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How Does Fly Ash Work Anyway?

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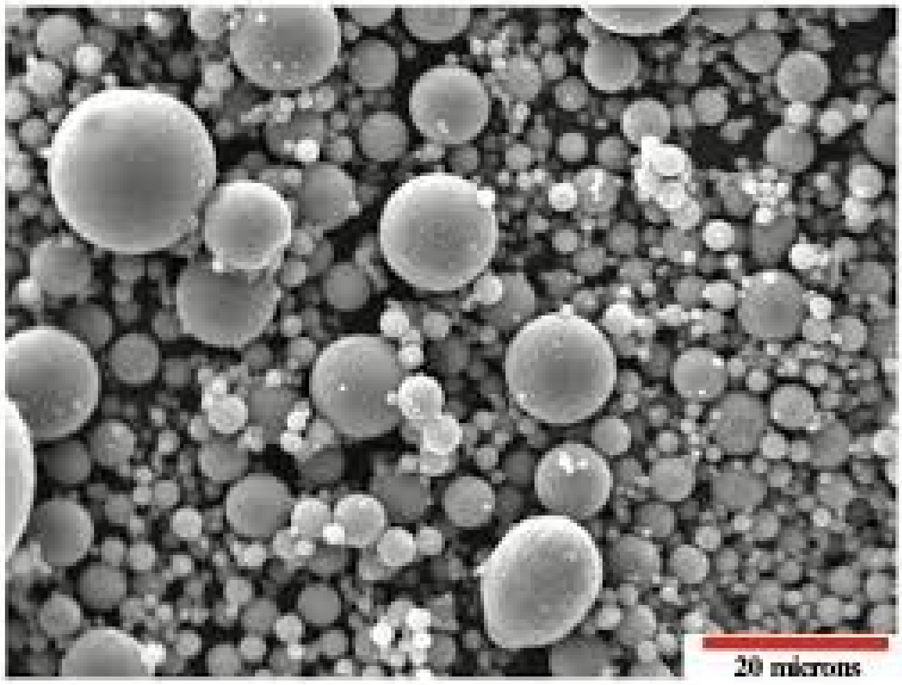
What is Fly Ash?

Fly ash is a fine residue byproduct from coal-fired power plants. When coal combusts in a power plant, much of the impurities in the coal, such as quartz, limestone, and clays, melt off and are carried away with exhaust gases. These materials cool into spherical glassy particles that are then collected by precipitators in the plant. Larger particles fall to the bottom of the combustion chamber and are referred to as “bottom ash”. The fly ash is stored and sold for use as a supplementary cementitious product in concrete.



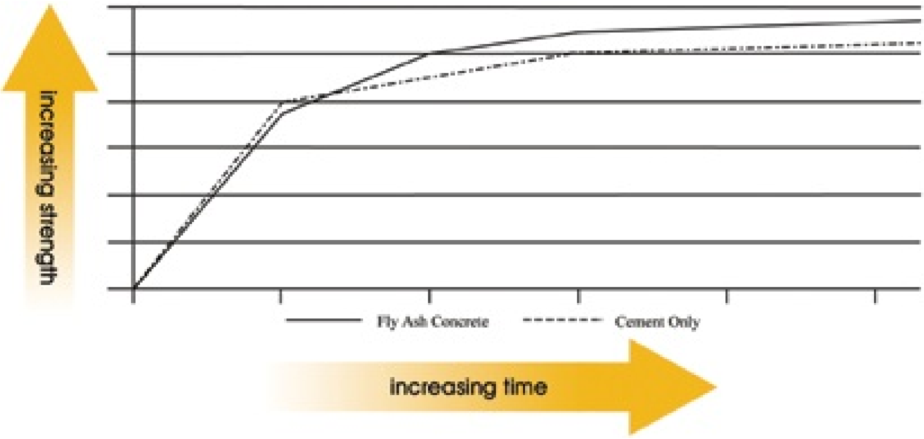
Are all fly ashes the same?
There are two different classes of concrete-grade fly ash. Class F fly ash is produced from burning anthracite or bituminous coal, and has a low calcium content. This means Class F ashes supply what is known as a pozzolanic reaction. Class C fly ash is produced from burning lignite or subbituminous coal, and has a high calcium content. A high calcium content allows Class C ashes to have hydraulic cementitious properties as well as pozzolanic properties. Regardless of the class of fly ash, ashes can be highly variable source to source, and at some power plants, highly variable day to day. At Hahn Ready Mix, we have historically used Class C ashes with extremely high consistency in production.

