Permeability and expansion of concrete mortars made with incinerator fly ash

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Permeability and expansion of concrete mortars made with incinerator fly ash

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ABSTRACT

The main theme of this research is to investigate the durability of concrete made using waste materials as a cement replacement in order to produce green sustainable concrete. The mixes contained incinerator fly ash which was obtained locally from the domestic waste incinerator at Coventry. The other materials used in the mixes included blastfurnace slag, silica fume and kiln bypass dust, which was used as an activator and was also obtained locally from the Rugby cement plant. Mix designs were developed to optimise the strength results. The optimised mixes were then tested for permeability and expansion. Promising results were achieved for the expansion of the mixes with a low W/B ratio. Some initial expansion was, however, observed for the wet cured samples. Some loss of mass was observed after wet curing, despite strength increases, indicating some dissolution into the curing water.

1. INTRODUCTION

In this research, the durability aspects of concrete made with waste materials as cement replacements were investigated. The study of sustainable concrete is an environmental necessity in 21st Century with the threat of global warming. All countries are expected to reduce their carbon footprint and replacing cement with waste materials is a practical step towards of achieving this.

2. THE MAIN THEME OF THIS RESEARCH

The main theme of the research is to study the mechanical, physical and chemical properties of concrete made with incinerator fly ash (IFA) as a partial cement replacement. The incinerator fly ash used was won locally from the local domestic waste incinerator at Coventry. Other secondary materials were also are used in the mixes including Ground Granulated Blastfurnace Slag (GGBS), silica fume (SF) and kiln bypass dust (BPD), which was used as an activator and was also obtained locally from the Rugby cement plant.

3. EXPERIMENTAL METHODS

Compressive strength, permeability, and rate of expansion were tested. The method used to optimise the strength was to start with binary mixes and then use the results from them to develop multi-component mixes.

3.1 Mix designs, casting and curing

A single basic mix design containing 10% silica fume, 32.5% incinerator fly ash, 15% cement Kiln Bypass Dust, 10% GGBS, 30% OPC and 2.5% Superplasticerser was used for most of the multi-component samples. Both 0.3 & 0.4 water/binder ratios were used and wet and dry curing. Superplasticiser (SP) was used in order to reduce the w/b ratio and improve the strength.
Some loss of mass was observed after wet curing, despite strength increases, indicating some dissolution into the curing water.

3.2 Test procedures

The compressive strength was measured on 50mm mortar cubes at 7 and 28 days. For the Rate of Expansion Experiment the ASTM testing procedure was followed (1), (2). However, for the permeability testing, a high pressure device developed at Coventry University has been used (3)

4. RESULTS

4.1 Compressive strength

The compressive strength results for the binary mixes are in figures 1 and 2. These mixes contained only IFA and OPC. It may be seen that the mixes with w/b=0.3 were particularly sensitive to poor curing and at all proportions of IFA.

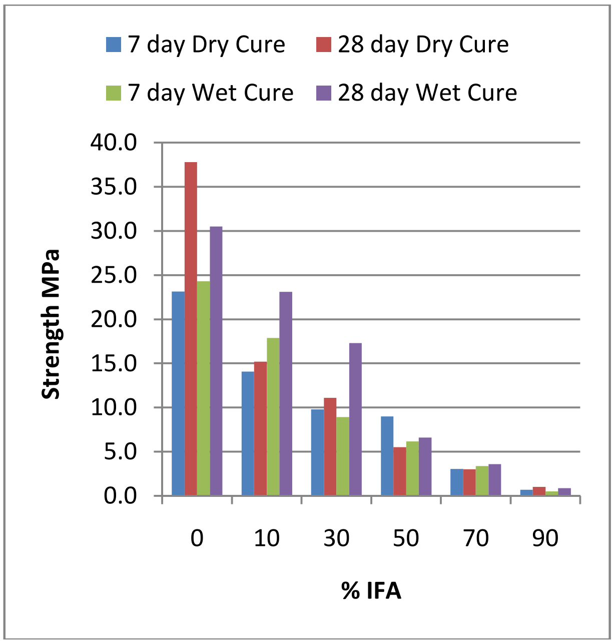

Figure 1. Strengths for binary mixes with w/b=0.4. The first 2 columns in each group are 7 and 28 day dry cure and the next 2 are wet cure.

