

# CONCRETE TECHNOLOGY (BFS40603)

## *CHAPTER 3: Blended Cement Concrete*

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# Outline

- Industrial ash concrete
- Agricultural ash concrete
- Ground granulated blastfurnace slag (GGBS) concrete
- Silica fume concrete
- Effect of fly ash on the properties of concrete
- Effect of GGBS on the properties of concrete
- Effect of silica fume on the properties of concrete



# 4.1 INDUSTRIAL ASH CONCRETE



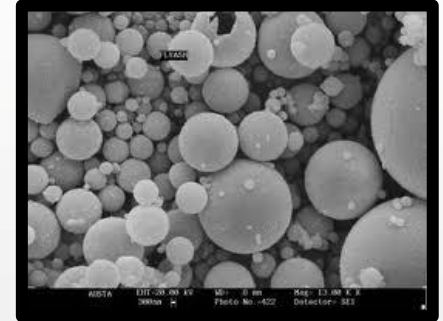
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# 4.1 Industrial Ash

- Cement industry has huge effects on environment, economy and usage of energy.
- The use of sustainable cement is logical way for preventing of resource depletion, emission to air, embodied energy, water consumption and wastage.
- Supplementary cement materials especially ash in concrete that today has been greatly used in construction industry.
- The usage of ash should be evaluated using laboratory batches to establish the desired quality.
- The agricultural ash will be produce by the by product of the agricultural product.
- Ash consists of silica, alumina, and iron that is made of burning coal and generally lead to landfill. Conventional concrete releases many carbon dioxide and greenhouse gases into the air.

## 4.1.1 Fly Ash

- The finely divided residue resulting from the combustion of ground or powdered coal.
- Transported from the firebox through the boiler by flue gases.
- Two classifications of fly ash:-
  - Class F (Produced by anthracite and bituminous coal)
  - Class C (Produced by burning lignite or subbituminous coal)
- Class C fly ash is preferable for the applications presented in the Green Building Guide and is the main type offered for residential applications from ready-mix suppliers.
- They are spherical shaped “balls” finer than cement particles.
- Fly ash could be an expensive replacement for Portland cement in concrete and using it, improves strength, segregation and ease of pumping concrete.
- The rate of substitution typically specified is a minimum of 1 to 1 ½ pounds of fly ash to 1 pound of cement



# 4.1.2 Chemical Properties

| MATERIALS                      | PORTLAND CEMENT% | FLY ASH% |
|--------------------------------|------------------|----------|
| SiO <sub>2</sub>               | 21.82            | 53.39    |
| Al <sub>2</sub> O <sub>3</sub> | 6.49             | 16.07    |
| Fe <sub>2</sub> O <sub>3</sub> | 1.93             | 13.05    |
| CaO                            | 60.74            | 6.33     |
| MgO                            | 1.08             | 5.48     |
| SO <sub>3</sub>                | 2.62             | 1.06     |
| Na <sub>2</sub> O              | 0.14             | 1.59     |
| Free Cao                       | 0.84             | 0.11     |

- fly ash are amorphous (glassy) due to rapid cooling; those of cement are crystalline, formed by slower cooling.
- 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

| CHEMICAL COMPOUND                    | POZZOLAN TYPE |         |         | CEMENT |
|--------------------------------------|---------------|---------|---------|--------|
|                                      | CLASS F       | CLASS C | CLASS N |        |
| SiO                                  | 54.90         | 39.90   | 58.20   | 22.60  |
| Al <sub>2</sub> O <sub>3</sub>       | 25.80         | 16.70   | 18.40   | 4.30   |
| Fe <sub>2</sub> O <sub>3</sub>       | 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 <sub>3</sub>                      | 0.60          | 3.30    | 1.10    | 2.30   |
| Na <sub>2</sub> O & K <sub>2</sub> O | 0.60          | 1.30    | 1.10    | 0.60   |

## 4.1.3 Advantage Of Using Fly Ash

1. Increases **ULTIMATE CONCRETE STRENGTH**
2. Increases **CONCRETE DURABILITY HYDRATION**
3. Is **MORE ECONOMICAL** than portland cement
4. Reduces risk of **ALKALI-SILICA REACTION (ASR)**
5. Increases **RESISTANCE TO SULFATE ATTACK**
6. Reduces **CONCRETE BLEEDING** (water loss at the surface after placement)
7. Reduces **CONCRETE SHRINKAGE** during curing
8. Reduces the **AMOUNT OF WATER REQUIRED** in mixtures
9. Reduces **PERMEABILITY** (increases concrete's resistance to water penetration)

