ABSTRACT

In recent years the use of supplementary cementitious materials in the production of concrete has become an ever more frequent trend, since such use contributes to a sustainable concrete industry. The main reason for this lies in the reduction of the specific energy requirement and of carbon dioxide emissions in the production of cement (OPC). One such environmentally friendly product is fly ash (FA), which occurs as a by-product of coal-fired thermal power plants.

The aim of the present work was to examine the hydration process, mechanical properties and durability of concrete with different replacement level of the OPC content by FA. In the first part of the thesis the hydration of OPC and FA at early ages, as well as at later ages, was monitored by means of calorimetry and thermogravimetry. A change in the hydration products that are formed in the FA blended cement, reflected over time in the observed increase in the mechanical strength of the binder. After 90 days, the compressive strength of concrete in which 20% of the OPC was replaced by FA exceeded the compressive strength of the unmodified concrete.

In the second part the composition of FA modified concrete mixtures which were made solely of very pure crushed limestone or dolostone aggregate, with a relatively high content of fine particles below 0.125 mm, were designed. The type of used aggregate was found to be of particular importance. When characterizing the mechanical properties of two concrete mixtures made with different types of carbonate aggregate but with identical mix designs, a considerable difference was observed. These differences initiated a further investigation into the alkali-carbonate reaction (ACR). I found out that no accelerators in the form of highly alkaline solutions or reactive components are needed to initiate the reaction.

In connection with the durability characteristics of FA modified concrete, three test methods which were related to carbonation, chloride ingress, and frost/salt scaling were used. The effect of exposure time, FA content, and FA composition were examined. The performance of FA modified concrete was poorer in the case of carbonation and frost/salt attack by de-icing salts, especially in the concrete mixture containing 50% of FA. In contrast, a beneficial effect of FA modified concrete in the case of chloride ingress was indicated, even when 50% of the OPC was replaced by FA. A lower effective porosity for FA modified concrete was experimentally determined by mercury porosimetry. This leads to a higher percentage of ink-bottle porosity which confirmed a higher resistance of the concrete to chloride penetration. I found new insights concerning the effect of FA on the porosity of concrete, and concerning the importance of the ink-bottle porosity.

Key words: fly ash, concrete, alkali carbonate reaction, chloride ingress