

An overview of PFA/Fly ash in recent years

The UK power industry has undergone many changes in recent years since de-nationalisation and the environmental pressures being applied to reduce dependence on coal fired power generation. In addition, there have been major changes to the specification of Pulverised Fuel Ash (PFA)/fly ash for use in concrete due to the revision of BS EN450, published in 2005. This document reviews the performance of fly ash in recent years from laboratory testing carried out on behalf of the UKQAA by Kirton Concrete Services Ltd.

During 1998/99 the UKQAA commissioned a series of test to be carried out to BS3892 Part 1 and EN450:1994. These were designed to compare the relative performance of a number of sources of PFA to both testing standards, BS3892 Part 1 and BS EN450:1994, over an extended period of time, i.e. 20 weeks. The power stations tested were the main suppliers of PFA used at the time for the concrete industry. Fineness, water requirement and strength factor were carried out to BS3892: Part 1: 1997 and fineness and activity index carried out to BS EN450:1994 on all samples by a single laboratory. In addition pozzolanicity to BS EN196-5 and standard consistence were carried out by other laboratories, plus some concrete mixes on the same samples.

In 2004 a limited programme to repeat this work was carried out using the same sources of ash where possible. Only one source of ash from the five originally tested in the 1998/99 had disappeared due to the power station closing down. Again BS3892 Part 1 plus the new BS EN450-1:2005 test methods were used. BS3892 Part 1 PFA has now been superseded by Category S fly ash to BS EN450-1:2005 and BS EN450:1994 fly ash is now known as Category N fly ash. For the sake of brevity, the two types of ashes will be referred to as Category S and N as appropriate irrespective of date.

The results

The following outline the results found and the changes seen in fly ash and concrete performance over the period of 1998 to 2005.

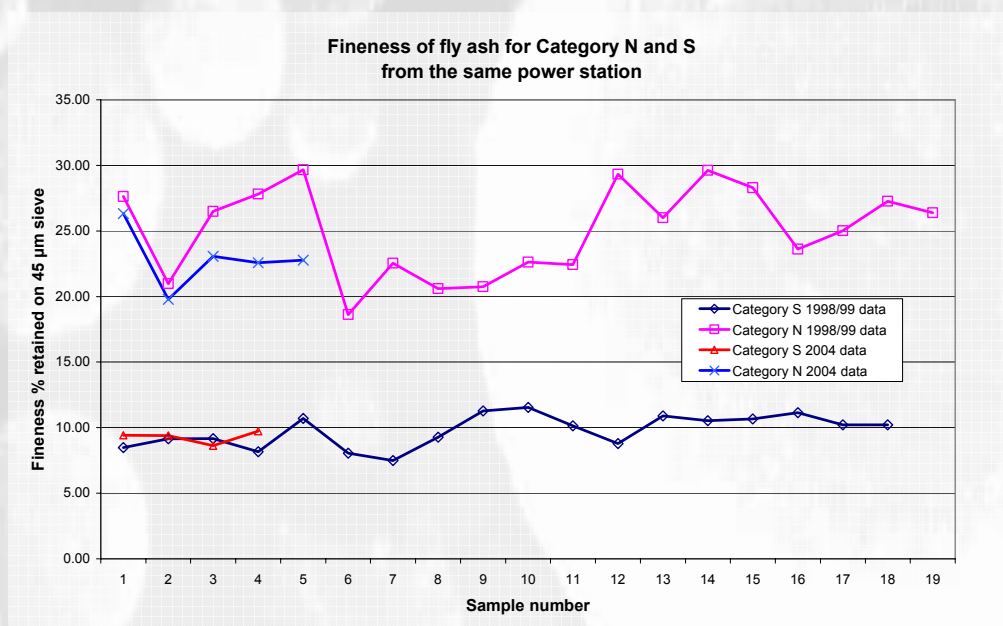


Figure 1 - Comparison of fineness in 1998/99 and 2004

Fineness of the fly ash

Comparison between the fineness between 1998/99 and 2004 from the four sources still in existence showed there were no significant differences in ash fineness over the period, as indicated in figure 1. As

coal fineness affects the performance of the furnace and the efficiency of power generation, it is of no surprise EN 450 Category N ash is similar. As Category S ash material is classified, again the material should be of similar quality because of the nature of the processing carried out.