## 4.1.4 Physical properties

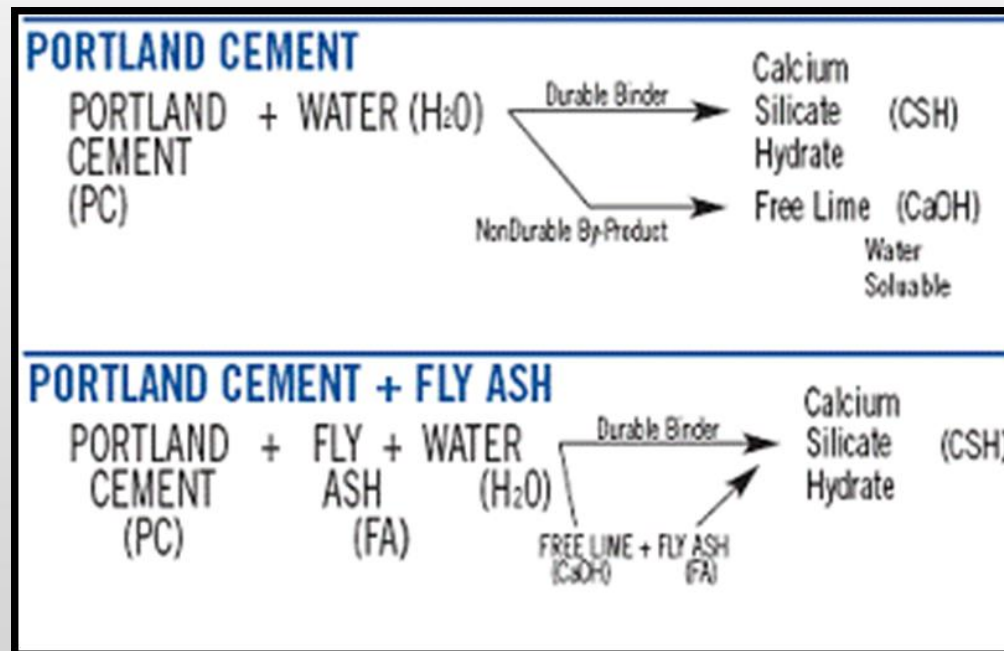
- The fly ash from boilers where mechanical collectors are used is coarser than fly ash from electrostatic precipitators.
  - The color varies from light to dark grey depending upon its carbon contents.
  - The quality of fly ash varies from source to source.
  - fly ash particles are small, they effectively fill voids





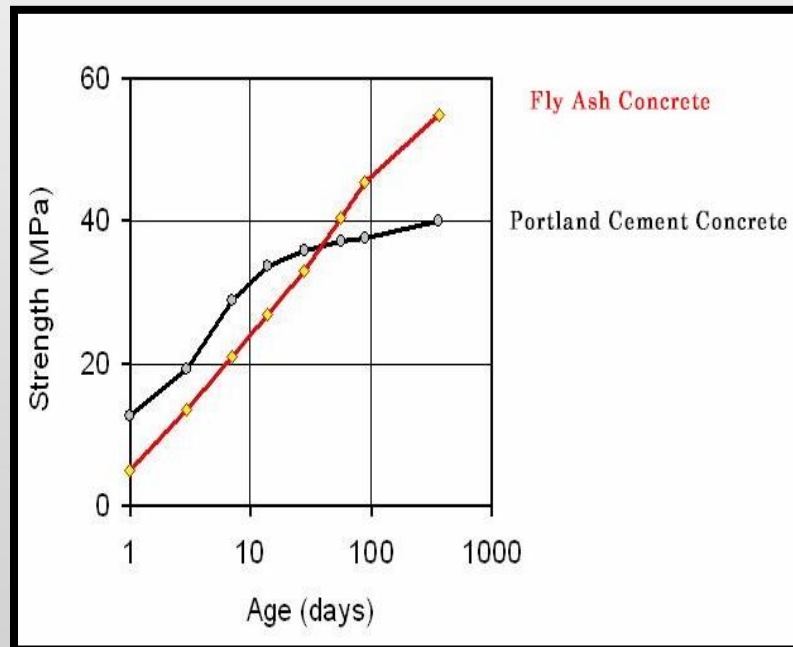
# 4.1.5 Mechanical Properties

The main benefit of fly ash in concrete is that it not only reduces the amount of non durable calcium hydroxide (lime), but in the process converts it into calcium silicate hydrate (CSH), which is the strongest and most durable portion of the paste in concrete.



