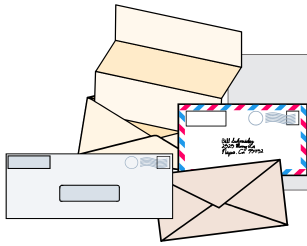

Letters to the Editor

Effect of partial replacement of cement with flyash on the strength and durability of HPC

This has reference to the immensely informative article "Effect of partial replacement of cement with flyash on the strength and durability of HPC" by Mr S. Gopalakrishnan *et al* published in The *Indian Concrete Journal*, May 2001 issue, pp. 355-341, which I read recently. They have, through their very credible and simple laboratory tests conclusively found out that OPC blended with low-calcium fly ash (class F) to the extent of 25 per cent by weight of cement, with a water-cement ratio of 0.40 and water binder ratio of 0.30 can give a 80 MPa concrete at 28 days going upto 90 MPa at 90 days with practically very little reduction in compressive strength at 7 days and with substantially superior durability characteristics than that of OPC concrete. It has higher tensile and flexural strengths than those of normal concrete with OPC, coefficient of water absorption, almost half that of control concrete (0.60 x 10^{-10} m^2/s as against 1.36 x 10^{-10} m^2/s), chloride diffusion coefficient (under 12 accelerated test) also half that of the control OPC concrete (0.102 x 10^{-12} m^2/s as against 0.204 x 10^{-12} m^2/s etc). Conversion to chloride permeability has also fetched similar result (334 coulombs as against 668 coulombs as per relevant ASTM). This premium concrete will obviously be substantially cheaper, less energy-consuming, more eco-cleansing and eminently eco-friendly. The discusser would request a few clarifications from the authors to enhance the appreciation of this worthwhile experimental effort.

(*i*) Apparently the mix design was started by guess proportioning on the basis of rational or modified replacement methods followed by a set of trial mixes to arrive at a final proportioning for casting the test specimens. The authors have mentioned about *K* factor – the cementing efficiency, (which apparently is directly related to pozzolanic activity, which in turn may be also dependent on the pozzolanic activity index), which the authors have reported as 75 at 28 days for this fly ash. Pozzolanic reactivity of some fly ashes has been reported to be 875[1]. This is considered to be the amount of depletion in the quantity of free lime through pozzolanic reaction and expressed in mg of $Ca(OH)_2$ per gram of the pozzolanic material. This has no relation to the rate of reaction (Chapelle test). The discusser would like to know how the index of 75 relates to this total reactivity figure of 875. Further, in a preliminary mix design even before trial mixes, it will be useful to assume some *K* values (cementing efficiency) of the supplementary cement material. Fly ash *K* values has been reported to be in the range of 0.5 to 2.00, the higher figure presumably applicable for long term hydration of more than 90 days. Apparently, this was taken as 'one', as the rounded and constant values of w-b ratio (0.30) and water content (160 l/m^3) tend to suggest. The authors may throw some more light in this regard.

(*ii*) For durability consideration, the coefficient of water permeability is taken to be a more common parameter for comparison rather than sorptivity or coefficient of absorption, though they are important and related to the permeability of the specimen. Sorptivity is through capillary suction; the absorption is simple in capillaries in 60 minutes as given by the authors, with no pressure head and permeability is always measured against a standard pressure head. It will be interesting to know what the coefficient of permeability is for each specimen tested by them.

(*iii*) The authors have found chloride diffusion coefficients only for the concrete specimen. The value for 80 MPa fly ash concrete (25 percent replacement) at 0.102 x 10^{-12} m^2/sec, under a modified testing method, is good. It will be interesting to know the same value for the control cement and the blended cement used by them in the test. Published figures give this coefficient for OPC paste (at $25^{o}C$) as 4.47 and for cement blend with 30 percent flyash as 1.47 in the same unit as before.

(*iv*) If UK and some other countries can process fly ash and design mix of blended cement concrete by reducing the effect w-b ratio to gain more early strength without sacrificing workability it is high time that we also improve our fly ash collection and processing technology for PFA cement so that the same is possible here and the little disadvantage of some what lesser 7-day strength compared to OPC is also overcome so as to get the same deshuttering time as that of OPC concrete. Perhaps the blended cement manufacturers will take note of this. Otherwise, use of some activator as in the case of slag cement concrete can be also thought of.

