

CEMENT MARKETING

LANKA PRIVATE LIMITED

Introduction to Fly Ash

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Agenda

- **Introduction**
- **What is Fly Ash?**
- **Classification Process**
- **Fly Ash Standards and Compliance**
- **Impact of Physical and Chemical Properties**
- **Benefits of Fly Ash in Concrete**

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The use of Fly Ash as a cement enhancing material, to improve the durability of concrete, is widely known in the civil engineering industry. Although the material has been widely used internationally, Fly Ash has only been made available in Sri Lanka more recently.

Unlike in other parts of the world, Fly ash and other mineral additives such as GGBS and microsilica do not offer any direct economic benefit to the concrete manufacturer as the cost of these materials are higher than a normal Portland cement. However, when lifecycle cost is taken into consideration, considerable savings can be made in the maintenance and longer service life of structures with the use of these materials.

Therefore, Consultants and Engineers alike have recognized this with the result that Fly Ash is continuously being specified and successfully used the world over for improving the durability of concrete.

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BENEFITS OF USING FLY ASH

There are two main reasons to use fly ash as an ingredient in concrete and other building products:

1. It improves the quality of the finished products.
2. It creates significant environmental benefits.

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IMPROVING PRODUCT QUALITY

Fly Ash has both mechanical and chemical properties that make it a valuable ingredient in concrete and concrete-based products. Its spherical shape makes concrete easier to work with during mixing and placing – fly ash acts like tiny ball bearings moving the aggregates and other components into voids. And when concrete hardens, the chemical properties of fly ash provides greater strength, reduced permeability and improved resistance to several types of chemical attack. The result is concrete product that lasts longer and is more durable - a key sustainability consideration.

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IMPROVING ENVIRONMENTAL PERFORMANCE

- Fly Ash use can also significantly decrease greenhouse gas emissions related to climate change. When fly ash is used to replace cement, it reduces the need for cement production – a highly energy intensive process that also creates significant greenhouse gases.
- Reducing cement production reduces greenhouse gas emissions on almost a ton for ton basis. Production of one ton of cement emits one ton of carbon dioxide. In many circumstances, a ton of fly ash can be used to displace a ton of cement. Concrete enhanced with fly ash can be designed to last in excess of 100-years. By simply doubling or tripling the design life of concrete, valuable natural resources are preserved and the environmental footprint is dramatically reduced.

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What is Fly Ash?

Fly Ash is a pozzolan...

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What is a Pozzolan?

Pozzolan is a finely divided material that reacts with calcium hydroxide and alkalies to form compounds possessing cementitious properties.

More than 2000 years ago, the Greeks and Romans have built structures that still survive today...?

The Romans used a pozzolana, a fine volcanic ash from the town Pozzuoli, *which gave its name to the term “pozzolan”*, mixing it with lime to create strong mortars and concretes for structures.

The Colosseum and Aqueducts in Rome stand testimony today to the durability of pozzolanic materials.



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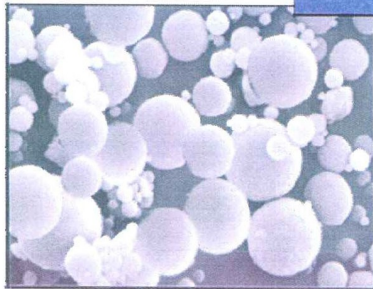
Modern Power Stations that burn pulverized coal have given the concrete technologist ...*Fly Ash*.

Engineering with Ash

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What is Fly Ash?



Briefly, Fly Ash is a pozzolan, which means it reacts with water and lime to form a cementitious compound.

Fly Ash Improves the properties of concrete in both the plastic and hardened state.

Fly Ash particles are spherical in shape in contrast to cement which are angular. This property enables Fly Ash particles to flow and blend easily in a concrete mix.

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Fly Ash (FA) / Pulverized Fuel Ash (PFA)...

is the ash produced from the combustion of powdered coal during the process of raising steam for the generation of electric power.



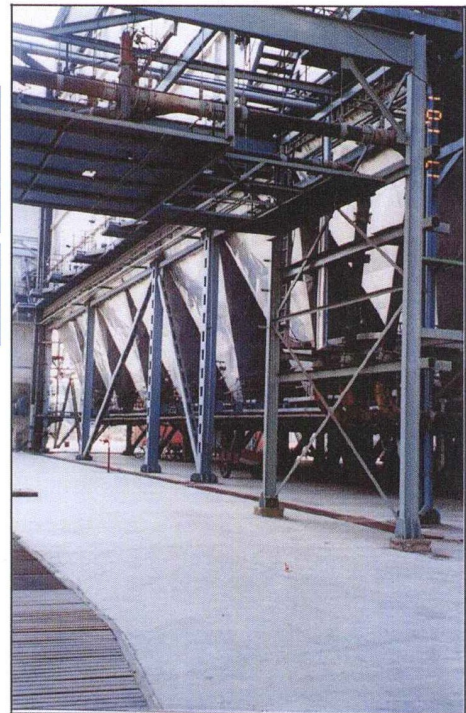
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FLY Ash (FA) or Pfa

The fly ash is separated from the air-stream by electrostatic precipitators and is collected in a series of hoppers.

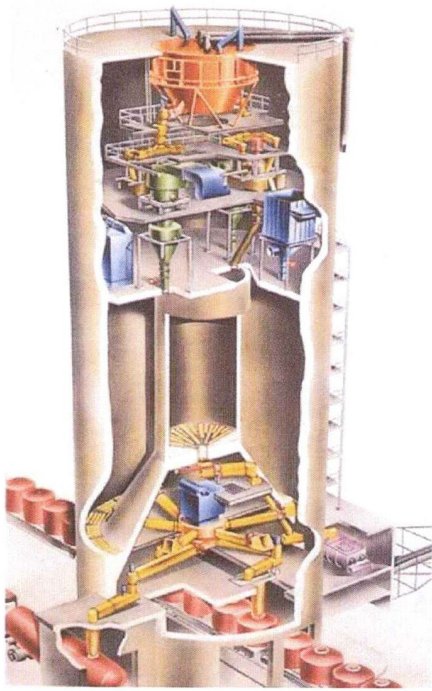
Ash from these hoppers can be processed into high quality and consistent products.



