INFO 07th May 2003 Daily mirror

SLSI gives construction industry strength opening debate on blended cements

The Sri Lanka Standard Institution recently published a press advertisement calling for public comments on Hydraulic Blended Cement. In this connection I wish to state that, blended cements are not a novelty. Pozzolanic cements have been standardized in Italy since 1929. Blast-furnace slag cements have been manufactured in Germany, France, Luxembourg, England and Belgium for more than half a century. Fly ash cement appeared in France about the end of 1950.

The importance of these binders have increased remarkably in recent times for energy saving reasons as well as for the growing importance of the durability of the works.

Replacement by pozzolana/ slag gives a higher resistance to chemical attack, a higher impermeability of the constructions and lesser expansivity due to alkali-aggregate reaction.

The actual technical benefits of the inclusion of blended cements on the concrete properties form the strongest argument in favour of their use. Indeed, in many cases blended cements should be used in preference to normal Portland cement. Various cementitious materials affect the progress of hydration in consequence of their chemical composition, reactivity, particle size distribution and particle shape. The improvement in the properties of concrete observed due to blending materials is not only due to their pozzolanicity / cementitious nature but also to the ability of very small particles of pozzolana/ Ground Granulated Blast furnace Slag (GGBS) to 'fit in' between cement particles.

A brief review of the blended cement properties is presented below keeping in view of this feature.

WORKABILITY- For a given total content of cementitious material, the inclusion of pozzolana or GGBS generally reduces water demand and improves workability. Placeability of concrete also improves. Typically water content may be reduced by 3% for every 10% pozzolana added. In the case of GGBS, the improvement may not be measurable in terms of slump but, once vibration has started, a concrete containing GGBS becomes 'mobile' and compacts well. The cement content and the grading of the aggregates are factors which have larger effect of workability than the cement type.

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BLEEDING - Concretes containing pozzolana and/ or GGBS are generally reported to show reduced segregation and bleeding. When pozzolana or GGBS is finer than normal Portland cement less bleeding is observed. Reduced bleeding is of considerable importance when concrete is placed by pumping and also in RMC.

HEAT OF HYDRATION - Blended cement (PPC & PSC) concrete does not develop heat as rapidly as normal Portland cement concrete. The reduction in the rate of heat evolution is not only an important advantage in the use of blended cements for mass concrete structures but also for normal structures in hot climates, like Sri Lanka.

SETTING TIME - Setting and hardening of concrete made with blended cements is considered slow in relation to normal Portland cement concrete. This retarding effect can be beneficially utilized where concrete has to be handled over long periods of time such as in dam projects, lining of tunnels and ready mix concrete industry.

STRENGTH DEVELOPMENT - The rate of gain of early strength up to 7 days age may be slower and if it is proposed to strike formwork or load the concrete at early ages such as by removal of props below the slabs, the decision should be based on the compressive strength of concrete at that time. It has been observed that the strength of concrete with blended cements at 7 days ranges from 58 to 79% of 28 day strength and in general construction practice this level of 7 days strength should be adequate. If replacement of blending material is substantial, early strength levels drop but it gives high ultimate strength compared to Ordinary Portland cement. At the cement factories, the slower rate of gain in strength is remedied by increasing fineness, by adding accelerating agents and by modifying the compositions of clinker.

FLEXURAL STRENGTH - In general at seven days and beyond, the flexural strength of concrete Incorporating blended cement Is comparable to or greater than the corresponding strength of normal Portland cement concrete. The increased flexural strength Is due to a stronger bond in the transition zone between the aggregate and cement paste and better packing characteristics.

PERMEABILITY - Pozzolana and ground granulated blast furnace slag when properly proportioned in the blended cement, the resulting concrete mix significantly reduce the moisture j chloride penetrability of concrete there by reducing the rate of corrosion.

