**Strength Optimisation in concrete mortars made with incinerator fly ash**

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**Abstract:**
The aim of this work is to reduce the environmental impact of concrete used by the author's employer (Warwickshire County Council) by making use of locally available materials to replace cement. Fly ash from the municipal waste incinerator in Coventry city centre has been used to make over a 100 different mixes in order to meet or exceed the minimum strength requirements for structural concrete, which is $15N/mm^2$ in accordance with BS8500. The paper will present the results obtained to date and discuss the plans for future work including a wide range of tests on three candidate mixes, and an investigation into the effects of variability in ash composition.

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**1. Introduction**

The aim of this work is to reduce the environmental impact of concrete used by the author's employer (Warwickshire County Council) by making use of locally available materials to replace cement. Fly ash from the municipal waste incinerator in Coventry city centre has been used to make over has been used.

Initial results were not promising, however, by adding silica fume they improved considerably. Further gains were obtained with the use of a multi-component mix with incinerator fly ash (32.5%), blastfurnace slag (10%), cement (30%), silica fume (10%) and cement kiln bypass dust (15%). Finally, the strength results were much improved by the use of Superplasticisers at a minimum of 0.5% of total cementitious content and a reduced water to cement ratio.

It was very important to optimise the strength results as much as possible because a minimum value is specified for most applications and other properties such as permeability and chloride ingress have a strong correlation with them. Therefore the start of the experiments to measure other properties such as durability was delayed until higher strengths were achieved.

The paper will present the results obtained to date and discuss the plans for future work including a wide range of tests on the three candidate mixes, and an investigation into the effects of variability in ash composition.

## 2. Experimental programme.

A ternary systems were introduced by using incinerator fly ash, GGBS and OPC with 10% Silica fume and cement kiln Bypass Dust (BPD) as an activator. Finally, the strength results were much improved by the introduction of the use of Superplasticisers to a minimum percentage of 0.5% of total cementitious content.

The programme is mainly to work on working out permeability effects of mortar mixes made with a ternary mix as shown above, measure strength patterns and chloride ingress for this year. Also, the author will be investigating the freeze and thaw effects of these ternary mixes before the end of the year.

## 3. Experimental methods.

For all the mortar mixes used a 50mmx50mm samples were used and cube crushed at laboratories of Coventry University, School of Built Environment. Furthermore, chloride content was measured and found out to be quite high at 12% using the method of titration.

## 4. Results

The results are shown in figures 4.1 until 4.4, in consecutive order.

Whilst carrying out most of the experiments, it was noticed that the higher the ash content the more water demanding the mix would be and by increasing the content of GGBS instead and reducing the ash the opposite was achieved and that is wet, highly viscous mixes.

The strength results were improved by taking various measures including the use of silica fume. At the beginning, various percentages of silica fume were experimented with, then better results were achieved when it was fixed to 10% throughout for every consecutive mix. (see fig 4.4)

The 3 best mixes where achieved that gave strength results over 20 N/mm. All 3 mixes had higher percentage of incinerator fly ash and this is most important, had a constant amount of BPD of 15%, a constant amount of Superplasticisers, which is 0.5% of total cement content, a constant amount of silica fume which is 10% and varying amounts of GGBS and OPC. These three mixes have a high percentage of incinerator fly ash and thus have the potential to achieve significant environmental gains. The high ash content was detrimental to workability but this was balanced by a positive contribution from the blastfurnace slag.

One of the main reasons why the strength results of concrete made with incinerator fly ash were low was the high chloride content in the ash (measured at 12%) and the high content of heavy metals (Sebok T, Kulisek K, 2001). These constituents make it environmentally hazardous and resistant to solidification, densification and strength gain. Other researchers washed incinerator ash before using it (Aubert J. E, Husson B, Vaquier A, 2003), but this would add considerably to the economic and environmental cost.

## 5. Conclusions and future research

### 5.1 Conclusions:

1- Initial findings showed that incinerator fly ash has a significant detrimental effect on concrete strength.