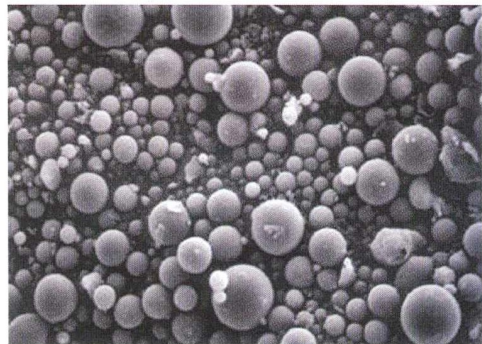
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Ash from power station



Air Classification



Fly Ash

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Physical Analysis

Relative Density	2.20
Surface Area (m²/kg)	3500 (classified)
pH	11 – 12
Colour	Light Grey
Particle Shape	Spherical
Particle Size, D₉₀	45 micron
D₉₉	110 micron
Mean Particle Size	15 micron

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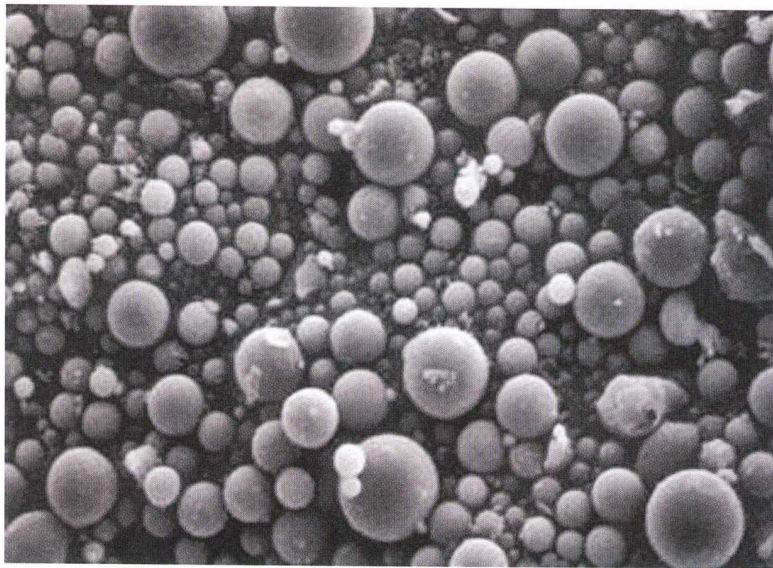
Typical Chemical Analysis (%)

SiO₂	53.5
Al₂O₃	34.3
CaO	4.4
Fe₂O₃	3.6
K₂O	0.8
MgO	1.0
TiO₂	1.7
L.O.I.	1.0
Carbon	0.5
Moisture	0.3

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Spherical

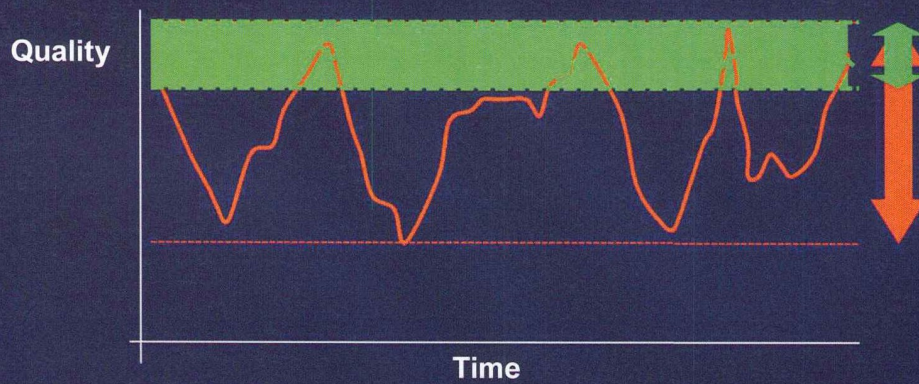


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Why do we classify Fly Ash?

Less variation
higher average quality

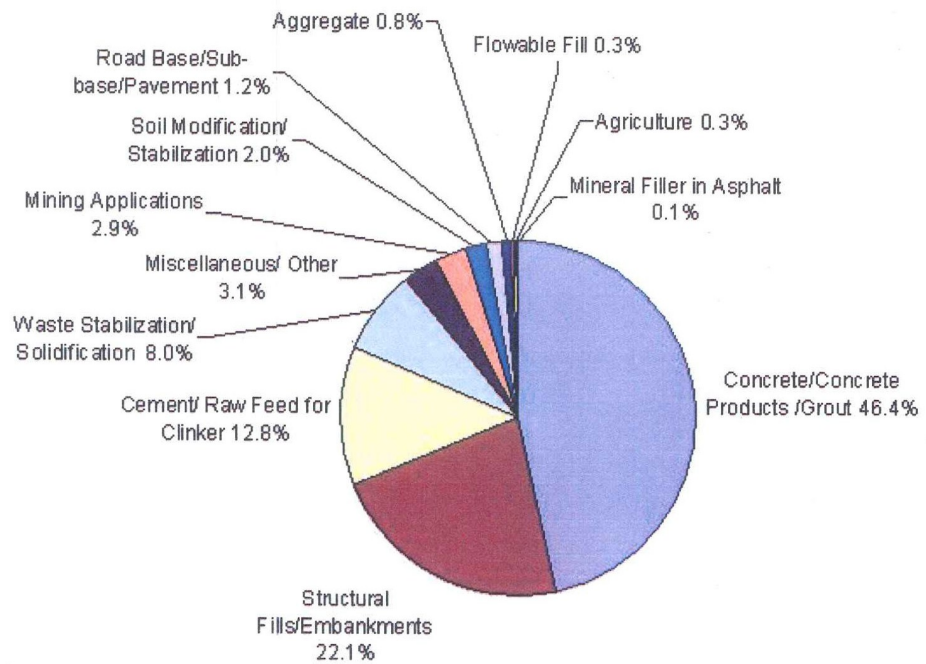


Using “raw” ash will certainly lead to a less consistent concrete quality!

