DETERMINATION OF THE HYDRATION PRODUCTS OF ECO-CEMENT

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1. INTRODUCTION

Eco-cement is a type of hydraulic cement produced from incineration ash. The technology for its manufacture was developed by the New Energy and Industrial Technology Development Organization of Japan. The ashes of burnt trash and sewage sludge obtained from waste incinerating plant are mixed with limestone and clay, and heated to a clinkering temperature of about 1,400 degrees. The clinker obtained is grounded with gypsum which controls the setting time to produce eco-cement.

The main aim of this study is to determine the hydration products of eco-cement pastes in comparison to ordinary portland cement pastes, and to try to determine how it gains strength.

2. EXPERIMENTAL PROCEDURES

The chemical compositions of the cements used are given in table 1. Eco-cement and OPC were used to prepare cement pastes with water-cement ratios of 0.45 and 0.55. Cylindrical specimens of 50mm diameter and 100mm high were produced for each type of cement. The specimens were cured in a saturated calcium hydroxide ($Ca(OH)_2$) solution and the following tests performed after 1, 3, 7, 17, 14, 28, and 91 days of curing: pulse velocity, electrical resistivity, X-ray powder diffraction analysis, scanning electron microscopy (SEM), differential scanning calorimetry (DSC) .

Table 1. Chemical compositions of eco-cement and OPC

	Ig.losses	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	Cl
ECO	0.5	15.7	10.4	2.2	59.0	1.7	8.1	0.6	0.0	0.6
OPC	1.6	21.7	5.3	2.9	63.7	1.2	2.1	0.33	0.54	--

3. RESULTS AND DISCUSSION

3.1 ELECTRICAL CONDUCTIVITY

As shown in Fig 1, for both w/c ratios, the electrical conductivity as well as its rate of decrease with curing time for the OPC paste is faster than that of the corresponding eco-cement paste. The electrical conductivity of each specimen decreased at a faster rate within the first 7 days of curing, and thereafter decreased at a slower. Since electrical conductivity through hydrating cement paste is essentially electrolytic, that is through the motion of ions in the pore solution (Na^+, K^+, OH^-, $SO4^{2-}$, Ca^{2+}, etc.), the rate of decrease in electrical conductivity is an indirect measurement of the rate of hydration. Thus it can be inferred that the rate of hydration in the OPC paste is higher than that of the eco cement.

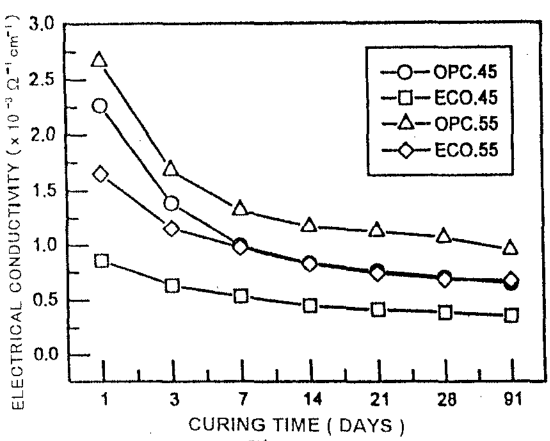

Fig1
Electrical conductivity vs curing time

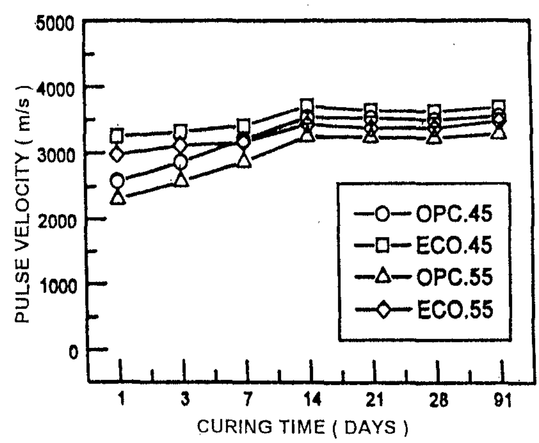

Fig 2
Pulse velocity vs curing time

3.2 PULSE VELOCITY

From the graph of pulse velocity versus curing time (Fig 2), it could be observed that for the same w/c ratio, the pulse velocity of both the OPC and eco-cement pastes increased up to the first 14 days of curing and thereafter remained almost constant. Also for the same w/c ratio, the pulse velocity of the OPC paste increased at a faster rate than that of the corresponding eco-cement paste during the first 14 days of curing. Since pulse velocity of cement paste or concrete, is an indirect measurement of strength, it can also be inferred that, for the same water-cement ratio, the OPC paste gained strength at a faster rate than that of the eco cement paste.

