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Discussion

A discussion of the paper "Use of cactus in mortars and concrete" by S. Chandra, L. Eklund, and R.R. Villarreal[1]

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A recent paper by Drs. Chandra, Eklund, and Villarreal [1] has indicated that useful results can be obtained from the employment of cactus extract in a Portland cement mortar. This extract not only increases the plasticity of the cementitious mix, but also improves both the water absorption and the freeze-thaw resistance. The cactus extract for the mortar had been prepared by cutting the Nopal cactus leaves into thin pieces and mixed with the water in proportions of 1:3 by mass and then, after 2 days, the gel was extracted and the leaves were discarded. The sticky solution remaining behind was what was utilised in the experiments undertaken. This contained both polysaccharides (of different types and compositions) and various proteins [1].

Of particular interest here are the flexural and compressive strength results obtained in the presence of 50% (with external water) and 100% cactus extract (CEX). Retardation from the polysaccharide components of CEX led to diminished strengths at 1 and 7 days; the diminution was progressive from the reference mortar in water with no CEX through that with 50% CEX to the one with 100% CEX. However, by 28 days, the strengths of the CEX-containing mortars are not so relatively low in comparison as at 7 days. By 90 days it is interesting to see that the strengths of the mortars are progressively higher with the CEX than without it.

The strength growth pattern suggests that CEX gives rise to a mild quasi-pozzolanic effect in the hydration behaviour of the mortars. CEX cannot be described as a pozzolan in the true sense, because proper pozzolans (such as pulverised fuel ash, rice husk ash, condensed silica fume, metakaolin, and natural pozzolans) effectively consume calcium hydroxide to form more C-S-H that permits higher later strengths. The triggering mechanism for pozzolanicity appears to be the availability of sufficient OH^- ions to interact with the glassy/disordered surfaces, and the majority of these OH^- ions actually come from the alkali hydroxide present in the aqueous phase [2]. The calcium hydroxide is thereby destabilised and the Ca^{2+} ions released are then available for reacting with the siliceous pozzolan to form more C-S-H.

CEX does not contain the bulk silica and other oxides like alumina and iron (III) oxide in the mass required to react with Ca^{2+} ions to supplement the C-S-H already forming and thereby improve the strength and impermeability in the usual pozzolanic way. CEX has been shown to modify the morphology of the hydration products, with calcium hydroxide forming small crystallites that are cryptocrystalline or amorphous and not producing the large characteristic hexagonal plates seen in neat portland cement pastes. Crack formations are thereby reduced [1]. Such small crystals have also been observed with polymers present, where the latter have been shown to influence the course of C_3S (alite) hydration and to hinder the formation of large crystals of calcium hydroxide [3]. It is noteworthy to mention that smaller crystals of calcium hydroxide are also formed in the presence of lignosulphonate retarders, which are also polymeric systems, in this case based upon phenylpropane units having -OH, $-CO_2H$, $-OCH_3$, and SO_3H groupings [4,5]. In the CEX-containing mortars there is also much less calcium hydroxide being formed than in the reference mortar, suggesting that at least some of it is being effectively consumed within the reactive alkaline hydration environment [1].

The explanation advanced that the calcium hydroxide has chemically reacted with some of the components of the CEX to produce some calcium complexes is very likely to take place in the alkaline conditions of the hydrating mortar. The complex mixture of polysaccharides and proteins in the CEX will hydrolyse to form carboxylic bonds, which can then interact with the Ca^{2+} ions. During the denaturisation of the proteins that occurs within the hydrating cementitious system, as the authors point out [1], the natural coils of these proteins will open up and expose both the more hydrophilic parts and the more hydrophobic parts of the protein

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[1] Cem Concr Res 28 (1998) 41–51.

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structures. The hydrophilic parts move to the aqueous phase, where they are likely to interact to produce calcium complexes, while the hydrophobic parts go to the air phase, where they will cause the surface to become hydrophobic. This provides an explanation as to why the mortar becomes more durable with time in the presence of the CEX, unlike the situation when synthetic polymers are used [1]. Similarly, if employed in concretes, for the same reasons CEX should also enable greater durability to be attained.

In the CEX mortars, because the CH formed is cryptocrystalline and gradually reacts to form calcium complexes, the C-S-H being formed from the Portland cement component becomes a relatively stronger binder with the passage of time than it would otherwise be in the absence of the CEX, through the smaller size and relative dearth of calcium hydroxide crystals that, with the concomitant increase in hydrophobicity, would facilitate a lower permeability and thus an improvement in the compressive and flexural strengths developed. Owing to the high sorption properties of C-S-H and its unsatisfied surface forces, the Ca^{2+} ions here are much less likely to undergo any form of independent complexation than those from the calcium hydroxide. Indeed some of the organic material is likely to be sorbed into the C-S-H. As a consequence, the compressive and flexural strengths of the hardened mortars benefit from the presence of the CEX, particularly in the 28–90-day hydration time period when pozzolanic activity commonly manifests itself.

It should also be borne in mind that changes in the morphology of calcium hydroxide also influence the morphological development of C-S-H. C-S-H cannot form without calcium hydroxide being concomitantly formed at the earlier stages of hydration [6]. When pozzolanic (or in this instance what appears to be quasi-pozzolanic) activity arises the situation becomes modified, since the calcium hydroxide becomes destabilised and disappears either partially or completely depending upon the particular conditions pertaining thereto. In the situation described here, there is a partial loss of calcium hydroxide for the reasons already given [1].

However, because the CEX does not contain the “building blocks” of silica together with some alumina and iron (III) oxide to form more C-S-H with available Ca^{2+} ions, the quasi-pozzolanicity observed when the CEX is present is only a mild effect in comparison with true pozzolanicity. Further experimentation might be able to optimally enhance this observed quasi-pozzolanicity. Certainly the experimental work undertaken [1] has clearly demonstrated the potential of the CEX in construction technology for enhancing the workability and durability, including freeze-thaw resistance, of mortars and (by inference from the conclusions obtained from this very interesting study) of concretes as well.

References

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