Calcined clays from dredging as cement constituent – impact of fluvial sediments from the Scheldt basin (Belgium, France) on composite cement hydration

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Introduction: Making better use of dredging sediments can be considered to be a key component of the developing blue economy. Using dredging sediments from inland waterways as a resource in construction works can pose important techno-economic challenges. In areas with a strong industrial legacy, historic contamination involves high remediation and disposal costs, and alternative pathways are being sought to valorize the resource potential of problematic materials or sediment fractions. In particular the clay-silt fraction (<63 μm) is often associated with high levels of undesirable substances (organic matter, sulphides,...) or contamination that limit or prohibit their application as a resource for construction materials.

From the opposite side, the construction industry is eager to use alternative, local raw materials that can contribute to making their products and processes more sustainable from an environmental, but also techno-economic perspective. The cement and concrete industry for instance uses very large amounts of by-products or residues from other industries, well-known examples are the use of blastfurnace slag or coal combustion fly ashes as supplementary cementitious materials (SCMs). To mitigate the climate impact of cement production, the demand for such SCMs is increasing, while supplies are decreasing due to shifting towards more sustainable steel or energy production processes. New sources of SCMs are therefore needed and have led to the development of alternatives such as calcined clays.

In this contribution the use of calcined clays recovered from fluvial dredging sediments in various locations of the Scheldt river basin is evaluated. The impact of the calcination temperature on clay reactivity and suitability is assessed, while the impact on the hydration kinetics and mechanism of the composite cement is investigated to confirm compatibility.

Materials and methods: Three dredging locations were considered in this study, all situated in or near industrial zonings in the Scheldt river basin, i.e. in the Ghent-Terneuzen port, Farciennes and Noyelles-sous-Lens. The selected sediments had slightly different composition, granulometry and showed varying degrees of contamination by heavy metals and organics. The dredged sediments were separated into size fractions and subsequently dewatered, the <63 μm was kept for further investigation. Subsequently the materials were dried at 60 °C, and calcined at temperatures ranging from 650 to 950 °C. The calcined materials were characterized in terms of physical and chemical properties and reactivity performance as SCM.

Composite cements were formulated based on blends of Portland cement and calcined dredging clays. The hydration kinetics and mechanism of these composite cements were investigated using a combination of techniques, including measurements of hydration heat, reaction degree, and identification and quantification of reaction products. The robustness of the composite cement to changes in water to cement ratio and curing temperature was evaluated.

Results: The three clay fraction were predominantly composed of 2:1 illite and smectite clay minerals and quartz, in addition kaolinite was present in minor amounts. The Lens material also contained calcite. The optimal calcination temperature of the dredging sediments varied between 750 and 850 °C. In this temperature range the clay minerals dehydroxylated and structurally disordered to form meta-clays. Organic matter and sulphides are combusted, eliminating their detrimental effect on cement performance. Higher calcination temperatures lead to formation of inert high-temperature phases, while temperatures below the optimum provided incomplete activation of the clay minerals. Calcite in the Lens material converted to free lime and additional reactive phases at the optimal calcination temperature of 750 °C.

The composite cement hydration studies confirm earlier findings that the calcined fluvial sediments from the Scheldt basin are reactive SCMs that enhance the hydration of Portland cement through filler and pozzolanic effects. The pozzolanic reaction of the calcined sediments is enhanced by curing at higher temperatures and the cements were found robust to changes in water to cement ratio.

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