

# Waterproof Concrete With Site Supervision Ltd

*Because concrete isn't waterproof without experienced, close supervision.*

## Pulverised Fuel Ash (PFA),

PFA is the ash from pulverised fuel used in coal fired power stations. It is collected in chimneys that allow the carbon dioxide through.

PFA can be used to substitute some Portland Cement (PC) in concrete. This is classified as CEM II in the UK.

The main benefit is the saving to landfill and production of carbon dioxide since PFA is otherwise waste that would be produced anyway.

Benefits in concrete are limited to thicker sections of concrete and those cured well for a long time.

Warning: Reports of greater strength and so on would be greatly exaggerated for most structural concrete with formwork removed after 15 hours or so.

In most structural concrete benefits and disadvantages will be of similar value, so it is important to understand them.

PFA is a pozzolan: material containing silica in a reactive form. To be reactive it needs to be very fine and have a glassy surface.

It has the potential to make concrete with lower permeability, better durability and better resistance to the ingress of deleterious chemicals.

The silica glass PFA surface reacts with lime which is itself a product of the hydration of PC. Therefore PFA is only cementitious mixed with and as an additive to PC since it will not itself react with water.

The reaction products are highly complex. Most important to understand is concrete crystals from PFA are finer and tend to fill the smaller spaces between concrete crystals from PC, hardening is retarded during some phases and the PFA needs access to water for far longer than PC to maintain the hydration process.

In short, the PFA slows down the hardening of PC for at least 24 hours (at 20°C, longer if colder); neither does the PFA harden noticeably for the first 24 hours; however the PC products surround the PFA grains. This is advantageous. The PC products are now forming an organised skeleton of crystals – rather like an Aero bar if the holes were PFA and the chocolate from PC. Stronger than a disorganised clump.

But the more PFA the lower the early strengths. At later ages the contribution of PFA to strength gain increases greatly, provided there is adequate moisture to continue the reaction process.

Neither PFA nor PC are entirely consistent materials. British Standards keep both within sensible ranges but, together, there are many combinations.

Most PFA/PC combinations will become stronger if water is available for long enough (56 days or so), curing for longer than pure PC concrete is necessary. If the relative humidity within the concrete drops to much less than 100% then the PFA will stop reacting never to react any further even if relative humidity is returned to 100%.

Clearly, therefore, the practice of removing formwork the following morning (when on cool days a cloud of vapour can be seen to escape) is detrimental to the curing of PFA and if such walls and columns are not re-wetted and kept wet within hours then the reality is that the concrete, particularly at the surface, will not gain its design strength or required durability.

Most PFA/PC combinations will become stronger if temperatures are maintained for long enough. So most structural concrete

sections will need the formwork leaving on for weeks during cold weather.

PFA is able to reduce the heat of hydration very effectively. In one study CEM I P360 peaked at 57°C at 12 hours; A combination of 265kgs of PC and 150kgs of PFA peaked at 38°C at 16 hours.

The spherical shape, reduced mechanical interlock compared to grains of PC, reduces friction so wet concrete is more fluid and packs better.

This tends to give better looking surface finishes.

Whilst PFA makes concrete more cohesive (sticks together better), GGBS does so even more.

Sulphate Resistance.

Winter (Understanding Cement) tells us: Sulfate reacts with hydrated aluminate phases and any unreacted aluminate to produce ettringite, which expands on formation and causes cracking. When the initial supply of calcium hydroxide, also needed to produce ettringite, is exhausted, the cured concrete crystals are attacked.

Remarkably, evidence to support the use of PFA or GGBS (both said to be sulfate resisting) seems hard to find. All Kelham (in Advanced Concrete Technology: Constituent Materials edited by Newman and Choo) seems able to offer is, from EN 206 and ACI 201 which give limits for concrete mix variables and allowed cement types. EN 206 only has an informative annex which gives recommended concrete compositions for CEM I only. ACI seems, for moderate and severe situations, to rely only on reduced water in the concrete. (Very severe calls for suitable slag as well).

PFA mixes require a little less water but I feel PFA probably makes concrete sulfate resisting by physically covering aluminate crystals, keeping them beyond the reach of sulfates.

In conclusion:

PFA/PC combinations have the potential to become stronger, more durable and denser at the surface to better resist the ingress of chemicals that would attack reinforcing steel. But there must be grave concerns that in a lot of reinforced concrete work much of this potential is not realised.

There must be a real issue, in winter, whether a test cube crushed at 28 days and found to be 110% of the specified compressive strength bears any resemblance to the insitu concrete from the same load if the cube was cured in a heated water tank while the formwork was removed on site after 15 hours and the concrete left exposed to cold, drying winds.

The academic texts are full of warnings such as “months are needed in cold conditions before full design strength will be reached”, “PFA concretes need curing many times longer than straight PC concrete”, and “any amount of PC replaced by PFA needs to be replaced by much more PFA than the PC that was left out”.

A note about PFA in waterproof concrete.

Advantages

PFA can reduce permeability in concrete (if cured) which will reduce transportation of chloride and other ions to reinforcing steel but then PFA concrete is more porous.

PFA blocks interconnections but then so does PC in waterproof concrete with a w:c ratio of 0.45 – and I expect that the PC would do so faster than PFA.

One mix design for Caltite I was shown, where sulfate resistance was required, had PFA in the concrete but the PC was increased as well, so the concrete would have cost more and might have been too sticky to place easily.

## Disadvantages.

PFA takes longer to react.

PFA will not react if the concrete is not cured which will leave gaps through.

Concrete would need to be cured for far longer before it could be expected to resist water under pressure (If a basement was backfilled and a pump turned off too early, groundwater could wash uncured cement grains out/aside. (This is called Leaching)).

Typically only the glassy surface of PFA reacts. This means more than three quarters will still be unreacted after a month and at least half will never react. The centres of the PFA grains that always remain are crystalline and can be very porous (even hollow) and let water through under pressure.