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Solidification of APC residues using PFA

R. Shirley*, L. Black
School of Civil Engineering, University of Leeds, Leeds LS2 9JT, UK
* cnrs@leeds.ac.uk

Abstract: A pulverised fuel ash (PFA) classed as waste due to high loss on ignition (LOI) was blended with a waste alkali and used to solidify air pollution control (APC) residue from a waste incinerator. The resultant samples were tested for compressive strength, and characterised using thermo gravimetric analysis (TGA). The effects of various variables including l/s ratio, APC content, curing temperature, and alkalinity of the liquid phase were examined. Results showed a lower l/s gave a higher compressive strength, analogous to that seen for cement mixes,. Curing at slightly elevated temperatures were necessary for setting of the mixes within 7 days. An alkaline liquid fraction increased early age strength. The %(w/w) APC content showed no clear correlation with compressive strength results, but some APC was necessary for the mix to set. Results suggest the optimum APC content for compressive strength and solidification may be between 10-20%.

1. Introduction

Waste incineration is an increasingly popular method of reducing landfilled material and creating energy. Air pollution control (APC) residue collected in the stacks during incineration is classed as a hazardous material (European waste catalogue (19 01 07)) due to heavy metal content, alkalinity and chloride content. The residue must therefore be treated in order to comply with the waste acceptance criteria (WAC)[1].

One promising option for treating the residue is solidification, through which immobilisation of heavy metals and chlorides may be possible, as well as reducing the alkalinity. Solidification also makes the residues easier to handle than in their original granular form. Solidification of APC residues has been tested previously using various materials including Portland cement[2,3], ground granulated blast furnace slag[4] and alkali activated cements including metakaolin and coal fly ash[5].

The PFA used in this study is classed as a waste due to high LOI and sulphur content (EN450). There are clear benefits to treating a waste with waste such as the avoidance of using new materials. The compressive strengths of the samples were tested and effects of l/s ratio, APC content (% weight), curing temperature and alkalinity of the liquid phase were determined.

1.1. Materials and Experimental

The XRF analysis of the PFA and APC residues are given in table 1. The liquid phase used was either tapwater, a waste alkali solution containing aluminium, or a laboratory prepared NaOH solution (3.5M). Unless otherwise stated the waste alkali was used.

Element	**Si**	**Al**	**S**	**Ca**	**Fe**	**K**	**Mg**	**Na**	**Cl**	**LOI**
PFA %mass	24.06	10.22	3.75	3.07	3.84	1.94	1.03	0.831	0.038	12.36
APC %mass	0.236	0.029	0.652	39.78	0.088	0.228	0.133	1.46	13.9	24.02

Table 1 XRF results for raw materials

Samples were cast as 50mm cubes and, unless otherwise stated, cured in a temperature controlled room, at 38˚C. Compressive strength was measured according to BS EN 12390-3 (2002) with the only deviation being the sample size.

2. Results

2.1 L/S ratio

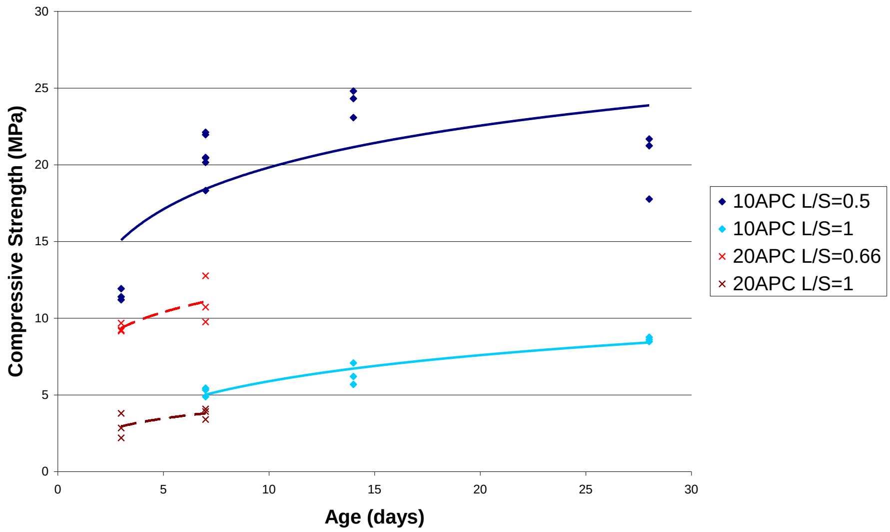

Figure 1 Effects of l/s ratio on compressive strength

Figure 1 shows the results of varying l/s ratio on the compressive strength of the samples. As can be seen a lower l/s ratio results in higher compressive strengths.

