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Discussion

A discussion of the paper "Study of pozzolanic properties of wheat straw ash" by H. Biricik, F. Aköz, I. Berktay and A.N. Tulgar☆

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Dr. Biricik et al. [1] have written a very interesting and detailed paper on the intrinsic pozzolanic properties of wheat straw ash (WSA). WSA contains large amounts of silica, SiO_2, which, when burnt, gives an ash that is not only very rich in its silica content, but also demonstrates pozzolanicity. The wheat straws were ground to 1–5 mm particle size and preburnt. After preburning, the material was later burnt under controlled conditions for 5 h at 570°C and 670°C, with the ash being rapidly cooled and ground to 90–200 μm size fractions.

The wheat straw utilised in this particular study [1] had an ash content of 8.6%, with the silica level of the ash being 73%. The WSA burnt at both 570°C and 670°C exhibited pozzolanic properties in the presence of Portland cement, and these were better when the temperature of calcination was at 670°C rather than at 570°C. The preburning step has been designed to be environmentally friendly by saving on some of the energy required for burning and also for preventing the formation of smoke and subsequent contamination therefrom. It was stated that the ash obtained from the wheat straw can be used as a pozzolanic material wherever wheat production is large and therefore capable of giving rise to large quantities of the ash for cement extension [1].

WSA appears to have similarities in its pozzolanic behaviour to the more commonly encountered rice husk ash (RHA) in a number of Asian countries [2, 3]. RHA has been used for some time as a pozzolanic cement extender. As with RHA, it is clear that the overall quality of the ashing process for WSA is critical for establishing good pozzolanic properties, such that WSA should be able to become a good quality cement extender. This means that the burning process should be optimal in maximising the random distribution of groupings like SiO_4^{4-}, AlO_4^{5-}, FeO_4^{5-}, etc. within the disordered structure of the burnt ash and minimising its content of any crystalline minerals.

Slags are not pozzolanic but latently hydraulic. Ground granulated slags like blast furnace slag from steel production do not hydrate by themselves to any significant extent at ambient temperature because of the presence of surface films that inhibit the occurrence of significant hydration. With various activators like Portland cement, lime, calcium sulphate, etc. the granulated slags hydrate to form cementitious products, which give the resultant hydrated cement high later compressive strengths at 28 days and beyond together with beneficial lower permeability [4].

In the case of pozzolans like calcined clays such as metakaolin (MK), pulverised fuel ash (PFA), condensed silica fume (CSF), rice husk ash (RHA), calcined hazelnut shells (CHS) and wheat straw ash (WSA), it is actually the presence of alkalis that impart cementitious properties to the pozzolan. These extended cements can have beneficial properties like lowering the heat of hydration, which prevents or at least minimises thermal cracking. Also, the hydrated pozzolans in their increasing the later compressive strengths beyond 28 days decrease the permeability and thus raise the durability of the hardened extended cement structure.

Pozzolans have traditionally been defined as materials which, though not cementitious in themselves, react with calcium hydroxide, such as is produced by Portland cement, to form cementitious products. In actual fact it is the alkali hydroxides NaOH and KOH rather than calcium hydroxide $Ca(OH)_2$ that instigate the onset of pozzolanicity [4].

Hydroxide ions OH^- from the alkalis have the effect of destabilising the pozzolan, for example with PFA cenospheres [5], where the surfaces exposed to the water in the cement slurry tend to peel off gradually as they react with the alkalis present. The calcium hydroxide formed by the hydration of the Portland cement component is also destabilised in this reactive alkaline medium and gradually

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disintegrates, causing the dissolution of at least some of the calcium ions Ca^{2+}. These dissolved calcium ions are then available to react, as has been observed, with the glassy cenospheres of PFA, when the latter have been loosened up by the alkali ions Na^{+} and K^{+} in particular. The product is a calcium silicate hydrate C–S–H binder, which supplements that produced from the Portland cement component. It is this additional C–S–H forming that gives pozzolanic cements their higher long-term compressive strength and lower permeability, since this additional C–S–H is occupying space previously occupied by water [5]. WSA probably has a pozzolanic reaction mechanism that has certain similarities to that given by PFA.

However, the alkali content of WSA, as evidenced from the specimen K5 described [1], does appear to be intrinsically high, with contents of 5.85% for K and 1.83% for Na reported in Table 5. If WSA is to function as an effective pozzolanic cement extender in the future, then it is important that (like PFA) the alkali content is not readily mobile and hence not subject to ready exsolution with time. Otherwise, the propensity for other destructive phenomena like alkali–silica reaction [6, 7] could ensue. Should the alkalis from WSA be mostly entrapped and hence not readily available for becoming exsolved, then WSA could be a valuable cement extender, and thus a useful way of employing what is currently a waste product to a large extent.

The work reported by the authors [1] is an interesting study of a potentially important new cement extender. Clearly more studies need to be undertaken on this material in order to satisfy the aforementioned points raised. Maybe, as well as WSA, other ashes known to be of high residual silica content, like calcined sunflower ash (CSA) and calcined tobacco ash (CTA) could also find some useful application as pozzolans in extended Portland cements.

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