## 4.1.6 Compressive Strength

- Typically, concrete made with fly ash will be slightly lower in strength than straight cement concrete up to 28 days, equal strength at 28 days, and substantially higher strength within a year's time.
- Thus, fly ash concrete achieves significantly higher ultimate strength than can be achieved with conventional concrete



## 4.1.7 Conclusion

- Some of the industrial ash generally showed **BETTER WORKABILITY, INTEGRATION, PACKAGING, ULTIMATE STRENGTH, AND ENDURANCE.**
- It was found that industrial ash is of particular value in **HIGH-STRENGTH CONCRETE.**
- Fly ash in concrete mixtures efficiently replace Portland cement, which in turn can help in making significant **SAVINGS IN CONCRETE MATERIAL PRICES.** It also is an **ENVIRONMENTALLY FRIENDLY** solution, which meets the performance specifications.



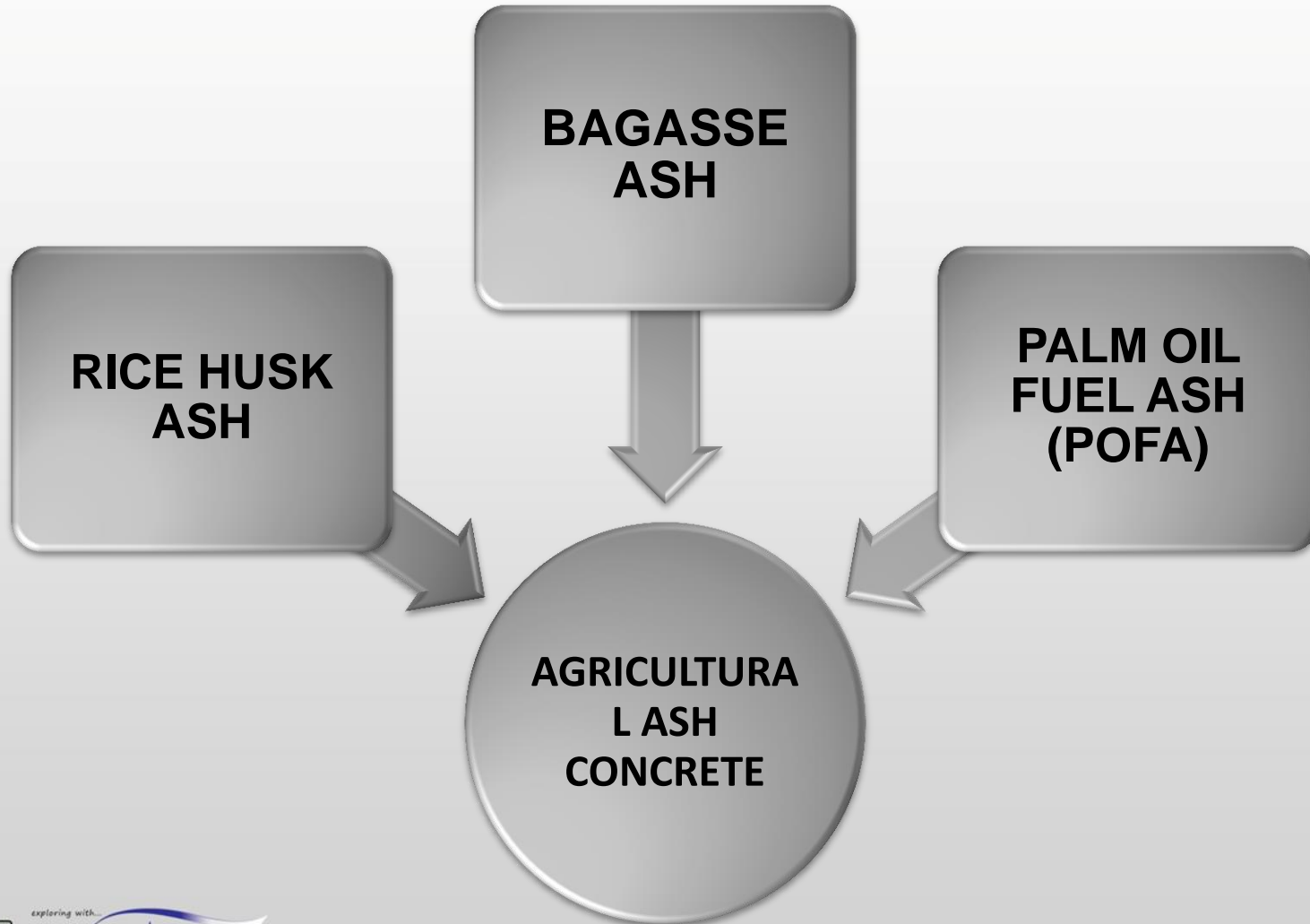
## 4.2 AGRICULTURAL ASH CONCRETE

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## 4.2.1 INTRODUCTION

- Wastes are produced in large quantities from agro-based industries.