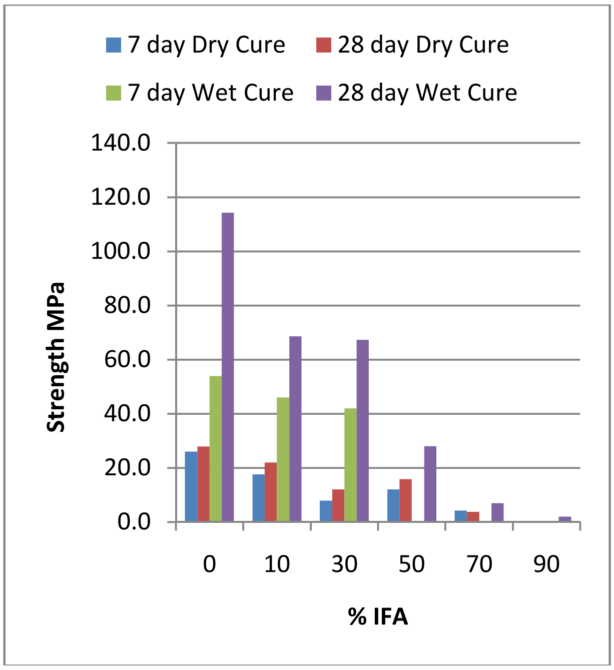

Figure 2. Strengths for binary mixes with w/b=0.3

The results for the multi-component mixes are in figures 3 and 4

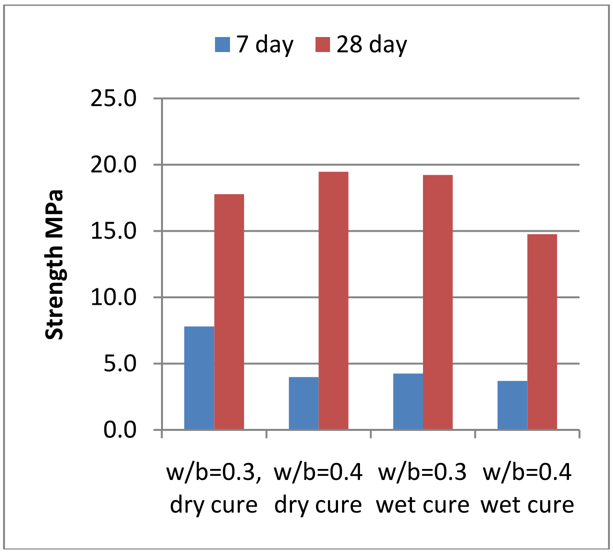

Figure 3. Strength for mixes with 2.5% SP, 32.5% IFA, 10% SF, 15% BPD, 10% GGBS and 30% OPC

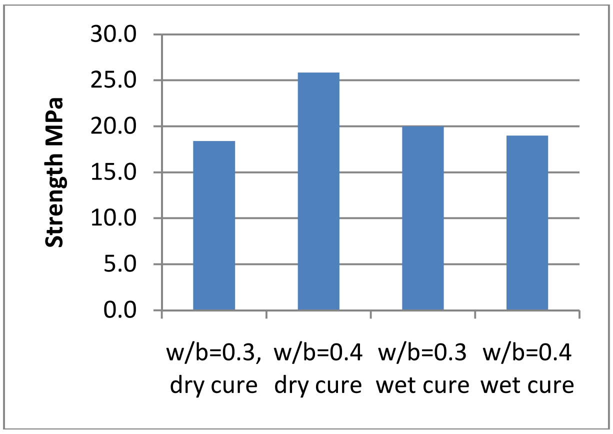

Figure 4. 28 Day Strength for mixes with 2.5% SP, 42.5% IFA, 10% SF, 15% BPD, 30% GGBS

The use of a multi-component system produced the best results even with a higher percentage of waste materials (42.5% IFA). The strength results were much improved by the introducing the use of Superplasticisers to a minimum percentage of 2.5% of total binder content in order to reduce the water demand.