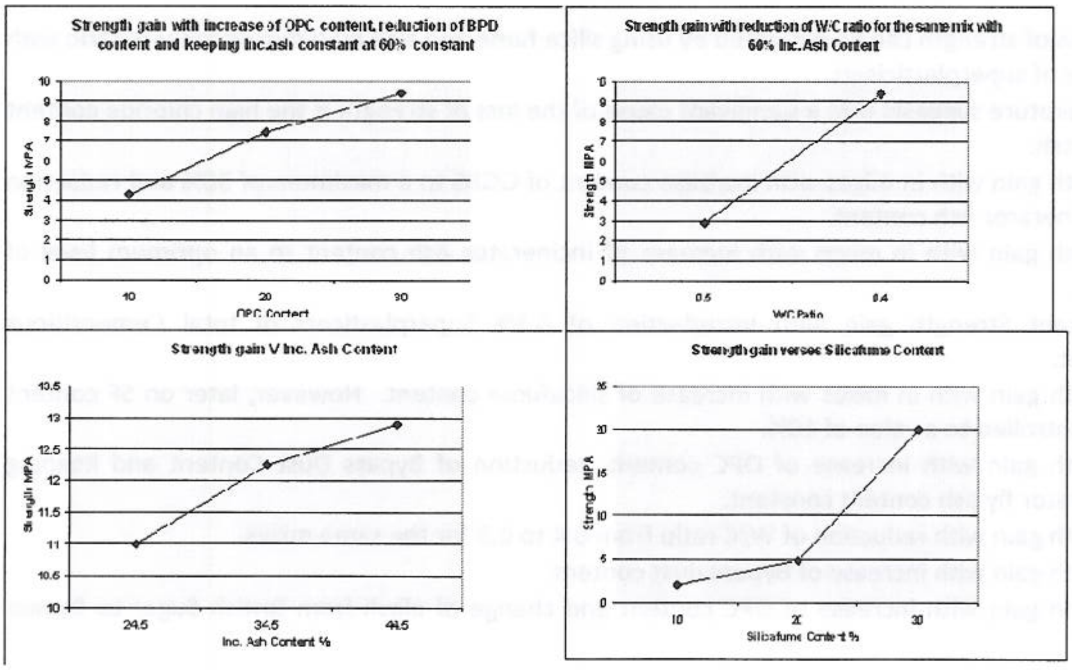
- The loss of strength can be mitigated by using silica fume and also by reducing the w/c ratio with the use of superplasticisers.
- The literature suggests that a significant cause of the loss of strength is the high chloride content in the ash.
- Strength gain with in mixes with increase content of GGBS to a maximum of 30% and reduction of Incinerator Ash content.
- Strength gain with in mixes with increase of Incinerator Ash content to an optimum level of 44.5%.
- Significant Strength gain with introduction of 0.5% Superplasticers of total Cementitious content.
- Strength gain with in mixes with increase of silicafume content. However, later on SF content was controlled to a value of 10%.
- Strength gain with increase of OPC content, reduction of Bypass Dust Content and keeping incinerator fly ash content constant.
- Strength gain with reduction of W/C ratio from 0.4 to 0.5 for the same mixes.
- Strength gain with increase of Bypass dust content.
- Strength gain with increase of OPC content and change of alkali from British Sugar to Bypass Dust.

### 5.2 Further work:

- The permeability and chloride ingress of the candidate mixes will be measured.
- The strength characteristics of a binary system will be studied, where, various mixes of purely incinerator fly ash and OPC will be investigated in terms of strength gain. This is to help find the optimum mix with maximum waste material content (incinerator fly ash) that will have strengths of structural concrete in accordance to BS8500.
- The behaviour of concrete made with incinerator fly ash soaked in water for a reasonable amount of time will be examined to investigate whether, material strength, composition, and density get effected by being soaked in water. These findings would be quite crucial in determining the success of using waste material (incinerator fly ash) in concrete production for structural use, thus achieving, green form of concrete which is sustainable and eco friendly.
- The material variability of every ash batch received will be studied and investigated to ascertain the reason why some of the anomalous results achieved for strength and other mechanical characteristics
- Most of the concrete samples were cured by air and 0.4 water cement ratio was used. However, the last optimised three mixes which will be the main mixes of investigation will be repeated with a water/cement ratio of 0.3 and wet curing will be used to further enhance the strength results.

## 5.3 – Best three mixes – Table 5.1

| Mix | W/C | silicafume | Inc.Ash | SP | BPD | GGBS | OPC |
|---|---|---|---|---|---|---|---|
| 1 | 0.3 | 10 | 42.5 | 2.5 | 15 | 30 | 0 |
| 2 | 0.3 | 10 | 32.5 | 2.5 | 15 | 40 | 0 |
| 3 | 0.3 | 10 | 32.5 | 2.5 | 15 | 10 | 30 |




## 7. References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