled and integrated into the technological cycle of basalt fiber production. Properties of ZrO_2 and TiO_2 allow these oxides to be used for the application in alkali-resistant coatings.

The aim of this work was to develop zirconia- and titania-coated basalt fibers and to study their alkaline resistance.

As precursors $ZrOCl_2 \cdot 8H_2O$ and $TiCl_4$ were used for preparation of hydrated zirconia and titania sols with a concentration of 0.1–1.0 M and 0.2–0.8 M, respectively. Fibers were briefly dipped into a sol followed by drying and heat treatment to remove the solvent and to form the crystalline ZrO_2 and TiO_2 coatings. 2M NaOH solution and saturated solution of $Ca(OH)_2$ were used as a media for alkaline etching.

It was found that coatings were uniform and smooth with the thickness of 300–400 nm and 400–1000 nm for ZrO_2 and TiO_2, respectively. One can note the presence of elongated aggregates (traces of the sol) on the surface of some fibers which are due to the retention of the sol between fibers which are close to each other. The morphology, phase and elemental composition, mechanical properties of the etched fibers were investigated. The surface morphology of basalt fibers etched in different alkaline media changed greatly. The formation of a layer of hexagonal $Fe(OH)_2$ plates was observed both for NaOH and $Ca(OH)_2$ media. The rate of the formation of this layer is much slower for $Ca(OH)_2$ media. Another feature was the morphology of calcium carbonate drusen, namely, dense spheres were formed in NaOH solution, whereas needle-like spheres or flower-like drusen were formed in $Ca(OH)_2$ solution. It was found that the presence of dense protective ZrO_2 and TiO_2 coatings on the surface of basalt fibers can significantly slows down the etching process.