Activity Index

Activity index is a measure of the pozzolanicity, which is related to the surface area of the particles exposed to the reactions. Therefore, it follows finer ash, such as Category S fly ash, should have a greater Activity Index. This is clearly seen in the 1998/99 and the 2004 data as shown in figure 2.

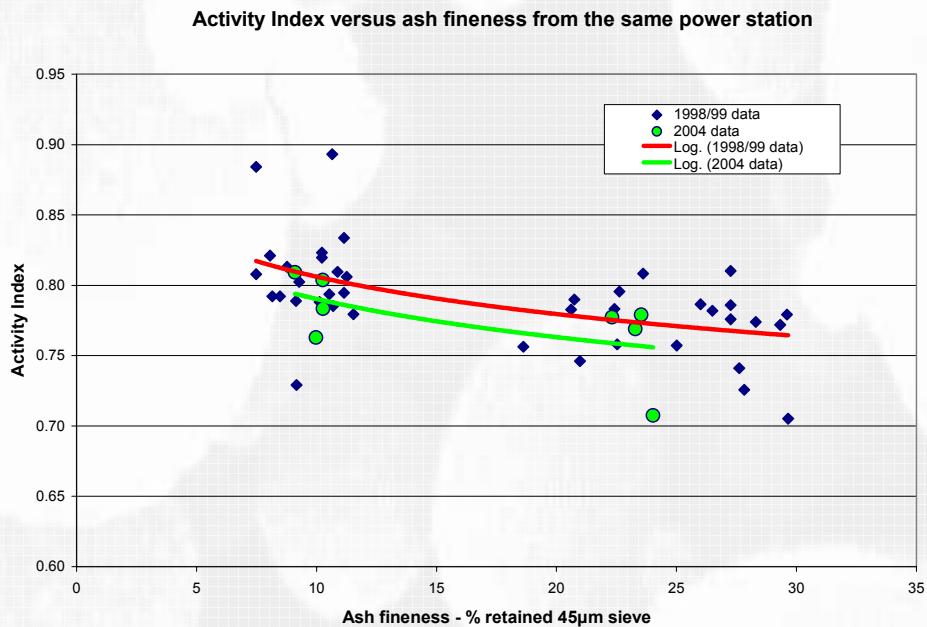


Figure 2 – Activity Index depends on ash fineness

While the activity index of the ash was similar between the two datasets, there were large differences in cement strength, as seen in Figure 3.

The effect on fineness on mortar prism strength has been well documented. This is clearly visible in the 1998/99 data, finer ash makes for greater strength. However, the 2004 data shows the mean strength to be some 7.9MPa lower than from the previous work for exactly the same testing regime. From the CEM I control strengths it was clear that there is 6.0MPa strength reduction. Did this explain the difference in the fly ash strengths?

