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Cement & Concrete Composites

Editorial

Of the many innovations in concrete technology during this century, the use of chemical admixtures, and in particular, that of water-reducing agents and air-entraining agents, would probably rank as the most relevant, appropriate and critical to the enhancement of the quality of concrete. The use of pozzolanic materials, on the other hand, dates back to more than two millennia, but the more recent use of pozzolanic and cementitious industrial byproducts, such as fly ash (FA) and ground granulated blastfurnace slag (slag), has shown that they can outstandingly enhance the durability properties of concrete. The combined use of chemical admixtures and mineral admixtures, such as supplementary cementitious materials, should then be able to bring out the unique properties of each of these concrete components, and show that the synergic interaction between them can produce a much more durable and stronger concrete than when either of these materials is used alone with portland cement. There is now enough evidence to show that this synergistic interaction, between high-range water-reducing admixtures (HRWRA), and the portland cement-slag system, for example, can be designed for, and achieved to produce a concrete of excellent flow characteristics, high strength and high durability.

It is now universally recognized that the major problem confronting portland cement concrete is its lack of durability when exposed to aggressive environmental conditions. Very often the use of chemical admixtures or mineral admixtures alone is seen as a means of overcoming the durability problem. Experience shows that this approach is neither adequate nor satisfactory in producing high strength, highly durable concrete.

Chemical admixtures are now seen as vital components of concrete. In particular, admixtures with water-reducing and plasticizing capabilities are recognized as essential requirement for proper placing and adequate compaction of concrete. Inspite of this, HRWRA are often largely seen as workability agents, with emphasis on possible savings in cement and increases in compressive strength. Further, the use of HRWRA does not automatically solve problems of loss of workability with time and segregation. Other factors such as high cementitious materials contents, large dosages of chemical admixtures and air entrainment also contribute to difficulties of finishing, particularly of large exposed surfaces such as bridge decks and slabs on grade. Low water-cementitious materials ratios (w/cm) can also aggravate the difficulties by increasing the viscosity of the mix and lack of bleeding.

Supplementary cementitious materials, such as slag, on the other hand, have a unique ability to contribute to durability, and through durability, to strength and stiffness. But this potential is chemically bound and locked within the material itself, and can only be extracted and mobilised by careful design of the concrete mix. The major drawback of slag and other pozzolanic admixtures is that their hydration reaction is a two-stage process. A direct consequence of this is low strength and slow development of strength, particularly at early ages, and worse still, all pozzolanic/cementitious admixtures are therefore highly susceptible to the consequences of poor or inadequate curing. A further factor to be considered is that both HRWRA and mineral admixtures are set retarders, and this may have an adverse effect on the development of early age strength.

Many high performance concretes (HPC) currently used are characterized by high cement factors and low w/cm ratios. Experience shows that it is extremely difficult to obtain proper workability with such mixes, and indeed, to retain the workability for a sufficiently long period of time. High dosages of water-reducing admixtures then become a necessity, and the resulting cohesive and thixotropic-sticky-mixes are equally difficult to compact. These problems indicate that there is probably a critical limit – a threshold – for the water content below which high superplasticizer dosages become not only essential but also unhelpful and undesirable, and often even harmful.

The major casualty of low w/cm ratio and very high superplasticizer dosages is the susceptibility of HPC to early age cracking. This may occur as early as 15 min after placing, and extend anything up to 5–6 h thereafter. Cracking under these conditions is very much influenced by the loss of workability, and the very quick drying at the open surfaces caused by the dual effects of lack of bleeding, and the inability of whatever bleed water is present to move up to the surface. The quicker these phenomena occur, the more likely for this cracking in the plastic stage to be intense. Experience of full scale construction activities shows that the early occurrence of

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such cracking leads to wide cracks of 1 to 3 mm width, whereas later age cracking results in a greater number of hairline cracks.

The exact mechanism of this very early age cracking of plastic concrete is not clear but this seems to be a combined effect of plastic shrinkage, thermal gradients and autogenous shrinkage or early volume contraction of the binder phase. A better formulation of the binder paste volume and less HRWRA dosages can help control this very early age cracking.

There appears to be a widely-held misconception that high strength concrete is, per se, highly durable. On the other hand, there is widespread evidence that HPCs formulated on the basis of high cementitious materials contents, low w/cm ratios and high proportion of very fine pozzolans are highly susceptible to early age cracking. Further, internal microcracking interlinked with external cracking is known to be a major cause of deterioration, even when the concrete is properly cured, and free from structural perturbations during the dormant period.

Since loss of workability is very much related to the cohesive and thixotropic nature of the concrete matrix, and large dosages of plasticizers are known to create problems of compaction and cracking in full scale construction, HRWRA having longer duration times, lower dosages of HRWRA and avoidance of very low w/cm ratios seem to be the way forward to produce High Durability Concrete (HDC). FA and slag are excellent partners in this respect since they both posses water-reducing properties, and this combined with the rheological dispersive actions of HRWRA can effectively counteract the adverse effects of high dosages of HRWRA and very low w/cm ratios, and impart qualities of flow essential for compaction, pumping and finishing. A judicious combination of HRWRA and amount of slag/FA can then produce concrete with high strength and excellent durability properties.