

# Fly Ash

Technical Bulletin 1

Basic principles of using Fly Ash in concrete



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## Basic principles of using Fly Ash in concrete

Good quality Fly Ash can be used to improve the properties of concrete. Processed Fly Ash (e.g. the classified product, DuraPozz®) enhances concrete characteristics by making it more cohesive, easier to place and consolidate, increases its density and improves off-shutter finish, and reduces shrinkage cracking and creep. The final product is a high quality, more durable concrete.

## How does this work?

- Being spherical, the Fly Ash lubricates the concrete so less water is required for a given slump or workability
- Less water implies less shrinkage because less voids or capillary pores are left behind
- Less voids improve the density of concrete, which is then better able to resist the ingress of chlorides and/or sulphates.

However, Fly Ash is not just a lubricant or an agglomeration of spheres. It is far more than that. It is an active mineral ingredient that is able to modify and improve the reactions taking place as concrete hardens and eventually matures into a durable commodity for the building and construction industry.

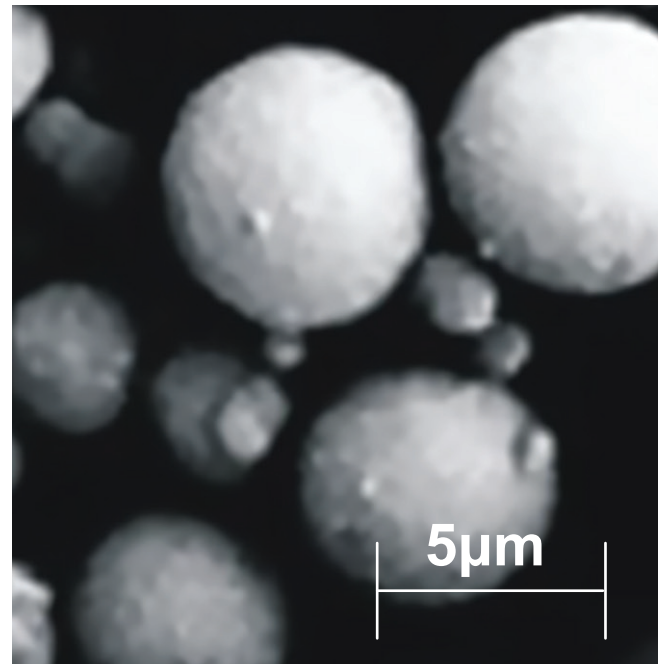
During the manufacture of Portland cement, the setting characteristics are adjusted by the addition of gypsum. This extends the setting and hardening time of concrete allowing it to be worked for a period of time before it finally sets. The addition of Fly Ash perfects this process. Much as the ageing of red wine in oak barrels modifies the chemistry and maturation of grapes, so Fly Ash is also able to improve the characteristics of concrete.

During the hardening process and for months afterwards, the Fly Ash is able to use the calcium hydroxide (Ca(OH)<sub>2</sub>) set free from the hydration (reaction with water) of cement. Instead of going to waste and being a weak point for environmental attack in concrete, the Ca(OH)<sub>2</sub> combines with the Fly Ash to form additional hydrates (compounds). These calcium silicate hydrates have the same composition as those formed by cement in the first place. This reaction, known as the pozzolanic reaction, allows the concrete to mature into a product with enhanced properties.

## Concrete mix design using Fly Ash

While Fly Ash is a cementitious material that greatly benefits concrete, the proportioning of concrete mixes containing Fly Ash requires adjustments because of its physical properties (being spherical in shape):

- The ball bearing shape improves workability. This can give rise to a reduction in the proportion of sand used (up to 5%), with the related performance improvement this brings
- Less water is typically required to achieve the same level of slump as in the control concrete. Dependent on the quantity of Fly Ash, this is normally in the range of 6 -12%. It is this water reducing



Fly Ash Micrograph

property that, together with an increase in total binder of 8%, enables strengths to be on a par at a similar weight replacement level to a CEM I cement concrete control mix

- Fly Ash, having a lower relative density (2,2) than Portland cement (3,15), produces a higher volume of cementitious paste. At a 30% replacement level, by mass, this translates to a 15% volume increase. Fly Ash also improves cohesion when difficult aggregates are being used e.g. crushed rock, heavily washed or marine sands, and enhances the quality of the off-shutter finish
- Admixtures can be used with Fly Ash concrete in the same way as a CEM I concrete. During periods of low temperature, it is advisable to use a conservative dosage of water reducing (dispersing) admixture, in order to maintain proper concrete set times
- Special air entraining admixtures are available to counteract the effects of carbon on air bubble generation. When admixtures are used in Fly Ash concretes, the supplier of the admixture should be consulted for the correct dosage rate and the relevant adjustments to the mix design

The use of a high quality Fly Ash such as DuraPozz® provides flexibility, enabling the design of innovative mixtures for the practical combination of aggregate, sand, cement, water and admixtures, to produce concrete of specific performance and properties.

## Concrete Properties

In summary, Fly Ash can be used to improve the properties of concrete in the plastic and hardened state:



## Plastic concrete (fresh)

- 'Workability' expresses the ease of handling, placing and finishing fresh or 'plastic' concrete. The spherically shaped particles of Fly Ash make a concrete mix more workable enabling a typical water reduction of between 6% and 12% when using classified fly ash
- Improves cohesion, enabling the concrete to be pumped, poured and placed more effectively without fear of segregation.
- The hydration of cement is a rapid exothermic reaction that causes the concrete temperature to rise. Replacing 20-50% of cement with DuraPozz® helps reduce the potential for thermal cracking.
- The heat of hydration is further lowered due to change in the sequence of chemical reactions: the cement sets as usual to provide the early strength, after which the Fly Ash uses up the calcium hydroxide from the hydration of the cement to provide additional binder.
- The extra paste allows for better surface finish and aesthetics.

## Hardened concrete (set)

Fly Ash concrete is more durable and has a higher life-expectancy due to:

- Better particle packing (more dense matrix)
- Fewer capillary pores which result in less ingress of chlorides and sulphates, improving the resistance to chloride and sulphate attack
- Reduced amount of 'free' calcium ions that can be sites for chemical attack

- No alkali aggregate attack (provided there is a minimum 20% Fly Ash content in the concrete)
- Not only does the lower permeability of a Fly Ash concrete impede penetration by chlorides but chlorides also chemically bind to the Fly Ash due to the high aluminate content (3 to 5 times higher than cement)

## Discussion

There are many factors to be taken into account when designing concrete, including the type of structure (columns, foundations, etc.), its environment, the materials available (sand, stone), the design lifetime, its strength, its placement and surface finish.

The emergence of Fly Ash as a pozzolanic extender has made concrete design a little less onerous. Its proper use counteracts many deleterious influences and provides concrete of higher quality.

Typically, Fly Ash is used at values of up to 30% of the total binder content. The properties of a high quality fly ash, such as DuraPozz® or DuraPozz® Pro, enable higher levels of replacement. Depending on the application, the concrete technologist can formulate innovative mixes with 40, 50 and even up to 70% Fly Ash (notably for mass concrete).

Certainly these high addition levels are not common but are not unique either. Fly Ash cannot compensate for poor mix design, site practice or inadequate curing. However, when used correctly it can be the key to 'making good concrete better'.

(1) *Fulton's Concrete Technology, 8th edition, ISBN 0-620-18221-X, 2001.*

(2) *South African fly ash: A Cement Extender by JE Kruger, published as a CD by the South African Coal Ash Association (SACAA).*

## The Gautrain Project





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