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Fly Ash Applications....

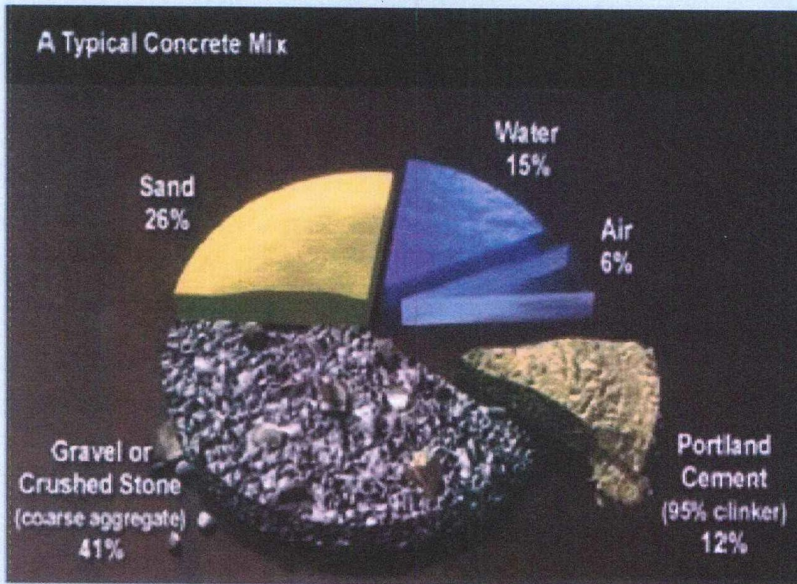
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In concrete...



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Typical Chemical Composition Comparison (%)

	CaO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO
Cement	66	21	5	2.5	1.5
Fly Ash	6	52	32	3.5	1.0

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HOW DOES FLY ASH REACT WITH CEMENT?

*Non stable
"by-product"*



Fly ash is the best known, “pozzolan” in the world—and one of the most commonly used.

The American Society for Testing and Materials (ASTM) defines pozzolan as “a siliceous or siliceous and aluminous material, which in itself possesses little or no cementitious value, but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.”

Class F and Class C fly ash are products of the combustion of coal in large power plants. Fly ash is collected in electrostatic precipitators or baghouses, then transferred to large silos for shipment. When needed, fly ash is classified by precise particle size requirements, thus assuring a uniform, quality product.

Class F fly ash is available in the largest quantities. Class F is generally low in lime, usually under 15 percent, and contains a greater combination of silica, alumina and iron (greater than 70 percent) than Class C fly ash.

Class C fly ash normally comes from coals which may produce an ash with higher lime content — generally more than 15 percent often as high as 30 percent. Elevated CaO may give Class C unique self-hardening characteristics.

Although both types of fly ash impart a wide range of qualities to many types of concrete, they differ chiefly in the following ways:

Class F

1. Most effectively moderates heat gain during concrete curing and is therefore considered an ideal cementitious material in mass concrete and high strength mixes. For the same reason, Class F is the solution to a wide range of summer concreting problems.
2. Provides sulfide and sulfate resistance equal or superior to Type V cement. Class F is often recommended for use where concrete may be exposed to sulfate ions in soil and ground water.

Class C

1. Most useful in “performance” mixes, prestressed applications, and other situations where higher early strengths are important.
2. Especially useful in soil stabilization since Class C may not require the addition of lime.

Concrete manufacturers, engineers, architects, developers and contractors all have an interest in specifying or using fly ash on a routine basis to improve the quality of their project and to increase their cost effectiveness.

Ready Mix Producers. A ready mix producer has several reasons for using fly ash in concrete.

1. Fly ash can compensate for fines not found in some sands and thereby enhance pumpability and concrete finishing.
2. Fly ash will result in a more predictable and consistent finished product that will ensure customer acceptance.
3. Fly ash offers flexibility in mix design providing a greater range of mixes — from liquid soil at 100 psi to high strength (8,000 plus psi concrete) — produced by the same batch plant without exotic equipment.
4. Fly ash improves the flowability of the concrete, which translates into less wear and tear on all the producer’s equipment, from batching facilities to trucks.
5. Fly ash enables the producer to customize designs to each customer’s needs, thus providing the producer a competitive advantage.

Engineers and Architects. Engineers and architects will find that fly ash provides the following benefits:

1. It enables engineers and architects to provide the client with a superior and more durable finished concrete.
2. Fly ash produces a high strength concrete that accommodates the design of thinner sections.
3. Fly ash permits design flexibility accommodating curves, arches and other pleasing architectural effects.
4. The addition of fly ash to the mix is a built-in insurance for later-age strength gain in concrete.
5. Fly ash ensures that the concrete will qualify as a durable building material.
6. Fly ash contributes to the aesthetic appearance of the concrete.

Developers, Contractors, Owners. Fly ash concrete provides the following advantages to developers, contractors and owners:

1. The workability of fly ash concrete generally ensures that the speed of construction is faster, which translates into a quicker return on investment.
2. Fly ash in the mix accommodates more creative designs.
3. Since fly ash concrete is not as vulnerable to deterioration or disintegration as rapidly as concrete without fly ash, it ensures low-maintenance buildings that will retain their value over the long-term.

Chemical Comparison of Fly Ash and Portland Cement

The chemical composition of fly ash is very similar to that of portland cement.

The table below shows typical compound analyses for two fly ashes and a natural pozzolan (Class F fly ash, Class C fly ash and Class N - Natural) and ordinary portland cement. A glance at the table reveals:

1. The same compounds exist in fly ash and portland cement. Those of fly ash are amorphous (glassy) due to rapid cooling; those of cement are crystalline, formed by slower cooling.
2. The major difference between fly ash and portland cement is the relative quantity of each of the different compounds. Portland cement is rich in lime (CaO) while fly ash is low. Fly ash is high in reactive silicates while portland cement has smaller amounts.