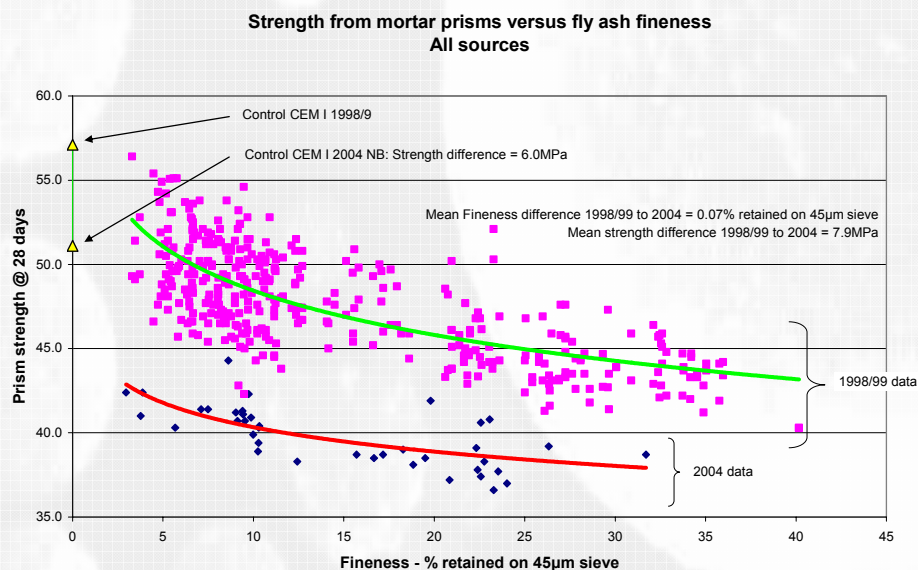


Figure 3 – Strengths performance reduced between 1998/99 and 2004?

In order to quantify whether this was a function of the control cement it was necessary to test the original ash samples with the current CEM I. By foresight sealed samples of some of the ashes used in the 1998/99 test programme were still in store at one of the test laboratories that carried out the 1998/99 project. These samples were re-tested using the 2004 CEM I with the results as shown in Table A;

Table A – Results from stored samples of ash with 2004 CEM I

1998/99 project samples	CEM I control	EN450 strength	Activity Index	1998/1999 data from project		
				CEM I	EN450 strength	Activity Index (28 days)
Source C 13th Nov 1998 Classified	51.1	41.6	81.4%	56.2	48.3	86%
Source C 13th Nov 1998 Unclassified	51.1	37.5	73.4%	57.5	41.9	73%
Source B 8th Jan 1999 Unclassified	51.1	39.2	76.7%	55.4	43.3	78%
Source E 13th Nov 98 Unclassified	51.1	39.7	77.7%	57.5	43.2	75%
Source E 13th Nov 98 Classified	51.1	41.4	81.0%	57.5	46.6	81%
Source D 20th Nov 1998 Unclassified	51.1	40.1	78.5%	56.2	45.2	80%
Source D 20th Nov 1998 Classified	51.1	41.4	81.0%	58.7	49.44	84%
Source B 8th Jan 1999 Classified	51.1	39.8	77.9%	56.2	45.4	81%
	Two tests were carried out on the control CEM I in 1998/99			58.7	51.9	88%
Averages	51.1	40.1	78.5%	57.1	46.1	79.8%

The difference in activity index was found to be 1.3% from the 1998/99 samples.

Conclusions

The following conclusions are made;

1. It is clear that the CEM I test cement control strengths have significantly reduced by 6.0MPa since the original work was carried out. This may simply be due to a rogue sample or a reflection in the changes in cement making in recent years. The strength of mortar prisms made containing fly ash have equally been affected by this change.
2. The change in CEM 1 performance has only had a marginal affect on the Activity Index of ash samples apparently causing a reduction of ~1.3% at 28 days.
3. Overall the activity index has reduced by 2.2% since 1998/99. However, ~1.3% of this reduction is assigned to the change in the control CEM I and the reduction due to changes in performance of fly ash is probably ~0.9%.
4. A small proportion (7%) of the Category N samples from the 2004 data failed the 28 day activity index criteria but all passed at 90 day. This is similar to the 1998/99 situation where 5.7% failed. All Category S fly ash in 2004 passed both 28 and 90 day requirements.
5. The performance of fly ash being supplied between 1998/99 and 2004 has not significantly changed, as the overall reduction in Activity Index of 0.9% is well within expected testing error^a (5.5%). The formulation of the CEM I does have some bearing on the results obtained and wherever possible the same source and sample should be used to ensure comparable data.

^a EN196-1 suggests reproducibility of <2.0% as coefficient of variation. As the activity index is already expressed as a proportion from two values, the increases the reproducibility by $\sqrt{2}$ to 2.8% expressed as a single standard deviation. Therefore, the 95% confidence limits on a single activity index result would be $\pm 5.5\%$. For the numbers of results in the two testing programmes, the 95% confidence limits can be shown to be $\pm 3.6\%$ on the overall mean activity index difference.