How does fly ash work in concrete?
Fly ash is used a supplementary cementitious material, in that it is used to replace a certain amount of cement in a mix design. Typically, this replacement is about 15-25% of the weight of cement. If you recall our March Technical Bulletin on cement, the strength producing reaction in cement is Calcium-Silicate-Hydrate or C-S-H. However, there is a great deal of inert Calcium-Hydroxide (C-H) that is left over from this reaction. Fly ash is high in silica, and this silica bonds with the leftover C-H and forms more C-S-H. This bond is called a pozzolanic reaction, and it makes the unreplaced cement in the concrete mix much more efficient in growing C-S-H. Additionally, Class C ashes are high in calcium, so they can produce their own hydraulic cementitious reaction in addition to the pozzolanic reaction. As fly ash's role in concrete is making the cement more efficient, there is a typically point where a fly ash's beneficial silica no longer outweighs the loss of calcium from the cement as replacement % increases. This typically happens around 25-30% replacement, which is why it is rare to see fly ash used at higher rates.

How does fly ash effect plastic concrete?
Due to the spherical shape of fly ash, workability and pumpability is improved, and water demand is reduced by 2-8%, depending on replacement levels. On account of the finer nature of fly ash relative to cement, bleeding is typically reduced and the mix will be less prone to segregation. Setting time is typically longer, as we have removed some amount of cement from the mix design and the pozzolanic reaction happens much slower than a hydraulic cement reaction. Concrete mixes utilizing a Class C ashes typically set a little slower than a regular cement-

only mix design, but Class F ashes normally set *much* slower. This also means lower heat of hydration, particularly with a class F ash, which can be helpful for mass concrete pours. Finishers often believe mix design with fly ash have a much higher finishability due to the spherical shape of the particles and the additional finishing time. One hazard of using fly ash is the effect on air contents. Some fly ashes, particularly class F ashes, have a high amount of unburnt carbon (LOI). A high LOI fly ash will consume the material used to entrain air in a concrete mix and result in a lower air content or a much higher demand for air entraining agents. A change in fly ash LOI during concrete production can cause drastic changes in air content in a load of concrete.

How does fly ash effect hardened concrete?
The more efficient use of cement and conversion of the C-H molecules means that concrete utilizing fly ash will typically have a higher long term strength than mixes without. A mix with a Class C ash will typically catch the strength curve of a cement-only mix within a week of placement.



A mix with Class F fly ash will gain strength at a slower rate. It may not catch a cement only mix for 28 days or beyond. Another benefit of fly ash is a lower permeability in the concrete surface. This is achieved through the fineness of the fly ash particles and the consumption of the C-H molecules. Reducing permeability is important to keep water and undesirable chemicals like chlorides from penetrating the concrete, and the use of fly ash can result in concrete that is 5-20 *times* less permeable than a cement-only mix. Class F ashes are more effective at reducing permeability than Class C ashes. Class F ashes are also very effective at mitigating sulfate attack and akali-aggregate reactions in concrete. Class C will mitigate a little bit, but not nearly as well as a Class F. Fly ash can also add a bit of a yellow-ish hue to hardened and plastic concrete.

Is fly ash supply a concern?
Unfortunately, yes. As more and more power plants 1) convert to natural gas, 2) are used only in peak hours and 3) shutdown entirely, fly ash supply is becoming increasingly constrained. As the primary supplement cementitious material used in the United States, the loss of fly ash for use in concrete would have major effects on the economics and quality of concrete mixes everywhere. Some fly ash marketers have turned to importing foreign fly ashes or mining fly ash that had been landfilled for generations. Both of these actions will help stretch fly ash supply for the intermediate term, but eventually fly ash will likely disappear as a normal use supplementary cementitious material.

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