- The use of these waste materials in construction industry would contribute towards a cleaner environment.
- It also results in a cost effective construction material.
- Agricultural waste, which includes both natural (organic) and non-natural wastes, is a general term used to describe waste produced on a farm through various farming activities.
- It has variously been estimated that these wastes can account for over 30% of world wide agricultural productivity.

## 4.2.2 TYPES OF AGRICULTURAL ASH



## 4.2.3 RICE HUSK ASH



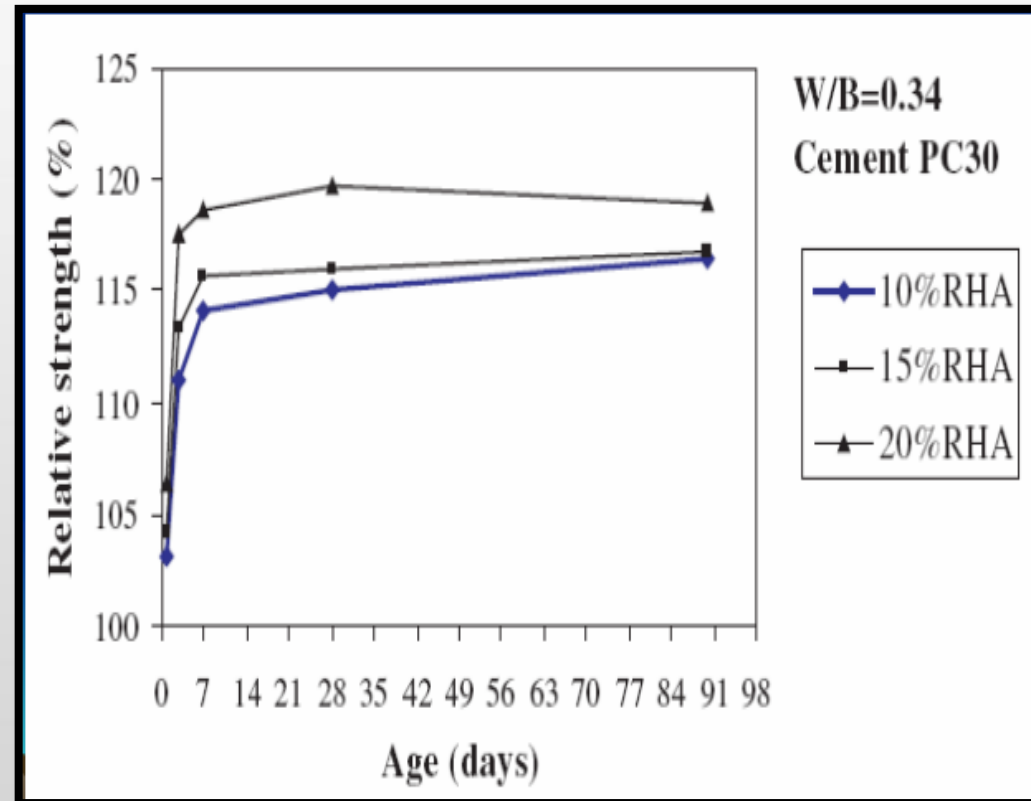
Rice husk which is an agricultural waste, constitutes about one-fifth of the 500 million tones of rice produced annually worldwide.

Normally, the residue is disposed off by burning at the mill sites and the resultant rice husk ash (RHA) is dumped on a waste land.

Under controlled burning and if sufficiently ground, the highly reactive ash that is produced can be **used as a supplementary cementing material or in the production of high strength concrete (HSC)**.

