ABSTRACT

There are many cement types available in the market today and several more are under development. The understanding that has been obtained through experience with the conventional cements is not sufficient to update the construction practices for the new cement types that are available in the market. Not only are these new cement types more sustainable, they also offer engineering properties that are advantageous in many situations. Due to the robustness and ease of production of Portland cement, its clinker still makes the majority of most modern cements, with a fraction of the cement being replaced by supplementary cementitious materials (SCMs) that are often more environmentally and economically efficient. Apart from improving the engineering properties of the cements, these SCMs also reduce the CO_2 emissions and the energy consumption in cement production. While sufficient knowledge is available to allow a safe use of cements with clinker fractions as low as 0.7 with fly ash, the further reduction of clinker factors and the advent of ternary cements, which use a combination of SCMs together, necessitates the understanding of the more complex interactions that occur in these cements. This research studies the influence of temperature on the hydration, microstructural development and strength development of cements with 30% and 50% clinker replacement using either single, or a combination of SCMs. In the study, slag-fly ash composite cement and limestone calcined clay cement, which have recently been used as more sustainable alternatives to pozzolanic cements, have especially been focused upon.

Although the characteristics of cements are usually similar from one location to another, their usage occurs in ambient conditions that vary highly, especially in a large and diverse country like India. In India, the temperature, which has been shown to play an important role in hydration and strength development, can vary by almost 50˚C at the same location between different weathers. Curing temperatures of 10˚C, 27˚C and 50˚C, which represent usual conditions in the country were chosen for this study. Studies on the rate of hydration and phase development showed that while higher curing temperatures can accelerate early-age development, the long-term development may be hindered. This limiting of hydration and strength development is seen to be more prominent in cements that have a lower clinker content, particularly those that have been replaced with SCMs that contain a higher alumina content.

Microstructural studies have shown that the nature of the hydration products is influenced both by the temperature and the chemical composition of the SCMs. In certain conditions, it is seen that the higher alumina available in the solution at higher temperatures leads to the formation of a more polymerized C-A-S-H, which may repress cement hydration by forming a physical barrier against the reaction,so much so that the hydration nearly stops in some of the blends. This also leads to a reduction in the long-term strength development of these cements and reduces the availability of portlandite, which is required for the hydration of the SCMs. It was found that higher curing temperatures also prevent the formation of hydration products, such as ettringite and carboaluminates, that make an important fraction of the hydrated microstructures of some of the cements. This also influences the strength and microstructural development. The permeability of the pastes and, hence, their durability characteristics are also affected.

The results, however, show that a delay in the exposure of the cements to higher temperatures can lead to an improvement in microstructural and strength development, allowing more of the potential of the SCMs to be utilised. The addition of surplus gypsum is also seen to improve the strength development in some conditions. The results provide important data that can be used in the design and construction of structures that use ternary low clinker cement blends.