2.2 APC Content (% w/w)

Samples containing higher levels of APC content showed significant unsoundness (figure 2), whilst samples produced without APC failed to set. The increase in strength between 20-30% APC (figure 3) may be attributed to secondary effects such as increased water demand at higher APC levels, and appears to have effects analogous to reducing the l/s ratio.

Figure 2 Unsoundness observed in 30%(w/w) APC samples

It can be assumed from the failure to set of samples containing no APC and from the TGA results that samples are setting due to pozzolanic reactions. TGA results (table 2) indicate that all of the calcium present in the 10% APC mixes has reacted within 7 days. Results also indicate little reaction in samples with higher APC content between 7 and 28 days, which coincides with the lack of strength gain in these mixes. The reaction appears slower in the diluted 20APC mix however, which coincides with continued strength development over 28 days (figure 6).

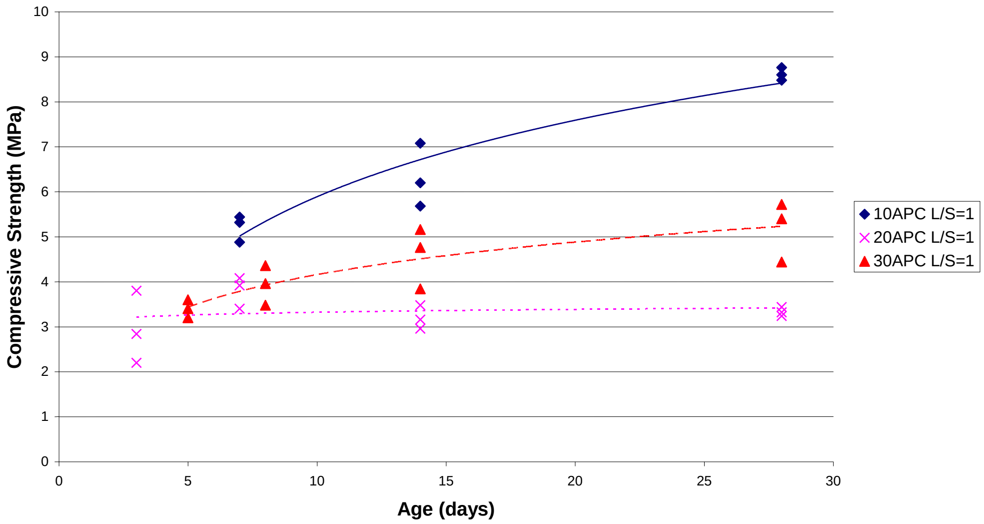

Figure 3 Effects of APC content (%w/w) on compressive strength

Mix				**7 Day**				**28 Day**			
	l/s	**Ca**	**CH**	**CH**	**CĈ**	**CH_{equiv}**	**UCS MPa**	**CH**	**CĈ**	**CH_{equiv}**	**UCS MPa**
10APC	0.5	5.5	10.18	0	0	0.00	20.58	0	0	0.00	20.23
10APC	1	5.2	9.64	0	0	0.00	5.21	0	0	0.00	8.61
20APC	1	8.9	16.43	4.48	4.27	7.64	3.8	3.74	3.61	6.41	3.33
20APC (dilute)	1	8.9	16.43	3.1	10.23	10.65	2.37	3.58	6.91	8.69	3.26
20APC (H2O)	0.5	9.3	17.37	3.7	5.36	7.71	7.52	4.11	4.73	7.61	10.26
20APC (NaOH)	0.5	9.3	17.37	2.0	1.99	3.42	13.16	1.54	1.7	2.8	14.32
30APC	1	12.6	23.22	7.7	3.41	10.21	3.93	7.24	4.68	10.70	5.19

Table 2 TGA results for mixes, showing %mass of portlandite in each mix.