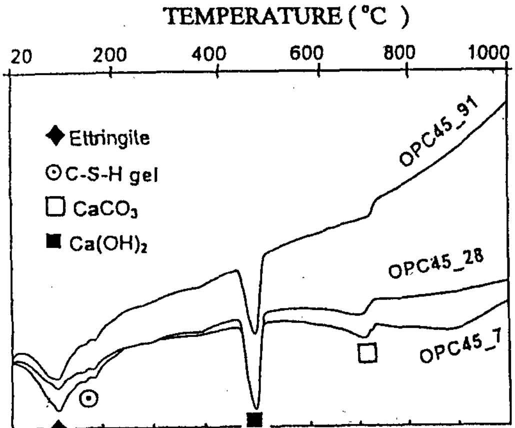

Fig 3.
DSC curves for OPC pastes

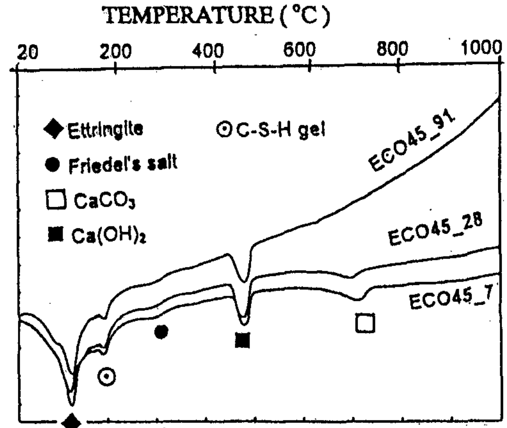

Fig 4.
DSC curves for eco-cement pastes

3.3 DIFFERENTIAL SCANNING CALORIMETRY, XRD ANALYSIS AND SEM OBSERVATION.

The XRD, DSC and SEM results indicated the presence of the following hydration products in the cement pastes: C-S-H gel, calcium hydroxide, monosulphate and ettringite for OPC pastes and C-S-H gel, calcium hydroxide, monosulphate, ettringite and Friedel's salt ECO-cement

From the SEM pictures it was also observed that the crystals of the hydration products of the OPC specimens are more closely packed than that of the eco-cement ones. A comparison of the XRD curves for OPC and eco-cement pastes indicated that more ettringite was formed in the eco-cement pastes than in the OPC pastes. This is to be expected since eco-cement contains more aluminate and sulphate than OPC. Another observation was that the amount of calcium hydroxide formed in the OPC paste is more than in eco-cement paste. This explains why the electrical conductivity of the eco-cement paste is lower than that of OPC even though SEM pictures depict a less closely packed crystal structure of its paste, which is expected to provide less resistance to the transport of ions and hence a higher electrical conductivity than OPC.

The DSC curves, Figs 3 and 4 indicate the formation of Friedel's salt in eco-cement paste. This is as a result of the high chloride and calcium aluminate content in eco-cement. However a closer look reveals that the quantity formed (indicated by the area under the broad endothermic peak around 300^0C) decreases with curing time, which suggests a decomposition of Friedel's salt in the later days of hydration. If the chloride ions resulting from this decomposition are not binded in some way, and enters the pore solution, then corrosion of steel reinforcement will be accelerated. The quantity of ettringite in the cement paste (which is proportional to the area under endothermic peak at 110^0C) decreases with curing time in both OPC and eco-cement pastes. This implies that, ettringite converts gradually to monosulfate as the curing time increases. The conversion rate is however greater in the OPC paste than that of eco-cement due to its higher sulphate content.

4. CONCLUSION

The main results obtained in this study are as follows;

1. The hydration mechanism in eco-cement is basically similar to that of OPC.
2. More ettringite is formed in the hydration of eco-cement than in OPC.
3. Less calcium hydroxide is formed in the hydration of eco-cement than in OPC.
4. The rate of hydration of eco-cement progresses at a slower rate than that of OPC although its setting is rapid.
5. Friedel's salt is formed in the hydration of eco-cement because of its high calcium chloro aluminate content.
6. The hydration products of OPC pastes are more closely packed than that of eco-cement pastes.