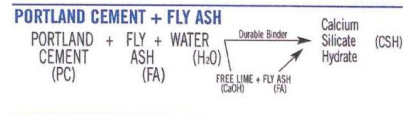
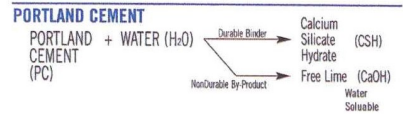
TYPICAL CHEMICAL COMPOUNDS
IN POZZOLANS AND PORTLAND CEMENT

CHEMICAL COMPOUND	POZZOLAN TYPE			CEMENT
	CLASS F	CLASS C	CLASS N	
SiO ₂	54.90	39.90	58.20	22.60
Al ₂ O ₃	25.80	16.70	18.40	4.30
Fe ₂ O ₃	6.90	5.80	9.30	2.40
CaO	8.70	24.30	3.30	64.40
MgO	1.80	4.60	3.90	2.10
SO ₃	0.60	3.30	1.10	2.30
Na ₂ O & K ₂ O	0.60	1.30	1.10	0.60

The table illustrates the basic chemical difference. Portland cement is manufactured with CaO, some of which is released in a free state during hydration. As much as 20 pounds of free lime is released during hydration of 100 pounds of cement. This liberated lime forms the necessary ingredient for reaction with fly ash silicates to form strong and durable cementing compounds no different from those formed during hydration of ordinary portland cement.

A review of the chemistry of both materials makes it apparent that a blend of the two will enhance the concrete product and efficiently utilize the properties of both.

HYDRATION PRODUCTS OF CEMENTING BINDERS



Through pozzolanic activity, fly ash combines with free lime to produce the same cementitious compounds formed by the hydration of portland cement.

Proportioning fly ash concrete mixtures is only slightly more complicated than proportioning plain cement concrete mixtures. The same solid volume proportioning techniques described in ACI 211 are employed as are used with conventional concrete mixtures.

ACI 211 gives the proportioner a series of steps through which values are selected for:

- cementitious materials content
- air content
- water content
- coarse aggregate size and content

These ingredients are converted into solid volumes. The difference between the sum of the total volumes and 27 cubic feet will determine the necessary volume of sand. Sand weight is then calculated to complete the trial mix proportions. The accuracy of this mix must be checked by physically preparing a sample of the proportioned ingredients and testing the mixture for yield.

While fly ash is a cementitious material that greatly benefits concrete, the proportioning of concrete containing fly ash requires adjustments because of the physical properties of the ash. Viewed microscopically, fly ash particles are spherical in shape. Because of this and other physical attributes of fly ash, one can expect the following:

- The ball bearing shape significantly aids the workability of concrete. This allows for lower sand content than conventional mixes while handling remains similar. As the proportion of sand is reduced, all performance aspects of the concrete are enhanced.
- Again, because of fly ash's spherical particle shape, less water is required to achieve the same level of slump as in the control concrete. The addition of fly ash in conventional mixtures typically reduces the water needed by 5% to 10% over plain concrete (depending upon the quantity of fly ash), and this reduction can be further increased where high levels of fly ash are used.
- The specific gravity of fly ash is much lower than that of portland cement; therefore, 100# of fly ash has a much greater solid volume than the same weight of portland cement. Past practice has dictated a cement reduction when water-reducing admixtures are used; however, in fly ash concrete, the cementitious materials (cement and fly ash) volume is higher, not lower. This higher quantity of cementitious materials greatly assists in the finishing process.
- Air entrainment is not affected adversely with high quality fly ash supplied by Headwaters. Headwaters has developed a proprietary foam index test that allows us to control fly ash quality with respect to air entrainment in concrete. A slight increase in admixture dosage can be expected because of the increased solid volume of cementitious fines, but performance should be uniform. This increase in dosage typically amounts to less than 0.25 ounces per 100# of cementitious materials.
- The use of water-reducing admixtures is encouraged with fly ash concrete mixtures; however, certain factors must be considered:
 1. During warm temperatures, a normal dosage of water-reducing admixture is calculated on the combined weight of cement plus fly ash.
 2. During periods of low temperatures, it is advisable to use a conservative dosage of normal set time water-reducing admixture calculating the dosage based only on the weight of cement. Under cool temperatures, normal setting water-reducing admixtures may cause retarded concrete set. Reducing the dosage utilized during cool conditions can help maintain proper concrete set times.

*Note - The American Concrete Institute now defines that water to cement ratio is equivalent to water to cementitious materials ratio. This means that fly ash is counted by weight the same as portland cement in this calculation. The importance of this to the concrete designer is the water reducing capability of fly ash. Where plain cement concrete may require 300# of water to provide the necessary degree of workability, fly ash concrete will use significantly less water, and may only require 90% of this, or 270# of water. If a max W/C of 0.5 is specified, the plain mix would need 600# of cement, while the fly ash mix would only need 540# of cementitious materials. The economic benefits are obvious.

DETERMINATION OF FLY ASH CONTENT

Several methods exist for the selection of the fly ash content in a mixture.

Specification. The specifications for a particular project may define a required fly ash content. The percentage of fly ash required may range from as little as 10% to as high as 50% or 60%, depending upon the intention of the engineer. Failure to adhere to the specified level of fly ash may result in concrete of substandard properties and may not be suitable for the intended purpose.

Optimum Ash Curves. In this method, a control curve is first generated by testing mixes with cement contents which vary from a low of 300# to a high of 700# per cubic yard in increments of 100#. All mixes should be of identical lump and yield. Plot cement contents on the abscissa (X axis), plot comprehensive strength on the ordinate (Y axis). A separate curve will be generated for each age of test. A family of optimum ash curves will be generated for each age of test. A family of optimum ash curves is then derived in the following manner:

For each point on the control curve, a series of mixes should be tested with fly ash contents varying between 10% and 30% of total cementitious material (by weight) in increments of 10%. Plot these results on the same chart as the control mixture. These curves can then be utilized to choose the appropriate proportions of cementitious materials for any requirements.

