UNITED KINGDOM QUALITY ASH ASSOCIATION

Technical Datasheet

Calculating the Alkali Content of concrete containing fly ash (PFA) for minimising the risk of Alkali Silica Reaction (ASR)

Introduction

The calculation of the Alkali content of a concrete mix is given within BS8500-2:2006+A1:2012 Annex D for combinations of CEM I and additions and for the equivalent factory made cements. However, one omission within previous versions of BS8500 is how to treat fly ash which has been added as filler aggregate, a so called Type I addition, to the concrete mix when used in conjunction with a factory-made composite cement, or mixer combination, containing Type II additions with the PC/CEM I component. While a Type I addition does not count towards the cementitious content of the concrete mix, i.e. does not count towards the Minimum Cement Content or Maximum Water Cement ratio, it will however provide the same amount of protection in minimising the risk of deleterious Alkali Silica Reaction (ASR) as fly ash added as a Type II addition.

The ASR reaction is a chemical reaction where materials of high alkalinity containing potassium and sodium hydroxide react with some aggregate types to produce a silica gel like material. This gel absorbs a high proportion of water over time and can lead to expansion, resulting in the gel disrupting the concrete matrix due to the massive expansive forces produced. The concrete will develop a characteristic crack pattern and fail as the proportion of gel disrupts the concrete matrix completely, see figure 1. This reaction can be stopped by ensuring the alkalinity of the pore water within the concrete is reduced to a sufficiently low value to minimise, or even prevent, the gel forming. The sources of high alkalinity are primarily found in the PC/CEM I component, though chlorides and alkalis from other sources cannot be ignored.

Figure 1 - ASR in PC concrete

Pozzolanas such as fly ash (also known as PFA) within EU standards, reacts with the potassium and sodium alkalis forming additional cementing compounds and thereby reducing the alkalinity of the concrete and thus preventing the ASR reaction. However, there is a critical quantity of fly ash required to ensure the high alkalinity hydroxides are used up. This is normally considered to be a minimum of 25% fly ash of the total cementitious content with normal reactivity aggregates and 40% with high reactivity aggregates. When fly ash is used as a filler aggregate, this will also be able to react with the high alkalinity sources as effectively as if it were considered to be a Type II fly ash.

When a factory-made composite cement containing fly ash is used, such as a CEM II/B-V and CEM/IV B-V, allowance should be made for the fly ash contained within the cement in the normal way as described within BS8500 plus an allowance for the fly ash added as a filler aggregate. The following calculation explains how this should be carried out and the results interpreted.

Calculation Steps and Assessing the Results

The following calculation steps are for a concrete mix having a cement content of CC kg/m^3 based on a CEM II/B-V or a CEM IV/B-V, e.g. fly ash based cements only. A fly ash type I addition as filler aggregate of Y kg/m^3 is also being used. UKQAA spreadsheet "ASR Calculator for fly ash.xls" was used to carry out the calculations based on the following steps;

- From the CEM II or IV cement, called CEM for ease hereafter, content (CC) of the concrete mix calculate the mass of fly ash in kg/m^3 (X). Cement manufacturers will provide the proportion of fly ash within their formulation to within 1%, see NA.3.4 of BS EN197-1.
- Add to this the proportion of filler aggregate (kg/m^3) for the concrete mix (Y).
- Calculate the total fly ash content as a proportion of the CEM plus filler content in %;

$$\frac{X + Y}{CC + Y} \times 100$$

- Compare this percentage against the proportions as given within Table D.1 (BS8500-2:2006+A1:2012 Annex D) and select the appropriate proportion (P in percent Na_2O_{eq}) of the declared mean alkali content for the fly ash to be taken into account, if any.
  - Note: The proportion of fly ash may exceed the usual maximum proportions for common cements, e.g. 55% fly ash for CEM IV/B-V, simply because there are no restrictions as to the amount of filler aggregates permitted within a concrete. In this case the amount of alkalis taken into account shall be taken as 0%, the same as for not less than 25% fly ash.
- Compute the alkali contributed by the filler fly ash (FA_{alk}) using the declared alkali content of the fly ash, see Annex D clause 5.2.4 BS8500-2;

$$\mathrm{FA_{alk}} = \frac{\mathrm{FA}}{100} \times \mathrm{Y} \times \frac{\mathrm{P}}{100}$$

Where FA is the % alkali content expressed as Na_2O_{eq} as declared by the supplier.

- Compute the alkali from the CEM component using the cement manufacturer's declared alkali content for the cement being used, see BS EN197-1:201X, Annex A;

$$\mathrm{C_{alk}} = \mathrm{CC} \times \frac{\mathrm{CA}}{100}$$

Where CA is the % alkali content of the CEM expressed as Na_2O_{eq} as declared by the cement supplier

- Sum these to give the Total alkali content for the mix from the CEM and filler fly ash ('cementitious') components;

$$\mathrm{Tot_{cem}} = \mathrm{FA_{alk}} + \mathrm{C_{alk}}$$

- Calculate the alkalis from other sources, e.g. chlorides, admixtures, etc as would normally be required.
- Use the total of Tot_{cem} plus alkalis from other sources to determine whether total alkalis in the concrete represent a risk of damaging ASR as given within BS8500.

The final step in these calculations involves comparing the total alkali content of the mix against limits values given within D.3 to D.8 of Annex D BS8500-2.

The alkali content of the Portland Cement (CEM I) used in the manufacture of the CEM II/B-V or CEM IV/B-V is not directly known within the above calculation method. However, it is considered safe to assume that the alkali content of the CEM II/B-V or CEM IV/B-V can be used as the appropriate alkali content for the calculations.

Using factory-made composite cements other than CEM II/B-V and CEM IV/B-V

There is no advice given within BS8500 or BRE Digest 330 for combinations of factory-made composite cements and additions, where the addition or filler is different to the material used within the factory-made cement. Examples would be the use of CEM II/B-S, or CIIB-S mixer combination, used in conjunction with fly ash as filler aggregate. Such blends are relatively rare in practice, but there are technical reasons they may be considered beneficial.

It is recommended for such combinations that calculations for ASR are carried out as above, but assuming that the factory-made cement is treated as if it were a CEM I Portland cement. In this manner it will ensure there is always sufficient reactive pozzolana available to prevent the risk of ASR by reducing the alkalinity within the resulting concrete.

Conclusions

The current BRE Digest 330 covers the combinations of cement and additions available at the time of publication. However, with the increased range of factory-made composite cements possible in BS EN197-1, mixer combinations via BS8500 and the greater use of pozzolanic materials, such as fly ash, as both a cementitious and filler material, its rules have been overtaken by technical developments.

The calculations suggested above are based on our understanding of the chemical reactions which occur and an interpretation of the rules within BS 8500 and BRE Digest 330.

In general usage the term 'fly ash' is used for pulverized coal ash but it can also cover ash from burning other materials. Such 'fly ash' may have significantly differing properties and might not offer the same advantages as ash from burning pulverized coal. UKQAA datasheets only refer to fly ash (PFA) produced from the burning of predominantly coal in power stations.

V2.1 19 December 2012