2.3 Curing Temperature

Curing temperature appears to be vital to the setting of the mixes. Samples left to cure at room temperature showed unacceptable failure until the 7 day age, deforming rather than failing, and very low compressive strengths compared an identical mix cured at 38˚C (figure 5). The higher temperature increases the rate of pozzolanic reaction.

UCS (MPa)	**3 Day**	**7 Day**	**14 Day**
Heat cured	11.51	20.58	24.07
Room Temp	0.00	1.00	3.12

Figure 5 UCS of 10APC, l/s=0.5

2.4 Alkalinity of Liquid Phase

Figure 6 shows compressive strength results for mixes using liquid phases of varying alkalinity. An alkaline liquid phase appears to increase the speed of the reaction. Interestingly after 28 days the compressive strengths of the mixes containing undiluted and 50% diluted waste alkali have converged. The 3.5M NaOH solution shows greater strengths than the equivalent aqueous mix, not only quicker strength gain.

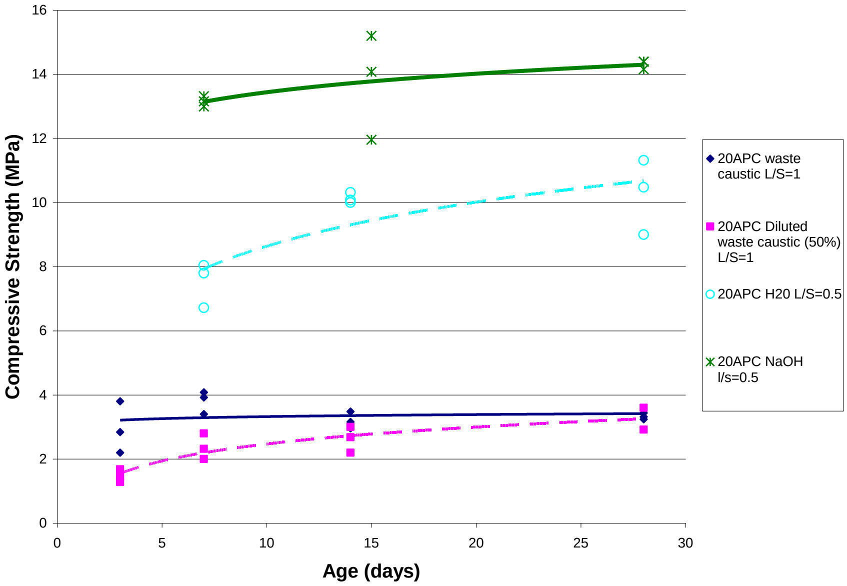

Figure 6 Effects of alkalinity of the liquid phase on compressive strength

3. Conclusions

The APC residue used could be solidified enabling it to be easily handled and landfilled using a PFA classed as a waste material. A wide range of mixes all met the 1MPa 28 day compressive strength required to meet the Waste Acceptance Criteria (WAC) as discussed in the legislation(1).

Mixes may contain up to 20% (w/w) of APC residue. Samples containing 30% (w/w) showed greater compressive strengths but unsoundness at a level likely to decrease the ease of handling.

An alkaline liquid phase improved compressive strength and the increased the rate of reaction. An alkaline liquid phase was not however necessary for solidification and fulfilment of the required compressive strength which can be achieved using water. What effect this has on the pH of the resultant sample was however untested.

The mixes solidify due to pozzolanic reactions as seen in blended Portland cements. The behaviour of the mixes was in many ways similar to these materials, for example a lower l/s ratio results in higher compressive strength. Increased curing temperature also increases the compressive strength of the mixes.

Though these materials are shown to solidify, due to the variance in APC residue compositions and morphologies, other APC residues may not behave in the same way if substituted into the mix. Importantly the leach behaviour of the produced samples was untested. The stabilization of hazardous elements is critical to the utility of solidification using these materials.

References

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