Water/Cementitious Materials Ratio Curves. In this method, the Abrams law of water to cement ratio is utilized. As this law is applicable to plain cement concrete, so is it applicable to fly ash concrete. The objective is to construct a family of curves which are plotted together, with each curve indicating a specific percentage of fly ash by weight of total cementitious materials (typically 0%, 10%, 20%, 30%, etc.). This method is particularly useful where specifications require a maximum water/cementitious materials ratio.*

Do not be surprised to find that for a fly ash mixture to be equivalent in strength to a plain cement mixture, the W/(C+FA) must be lower than the W/C. This is acceptable due to the fact that fly ash acts like a water reducer. Where cement is replaced by an equivalent weight of fly ash and the strengths are equal, they both have the same weight of cementitious materials but the fly ash mix will have a lower water demand.

Replacement Method. Another successful method of designing fly ash concrete is by replacement. This involves selecting a conventional mix which has demonstrated an adequate performance level. Replacement tests should be run on a series of mixes containing fly ash in amounts ranging from 10% to 30% or more. To obtain 28-day strengths equal to the straight cement mix, it may be necessary to replace cement at a ratio exceeding 1:1. This can be determined by experimenting with mixes designed with replacement ratios of 1:1, 1:1.1, 1:1.2, etc. As in the other methods, specification factors will influence the selection of the optimum replacement percentage and ratio.

For detailed explanations of the testing programs mentioned above, the following references are available:

1. Cannon, R. W., "Proportioning Fly Ash Concrete Mixes For Strength And Economy", Journal of The American Concrete Institute, V. 65, No. 11, November 1968.
2. Lovewell, C. E. and Hyland, Edward J., "Proportioning Concrete Mixes - A Method of Proportioning Structural Concrete Mixtures With Fly Ash And Other Pozzolans", American Concrete Institute Publications SP-46-8.
3. Lovewell, C. E. and Washa, G. W., "Proportioning Concrete Mixes Using Fly Ash", Journal of The American Concrete Institute, V. 54, No. 12, June 1958.

Fly Ash for concrete

Introduction

Fly ash has both pozzolanic and physical properties that enhance the performance of concrete. When Portland cement hydrates it produces quantities of alkali calcium hydroxide (lime). Pozzolanas like fly ash react with this lime to form stable calcium silicate and aluminate hydrates. These hydrates fill the voids within the concrete, removing some of the lime and thus reducing the permeability. This process improves the strength, durability, chloride and sulfate resistance of the concrete. The pozzolanic reaction occurs relatively slowly at normal temperatures enhancing strength in the longer term relative to normal Portland Cement (CEM1) concrete (Figure 1).

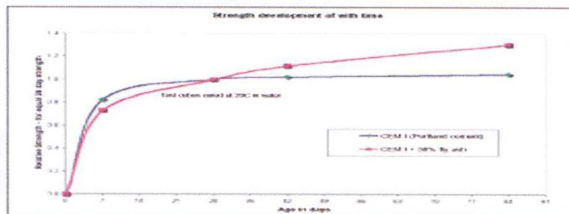


Figure 1 - The relative strength gain properties of fly ash concrete

durability. In addition the concrete is more cohesive, has a lower rate of bleeding and is less prone to segregation.

Fly ash readily reacts with sodium and potassium alkalis within the concrete. If there is 25% or more of fly ash within the cement content of a mix the high alkalinity from these metal alkalis is quickly reduced. Any risks of alkali silica reaction are significantly reduced if not completely eliminated.

The advantages of using fly ash in concrete can be summarised as follows:

- Improves long term strength performance and durability.
- Reduces permeability, which reduces shrinkage, creep and gives greater resistance to chloride ingress and sulfate attack.
- Minimises the risk of alkali silica reaction.
- Reduces the temperature rise in thick sections.
- Makes more cohesive concrete that has a reduced rate of bleeding, is easier to compact, gives better pumping properties and improves the surface finish of the finished structure, e.g. when used in Self Compacting Concrete.

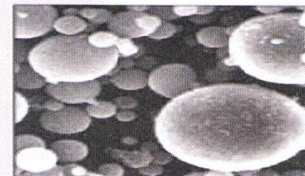


Figure 2 - Micrograph of fly ash

Using fly ash within your concrete

Fly ash can be used in site mixed, readymixed and pre-cast concrete. There are a number of differing ways of incorporating it within a concrete mix.

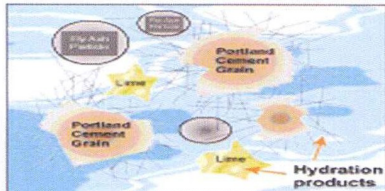
Pre-blended cement. Pre-blended CEM I and fly ash cement can be obtained complying with BS EN197-1 - Common cements. These cements are CE marked. CEM IIA-V contains between 6 to 20% fly ash, CEM IVA and VLH IVA can contain 11 to 35% fly ash and CEM IIB-V contains between 21 to 35% fly ash. CEM IV-B and VLH IVB¹ can contain up to 55% fly ash. These cements are more suitable for low heat applications. The proportion of fly ash in pre-blended cements is factory controlled by the manufacturer and full quality assurance certification is available. They can be supplied either in bulk tankers or in bags. Special blends of fly ash with other materials are catered for at some works by special arrangement.

¹ BS EN 14216:2004 "Cements - Composition, specifications and conformity criteria for very low heat special cements"

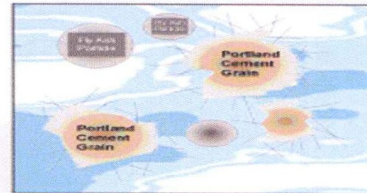
Mixer blended fly ash. A quality assured fly ash can be obtained complying with BS EN450 Category S or N. These are stored in separate silos to the CEM I and blended by the concrete producer in the concrete mixer. The suppliers of fly ash are able to provide certification for all the commonly available Portland cement and fly ash combinations used throughout the UK.

There are two ways of using mixer blended BS EN450 Category S and N Fly Ash as counting towards all or part of the cementitious content.

