Chloride resistance and transport properties of blends with high quantities of calcined clays

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Abstract

Substitution with pozzolanic materials such as calcined clays, even of average purity, is known to improve concrete properties. However above a certain threshold commonly accepted to be of about 30% of substitution, these materials reduce the mechanical properties, especially at early age. The results have shown that 45% of substitution by 30% of metakaolin and 15% of limestone powder gives better mechanical properties at 7 and 28 days than the 100% OPC reference. The porosity is globally refined although total porosity is slightly increasing. It could be demonstrated that there is a synergetic effect by formation of high amounts of carbo-AFm phases, besides the commonly accepted pozzolanic reaction. The synergy originates from the reaction of calcium hydroxide produced by cement hydration, the aluminates from the metakaolin dissolution and the carbonates from the limestone dissolution.

The resistance to chloride ingress of such blends has been studied by chloride binding isotherm, by the STADIUM migration test derived from ASTM C1202 -97 standard test procedure and by the ponding test. It has been set up for one pure metakaolin and for a natural calcined clay with only 50% kaolinite clay, in binary blend with pure metakaolin alone and in ternary blend with combined addition of 30% calcined clays and 15% limestone. Both blended cement, with and without further substitution of cement by limestone powder have demonstrated to significantly reduce the diffusion coefficient of chloride ions (for example D_{OH} of 7.8 10^{-11} m^2/s, 2.45 and 0.75 10^{-11} m^2/s for PC reference, 30% metakaolin substitution and combined addition of 30% metakaolin and 15% limestone respectively for 28d old samples).

The ponding experiments have confirmed the results obtained with the migration test, the blends with combined addition of 30% calcined clays and 15% limestone have shown the lowest chloride penetration.

The XRD analyses have demonstrated the formation of calcium chloroaluminates phases such as Friedel salt and also hydrocalumite in presence of carboaluminates. The total bound chloride measured by chloride binding isotherm is however not massively modified by the blending.

The very low ionic diffusion coefficient and excellent chloride resistance of the blends with combined addition of 30% calcined clays and 15% limestone is attributed to the refinement of the pore structure and its increased tortuosity.