Lime deposits were observed on the binary mixes with higher ash contents when they were wet cured. However, when high strength cement was used, the white lime deposits were not obvious. This indicates that high levels of calcium hydroxide in the IFA were depleted when mixed with high strength cement, to leave very little visible deposit, if any. In all dry cured mixes, there were no white lime deposits apparent.

4.2 Permeability

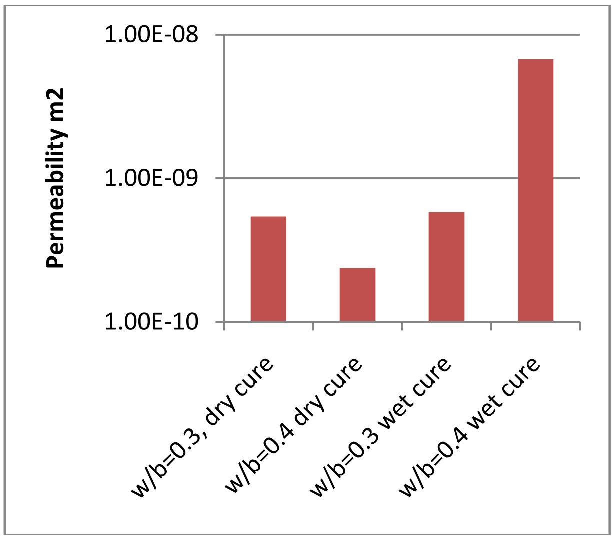

Figure 5 28 Day permeability for mixes with 2.5% SP, 42.5% IFA, 10% SF, 15% BPD, 30% GGBS

The permeability results are in figure 5. It may be seen that dry curing reduced the permeability indicating that the dissolution in the curing water which resulted in mass loss also increased the permeability.

4.3 Expansion

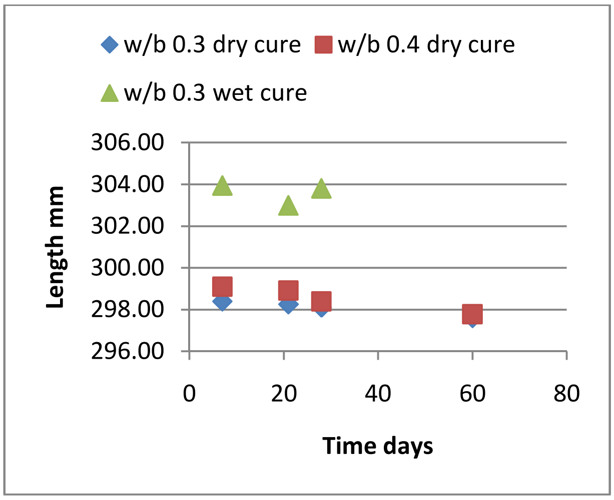

Figure 6. Expansion for mixes with 2.5% SP, 32.5% IFA, 10% SF, 15% BPD, 10% GGBS, 30% OPC

The expansion results are in figure 6. Some dry samples did undergo shrinkage beyond the allowable limits of BS8500.

5. DISCUSSION

Promising results were achieved for the multi-component mixes. Obtaining strengths of around 20MPa for a mix with over 40% IFA together with a blend of other secondary materials shows that practical zero-cement mixes for low strength applications. Concrete strengths are typically higher than the past results reported here. A site trial is planned to see if these mixes can be placed at full scale (this will be a foundation for a light structure). The producers of the IFA and BPD are very keen to pursue this (although at the time of writing we await a response from the EA). It is of note that the Coventry Incinerator where the IFA was produced is very old and was due for replacement. This could have been helpful because some of the literature indicates that new plants produce a better ash for use in concrete. However as a consequence of the the new “zero waste” policy introduced by the City Council this plan has been stopped. The existing plant will therefore remain in use for at least another 15 years.

The authors would also add that we are aware that wastes vary from day to day (particularly BPD) so, while we have sought to demonstrate that this technology is viable, we are aware that specific formulations are unlikely to work in all circumstances.

6. CONCLUSION

It is concluded that a viable concrete for low-medium strength applications can be produced with a blend of over 40% IFA combined with other secondary materials.

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