- **BS EN450 Category S fly ash.** This standard restricts the fineness of the fly ash to a maximum of 12.0% passing the 45µm sieve, which is achieved by classifying the ash. In addition the Loss On Ignition (LOI) is limited to a maximum of 7% (category A or B). These requirements ensure the optimum water reducing, reactivity and consistency properties are achieved within the concrete. Water reductions vary between 6% and 12% when compared to CEM I only concrete of the same cement content. Normally 25% to 55% of the cementitious content would be fly ash.



As hydration proceeds lime crystals form



When water is added to Portland Cement crystalline hydration products appear

- **EN 450 'Category N fly ash** is also permitted by BS EN206 and BS 8500. With this ash a greater range of fineness is allowed than with Category S fly ash. The supplier nominates a target fineness value between 0% and 40% passing the 45µm sieve. The fly ash supplied must not exceed $\pm 10\%$ of this target value. Again the LOI limit is as category A or B in the UK. There is no requirement for water reduction and as this effect is closely related to fineness it will be source specific.

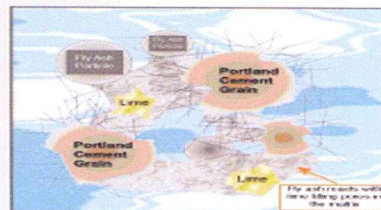
Both category S and N BS EN450 fly ashes are classed as Type II additions, that is they count towards the total cementitious content.

Fly ash can also be used in concrete as inert filler or an aggregate - known as a Type I addition.

- **Fly ash as a filler aggregate to BS EN 12620** is usually used in precast concrete products and grouting applications. The range of fineness permitted is 70% to 100% passing the 63µm sieve. Though the fly ash is assumed to be inert, in reality it will contribute to strength and durability as the pozzolanic reactions occur. Fly ash also complies with BS EN 13055-1 Lightweight filler aggregate.

The concrete standards

- **BS EN206 - Concrete.** BS EN206 only allows a maximum of 25% of BS EN450 Fly Ash within the total fly ash plus CEM I content to be treated as cementitious. However, more fly ash can be used within the concrete if it is treated as inert filler or 'aggregate'. Alternatively if the BS EN206 'equivalent performance' route is taken, it is the performance of the cementitious combination that is important. In this case all of the fly ash may be counted as being cementitious.
- **BS8500 the complementary standard to BS EN206.** This standard complements the European standard and provides the various data relating to mix design, specification and compliance for concrete. BS EN450 may count fully towards the cement content if compliance testing is carried out to the annex in BS8500.



The pozzolanic reaction adds to the hydration products helping to fill the voids thus reducing permeability

- **Conditioned, stockpile, and lagoon fly ash** can also be used in concrete. These ashes have been successfully used for sub base materials², roller compacted concrete and as a fine aggregate replacement world-wide. These can be used with CEM I, CEM I and lime, lime only and lime & gypsum combinations as the cementitious binder.

Other properties of fly ash in concrete

By the nature of fly ash many other properties may be exploited beneficially in concrete.

- **Particle Density** - fly ash has a lower particle density (2.30 typically) than Portland cements (3.12 typically). Therefore, for a given unit of mass, the volume of fly ash is greater than that for the PC. A 30% replacement by mass of the cement content with fly ash increases the total volume of cementitious material by 15%.

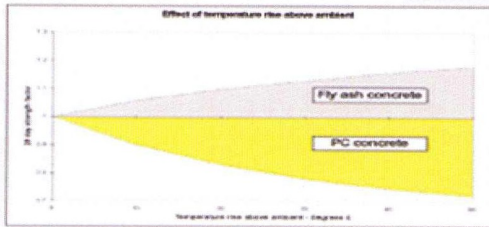


Figure 4 - Fly ash concrete increases in strength with higher curing temperatures

- **Effect of Curing Temperature** - Though the strength development of fly ash concrete can be relatively slow at 20C, the rate of reaction does depend on temperature. In adiabatic conditions the strength of PC concretes reduces with increasing temperature, whereas fly ash strength improves as shown in Figures 4 and 5.

- **Chloride Resistance** - The chloride resistance of fly ash concrete is improved because of the low permeability that can be achieved. Aluminates within cement can bind and immobilise Cl ions in the concrete. Fly ash contains about 3 to 5 times the aluminate content of PC concrete. Figure 6 shows the reduction in the coefficient of diffusion with varying percentages of fly ash. As the fly ash content and the grade of the concrete used increases the chloride diffusion coefficient reduces significantly.

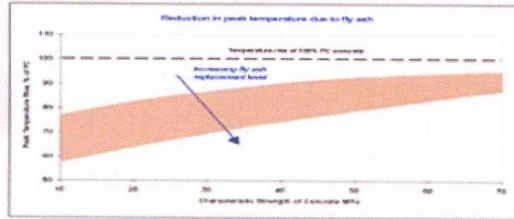


Figure 3 - Effect on peak temperature rise of fly ash

- **Particle Size Distribution** - fly ash can be used to correct for deficiencies in marine and single size sands, or for Self Compacting Concrete where a highly cohesive mix is required. The fly ash has a pore blocking effect that reduces bleeding, improves pumpability and surface finishing performance. Marine, crushed rock and heavily washed fine aggregates can benefit significantly from the addition of fly ash.
- **Peak Temperature Rise** - The pozzolanic reaction with lime occurs over an extended period of time and is temperature dependent. Figure 3 shows the peak temperature rise in a thick concrete section is reduced in comparison with PC of the same strength³.

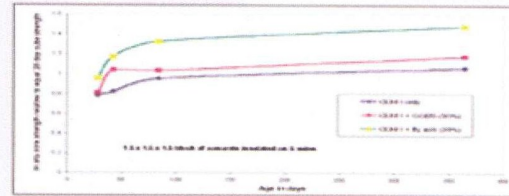


Figure 5 - The initial strength of thick section concrete is higher due to the pozzolanic reaction

² UKQAA Technical Datasheets 6 series discuss Fly Ash Bound Mixtures (FADM) for a variety of roads and airfield applications.

³ To take full advantage of the pozzolanic reaction the concrete must be properly cured, that is kept moist and warm, for as long as is practicable.