Blended cement concretes have a higher resistance to the penetration of chlorides. Investigations have revealed that when GGBS content is at least 60 % by mass of the cementitious material and W/C is 0.5, the diffusion coefficient of the concrete exposed to chloride ions is at least 10 times smaller than when the cementitious material consists entirely of Portland cement. Thus blended cements provide greatly increased protection to steel reinforcement in environments subject to chlorides. This can be particularly advantageous in structures exposed to saline atmosphere such as the one encountered in coastal areas. Use of blended cements can increase life expectancy of the concrete structures several times in such areas.

LEACHING - As compared to normal Portland cements hydrated pastes made with blended cements are more leaching resistant. If waters are acidic because of the presence of aggressive CO_2, lime leaching is increased in normal Portland cement, but in the case of blended cements leaching will be substantially less. The severity of leaching can be evaluated from the content of dissolved CaO. On an average, the compressive strength drops by about 2 % when 1 % CaO is leached out.

DURABILITY - No cement is totally free of durability problems. But blended cement can contribute to solving many of them such as resistance to sulphate, chloride, seawater, acid and carbonation.

In the case of hydration of a pure Portland cement, it is seen that the hydration of the bi and tri calcium silicates generate some lime $Ca(OH)_2$. This lime is partially or totally reacting with the pozzolanic materials of siliceous nature to produce a hydrated calcium silicate similar to the one generated by the direct hydration of the bi and tri calcium silicate contained in the cement.

As such when all the pozzolanic particles have reacted with the lime liberated by the hydration of the bi and tri calcium silicate we end up with a concrete free of anymore lime, the weakest component of a hardened concrete from a mechanical point of view as well as from durability point of view.

SULPHATE RESISTANCE - Investigations have revealed that concrete made with blended cements show improved resistance to sulphate attack when compared to normal portland cement concretes. Damage to concrete caused by sulphate due to its reaction with $Ca(OH)_2$ in concrete will form a new chemical compound calcium sulphate which reacts with calcium aluminate hydrate and cause the expansion of concrete that can reduce its strength.

The existence of active silica aluminate from pozzolana will reduce the effect of sulphate on concrete, caused by $Ca(OH)_2$ from mineral hydration C3S and C2S which will react to form calcium silicate hydrate (C-S-H) and Calcium aluminate hydrate (C-A-H), such reaction also reduce the damage risk caused by CO_2 and Ion chloride from environment.

RESISTANCE TO SEA WATER - In marine environment concrete containing blended cements exhibit enhanced durability. Several investigations have examined the effect of cement type on the performance of concrete exposed to long periods in sea. In all these studies: the slag cement (25-35% GGBS) has shown a more favourable behaviour than standard normal Portland cement, and slag cements rich in GGBS (greater than 50% GGBS) have proved without exception to have a better durability. Similarly Portland Pozzolana Cements(PPC) with higher Pozzolana contents (25-30%) have shown good resistance to sea water attack. It is desirable that PPC for use in such circumstances should be made from a clinker having C3A in the range of 5-8%. In conclusion, it may be stated that blended cements are better suited to marine environment where both chlorides and sulphates are present. The beneficial effects of blended cement concretes are so significant that their use in reinforced concrete liable to corrosion in hot climate is absolutely necessary; Portland cement -only mixture should not be used.

RESISTANCE TO ACIDS - In general, blended cement concretes provide improved resistance to chemical attack. This may come in several forms, whether through sulphate, chloride, acid present in ground waters or other external sources. Depending on the severity and type of acid attack, blended cements containing varying amount of slag or fly ash may be used to counter the problem. Mild acidity can occur in ground waters and in this situation use of blended cements have been found to improve durability. However, it should be noted that: (a) No Portland cement based concrete is completely immune to attack in acidic conditions (b) the quality of the concrete, in particular the water-cement ratio and compaction and good workmanship are equally important.

CARBONATION - The rate of carbonation depends on the permeability of concrete, its degree of saturation with water and the mass of $Ca(OH)_2$ available from reaction. Well compacted and properly cured concrete with a low W/C will be impermeable enough to resist carbonation.

It is clear from the above that the performance of blended cements concrete against carbonation will be superior to that of normal Portland cement concrete. Concrete strength

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