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Reference

1. RAJKUMAR, C. Provisions for cements and mineral admixtures. *The Indian Concrete Journal*, February 2001, Vol 75, No 2, pp. 105-112.

The authors reply:

we are thankful to Mr P K Singha Roy for his studied comments. The point-by-point clarification to the comments is given below.

(*i*) The existing mix design procedures are only guidelines, which help to arrive at preliminary mix proportions. This mix often needs modifications to meet the actual requirement. The final mix can only be arrived at by a trial and error procedure starting with the preliminary mix. It is for this reason that IS 456 : 2000 (Clause 9.2.1) has now stipulated that it is the mix designed that needs to be approved and not the method of mix design.

The cementing efficiency factor *K* as such is not directly related to the pozzolanic activity index. Because, it depends on a number of factors including the w-b ratio, cement replacement level (CRL), age, curing conditions, and other factors such as properties of fly ash and cement. However, pozzolanic activity reported in this paper is obtained as per BIS procedure and it corresponds to a mortar mix with known cement replacement level and a w-b ratio governed by workability. The pozzolanic reactivity, as reported by Dr C. Rajkumar, $Ca(OH)_2$ corresponds to depletion in levels (expressed in mg) due to pozzolanic reaction with lime, which has no direct correlation with pozzolanic activity.

We have not used the efficiency factor, *K*, for design of concrete mixes reported in the paper.

(*ii*) The authors agree that "coefficient of water permeability" is an important parameter for understanding of durability aspect of concrete. But, this parameter, being obtained based on Darcy's law, requires a steady state of water flow through the concrete under the influence of pressure head. This condition is difficult to achieve in the laboratory in case of high performance concretes, because of their extremely high degree of impermeability; the period to reach steady condition, may extend beyond few weeks. Hence, this test was not attempted in the present study. Moreover, this condition of water flow through concrete under high pressure heads occurs rarely in actual concrete structures, where, water/moisture penetrates into the concrete generally under very low pressure heads, and commonly through capillary action. Hence, measurements for degree of impermeability by tests such as sorptivity, coefficient of adsorption, etc can be considered to be representative.

(*iii*) The chloride diffusion coefficient measured for control concrete was 0.20×10^{-2} m^2/s and when the blending of cement with fly ash at 15 percent and 20 percent was done, the lower values of chloride diffusion coefficients, 0.165×10^{-2} m^2/s and 0.139×10^{-2} m^2/s respectively, were recorded. When fly ash content was increased to 25 percent and above, a very low value of about 0.1×10^{-2} m^2/s was observed. It may be noted here that this coefficient is very much influenced by w-b ratio. For example, a chloride diffusion coefficient was found to be nearly 10 times higher for a control concrete mixture when the water-binder ratio was 0.50, in a study at SERC, Madras. It is difficult to state a range of values for diffusion coefficients for blended cement concretes as it is influenced by various factors such as the type and cement replacement level of pozzolana, w-b, type and period of curing, etc.

(*iv*) The authors agree with the discusser that there is a need to improve fly ash collection systems at thermal power plants. If the fly ash is supplied as a branded product from thermal power plants with assured chemical and physical properties, it would encourage the practising engineers to adopt use of blended cement concrete on large scale and thereby enhance the durability of concrete constructions. Improvements in the microstructure of cement concrete due to addition of fly ash have been proved beyond doubt in several publications in India and abroad .

The need for increased de-shuttering time for fly ash concrete may not be a constraint in actual practice, since, it is possible to design any fly ash concrete to reach any level of strength at any age, by suitable adoption of water-binder ratio, mix proportions, ingredients of concrete, etc. Moreover, it must be noted that as per clause 11.3 of IS 456 : 2000, the strength of concrete at the time of formwork removal must be more than twice the stress to which the concrete will be subjected after removal of formwork. This strength condition can be easily achieved for blended cement concretes, and if need be, suitable modifications to the mix could always be made. Thus, even though the fly ash concrete may have lower strength at early ages than the corresponding cement concrete, the strength of suitably designed fly ash concrete itself may be sufficient to allow for removal of formwork at any desired time.

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