- Economy** - In addition to all the technical benefits that fly ash can give to concrete there are economic advantages. The later strength development properties can give enhanced benefits if the age at which the specified strength required is extended beyond the usual 28 days. When compared to PC at 56 days and 112 days fly ash concrete strengths are still increasing at a significant rate. Specifying later ages makes feasible economic concretes with high strengths. Fly Ash may be specified to enhance durability. BS 8500 provides lists of exposure classes for both designed, standardised prescribed and designated mixes and limits of the types and quantities of additions that may be used.

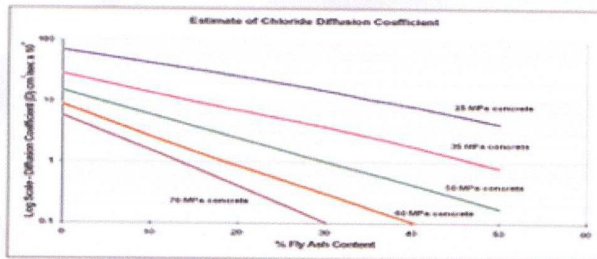


Figure 6 - Typical effect of fly ash on chloride diffusion coefficient

Environmental Considerations

As fly ash is a by product of the burning of coal in power stations to produce electricity, it is a valuable resource. It can be used as a source of silica in the cement making process as well as its use in blended cements. Using fly ash reduces the total energy demand of producing the concrete - simply because less CEM I is used. It reduces the need for extraction of raw materials used in the cement making process. Coupled with the enhanced durability of the resulting concrete structures and the subsequent extended

working life, fly ash can make a valuable contribution to reducing environmental impacts.

General Information

Storage - Bagged fly ash and pre-blended fly ash cement should be stored as one would Portland cement (CEM I). The lower particle density of fly ash means that less can be stored in a silo in comparison with CEM I. Fly ash in a silo should be kept well fluidised with dry aeration to prevent self compaction and in addition silos must be water tight.

Admixtures - Admixtures can be used with fly ash concrete in exactly the same way as CEM I concrete. For air entrainment higher than usual admixture dosages are likely to be required, to counteract the effects of carbon on the air bubble generation. Special air entraining admixtures are available that are designed to minimise these effects.

Mix Design - As the volume of cementitious material increases when substituting fly ash for CEM I, some adjustment in the mix design may give significant benefits. Normally a 5% reduction in fine aggregate content can be used without affecting the handling properties. The best results are achieved by carrying out laboratory trial mixes.



Fly ash concrete being used on East Midlands Airport taxiways
(courtesy of Fitzpatrick Contracting Ltd)

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 may not offer the same advantages as ash from burning pulverized coal. UKQAA datasheets only refer to fly ash produced from the burning of predominantly coal in power stations.

V4 November 2008

CEMENT MARKETING

LANKA PRIVATE LIMITED

FLY ASH STANDARDS

Physical attributes

Comparison of standards

Standard:	EN 450	ASTM C618, F	BS 3892, part 1	SABS 1491, part 2
Fineness (%>45 λ m)	40% max	34% max	12.0% max	12.5% max
Water demand (% of OPC Control)	N/A	105% max	95% max	95% max

CEMENT MARKETING

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FLY ASH STANDARDS

Chemical attributes

Comparison of standards

Standard:	EN 450	ASTM C618, F	BS 3892, part 1	SABS 1491, part 2
CaO	Max 10%	Max +/-10%	Max 10%	N/A
Soundness:	10mm Max	0.8% Max	10mm Max	10mm Max
SO ₃	3.0% Max	5.0% Max	2.0% Max	2.5% Max
LOI	5.0% Max	6.0% Max	7.0% Max	5.0% Max

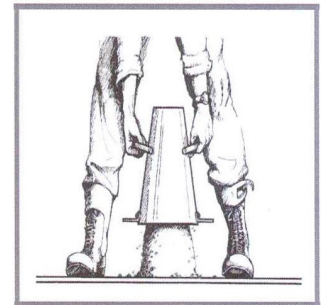
QUALITY OF FLY ASH AND ITS IMPACT ON CONCRETE PERFORMANCE

Physical attributes

Fineness ($\% > 45\mu\text{m}$)

Particle shape (spherical ?)

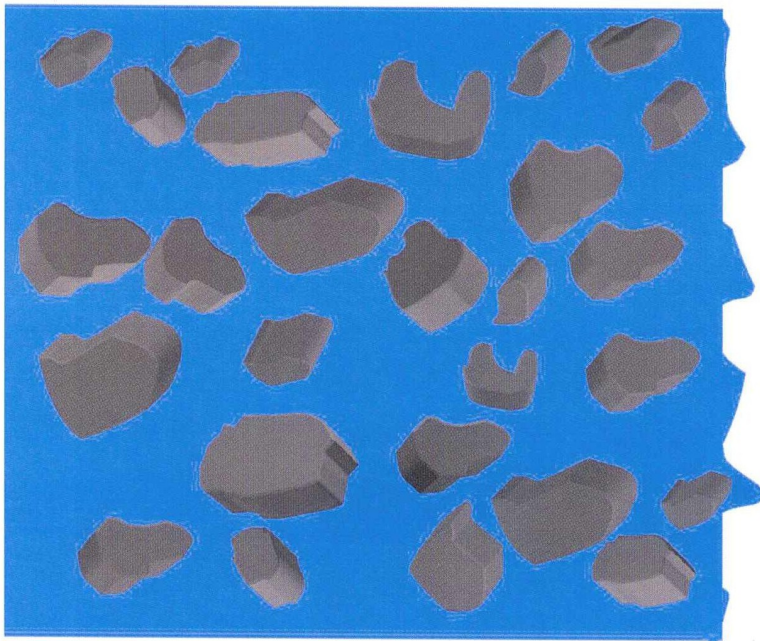
A fine and spherical fly ash will lower the water requirement and increase the workability of concrete. This will result in a decreased permeability and therefore improved durability.



CEMENT MARKETING

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Schematic cement / water paste:



A “*fine*” fly ash, when added to the mix, will fit between the cement particles, replacing water.

