Magazine of Concrete Research, 2009, **61**, No. 6, August, 387–388
doi: 10.1680/macr.2009.61.6.387

Editorial

Alternative cements—realising their potential

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With the challenges that modern construction work faces, there is considerable interest nowadays in using alternative cements for improvements in concrete workability and durability together with a greater emphasis upon sustainability. To this end, there is also an increased need to employ more industrial by-product materials in construction, where sustainability is an important factor because of the ever-rising costs and limitations on creating new landfill sites, so as to curb despoiling of the environment. Also, the use of industrial wastes with high calorific value lowers the costs of energy requirements for Portland cement manufacture. In addition, there is increased employment of suitable by-product gypsums such as desulphogypsum and better awareness of the importance of long-term durability of structures. One of the key areas for seeking improvements is to produce more alternative cements for particular construction activities in terms of lower energy and high concrete durability, rather than rely too much upon the high-level usage of standard Portland cements.

Blended cements (also known as extended cements) consist of Portland cement plus extenders that become more hydraulic by the alkaline medium produced when water is added. They are becoming increasingly employed in concrete usage, but there is a need for more such blends in producing durable concrete structures. Blending can take place either at the cement plant or at the site with Portland cement and the other constituents of concrete (fine and coarse aggregate plus water). Such extenders include ground-granulated blastfurnace slag (ggbs), fly ash and partially burnt shale. Their lower costs and resulting concretes reduce permeability and porosity. It is becomeing increasingly common to use mixes of the aforementioned cement extenders and/or the non-hydraulic ground limestone in combination with Portland cements in concretes as alternative cements. Rice husk ash in Asia and wheat straw ash in Turkey (both pozzolans) are now more commonly being used in these regions for 'greener' concrete.

Other types of slags and ashes in extended cements, such as non-ferrous slags and ashes such as paper mill sludge ash, bottom ash from municipal waste incinerators and sewage sludge incinerator ash, need to be used for 'greener' concrete. These materials should be beneficiated appropriately, so that they can likewise be employed in concrete for similar positive reasons.

High-activity pozzolans such as microsilica and metakaolin can be of use in high-strength concretes, where low permeability and porosity are needed.

Limestone additions are very popular at present. Up to 5% mass is permitted as a 'minor additional constituent' in common cements made to the European specification EN 197-1,[1] as also are Portland limestone cements containing up to 20% or 35% mass ground limestone additions, where good workability is usually encountered. Mild sulphate-resisting properties are apparent because of pore filling hindering transport of water through structures. Limestone additions to Portland cement are not, however, hydraulic or pozzolanic. This should be taken into account for determining water/binder ratios, because limestone is not a part of the binder. The addition of high limestone percentages also reduces the strength of resulting mortars and concretes to a level equivalent to the same concrete or mortar made with a reduced cement content; that is,

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30% mass limestone in a 300 kg mix can have a strength equivalent to a 270 kg mix. Such limestone-containing cements should not be used in concretes where there could be any risk of thaumasite sulphate attack taking place in the prevailing conditions.

Calcium sulphoaluminate cements and the related calcium sulphoferrite cements are manufactured on a large scale in China and on a much smaller scale in numerous other countries. Such cements utilise many industrial waste materials blended or calcined as appropriate. Calcium sulphoaluminate (often called kleinite) $4CaO.3Al_2O_3.SO_3$ is itself made by calcining raw materials, such as limestone, clay and anhydrite and (for calcium sulphoferrite cements) iron oxide sources, at lower temperatures than those obtained by Portland cement clinkering. There are many permutations and combinations involving waste materials that can be used as a basis for formulating suitable sulphoaluminate or sulphoferrite binders. More understanding of these cements is, however, needed to assess their setting and strength growth characteristics in concretes and mortars, and also both long-term durability and sustainability.

In Russia and Uzbekistan, incorporation of calcium chloride in the raw materials mixture for Portland clinker production using molten salt technology has enabled the normal clinkering temperatures to be reduced by around 500°C, thus saving on energy requirements. The product (alinite) can incorporate many industrial wastes by clinkering, such as pulverised fuel ash, limestone fines, mill scale and higher magnesium oxide levels than Portland cements, with optimum calcium chloride additions to the raw mix of around 7 to 8% mass. Alinite is softer than Portland cement for fine grinding, giving high-strength growth characteristics. Chloride can be encapsulated in the alinite phases or remain relatively labile. Gypsum blends or grinds primarily assist strength development rather than aid set regulation. In practice, alinite cement sometimes shows chloride corrosion of reinforcement and at other times reveals no such corrosion. Further background work is needed before alinite concrete can be used safely in reinforced concrete.

More development work should be undertaken in both industry and academia for obtaining more of the durable ‘greener’ concrete. A reduction of current energy requirements during cement manufacture and an increased use of industrial wastes in cement production after suitable treatment are needed instead of confinement to landfill, so as to give ‘greener’ concrete in the future.

References

1. BSI British Standards Institution. Cement. Composition, specifications and conformity criteria for common cements. BSI, London, 2000. BS EN 197-1: 2000.