A “*course*” fly ash when added to the mix, will push cement particles apart,

CEMENT MARKETING

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Therefore ...

fly ash used in reinforced concrete should be ...

- **fine**
- **spherical**
- **reactive**
- **sound (chemical composition)**

These parameters are controlled in various local and International Standards and are intended to safeguard the user against poor quality materials

What are the benefits of Fly Ash in Concrete?



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FLY ASH IN CONCRETE

• FLY ASH IN FRESH CONCRETE

- Lower Water demand (-10%/m³)
- Increased Workability
- Increased Cohesion
- Lower Bleed-rate



CEMENT MARKETING

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FLY ASH IN CONCRETE

• FLY ASH IN HARDENED CONCRETE

• Good early strength



Similar to OPC

• Increased late strengths



+ 25% @ 56 days



+ 45% @ 90 days

CEMENT MARKETING

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• FLY ASH IN HARDENED CONCRETE

• Good early strength

• Increased late strengths

• Lower Heat of Hydration

• Increased durability

* Marine environment

* Sulphate attack

* Later & Lower peak temperature

* Higher Tensile Strength Capacity

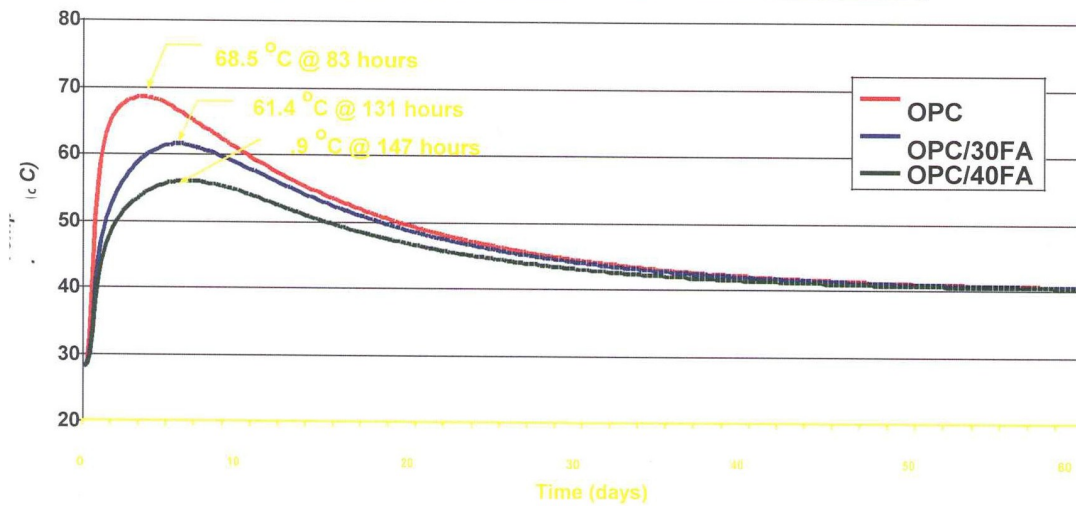
* Alkali Silica Reaction

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Effect of FLY ASH on Cracking induced by Heat of Hydration

Typical Heat of Hydration of Concrete



CEMENT MARKETING

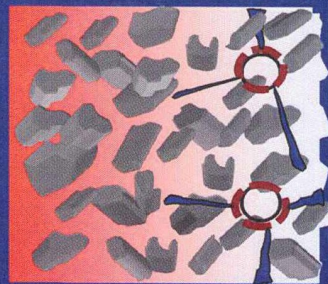
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CHLORIDE ATTACK OPC v FA CONCRETE

 Moving Chloride front

OPC/30FA CONCRETE:

- Less permeable
 - lower chloride ingress
- Lower diffusion
 - lower chloride ion ingress
 - slower chloride ingress
- Chloride binding
 - bound chlorides not available to attack steel



OPC Concrete



OPC/30FA Concrete

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FAMCET STUDY

Facility for Accelerated Marine Climate Exposure Testing

- Building at CSIR premises in Pretoria, South Africa
- Cyclic wetting & drying of specimens
- Salt spray (5% NaCl)

One year FAMCET exposure

=

+/- 6 years coastal exposure



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CORROSION OF STEEL IN OPC & 30FA CONCRETE

35 N/mm², 11 years FAMCET Exposure



OPC

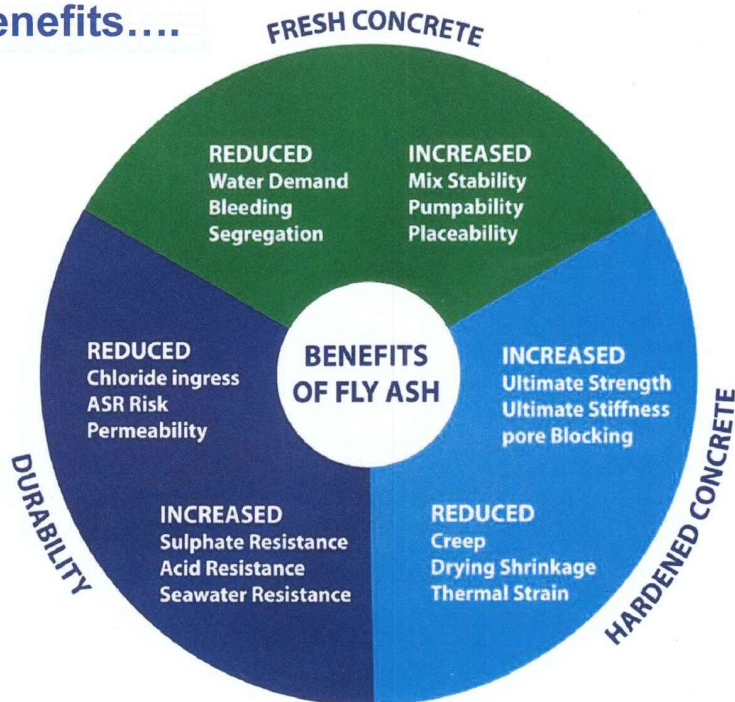


OPC/30FA

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Fly Ash Benefits....



Thank You