## 4.2.4 Effect Rice Husk Ash On Concrete

- Increased water demand (especially with finer cements)
- Increased strength





## 4.2.5 BAGASSE ASH

Sugar-cane bagasse is one such fibrous waste-product of the sugar refining industry, along with ethanol vapor.

Bagasse ash mainly contains aluminum ion and silica. Untreated bagasse ash has been partially replaced in the ratio of 0%, 10%, 20%, 30% and 40% by volume of fine aggregate in concrete.

Fresh concrete tests like compaction factor test and slump cone test were undertaken along with hardened concrete tests like compressive strength, split tensile strength and sorptivity.

The result shows that bagasse ash can be a suitable **replacement to fine aggregate**.



## 4.2.6 PALM OIL FUEL ASH (POFA)

Palm oil fuel ash is a by-product produced in palm oil mill. After palm oil is extracted from the palm oil fruit, both palm oil husk and palm oil shell are burned as fuel in the boiler of palm oil mill.

These by-products are commonly used as fuel in the boiler of palm oil mills and become ash. The ash, popularly known as palm oil fuel ash or POFA is a waste material the disposal of which poses enormous environmental pollution.

It has been identified that POFA has good pozzolanic properties that can be used as **a cement substitute in mortar and concrete mixes**



## 4.2.7 BENEFICIAL USE OF AGRICULTURAL ASH

Improving the  
durability of  
concrete  
structure

Produce high  
strength  
concrete of  
Grade 80

Enhance the  
concrete  
properties

Effective  
replacement  
to cement  
and fine  
aggregate

## 4.2.8 METHODS TO IMPROVE WASTE ASH REACTIVITY



Controlled  
burning/rapid cooling to  
form amorphous  
compounds



Grinding (to increase  
surface area)



Use of chemical  
activators ( $\text{CaCl}_2$ ,  
 $\text{NaOH}$ , and other alkali-  
based activators)



Heat curing of ash  
based cement products

## 4.2.9 CONCLUSION

- As a conclusion, agriculture ash are widely use nowadays, this proves that there are advantages of these waste materials.
- There are three types of agriculture ash that were famous in concrete mix as such POFA, rice husk ash, and bagasse ash
- Many studies that have been conducted and show that waste can still be used specifically in the concrete mix.



## 4.3 Effect of GGBS on the properties of concrete

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## 4.3.1 EFFECT ON STRENGTH

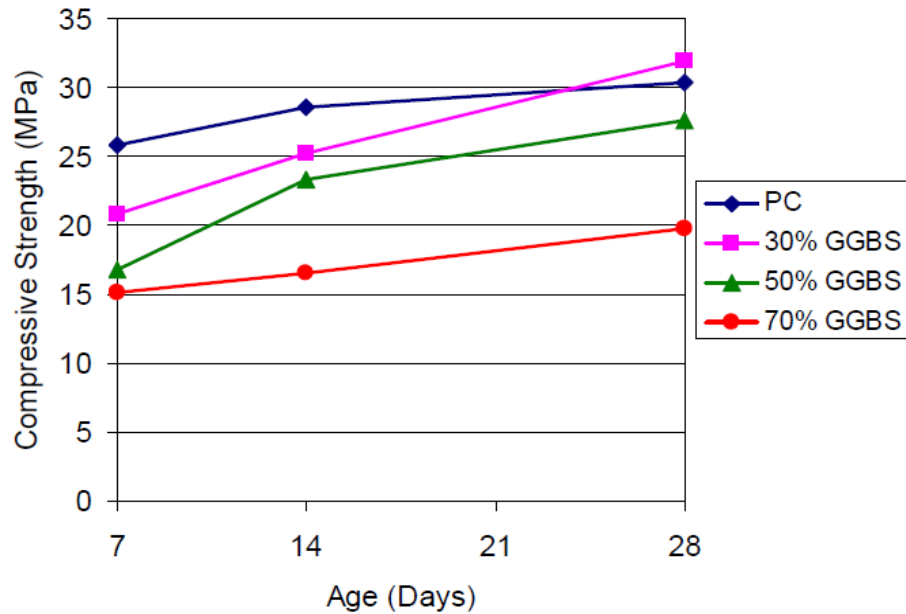
- ☞ GGBS concrete **gains strength more steadily** than equivalent concrete made with Portland cement.
- ☞ Along 28-day, GGBS concrete will have **lower strength at early ages** but its **long-term strength will be greater**.
- ☞ The reduction in early-strength will be most noticeable at high GGBS levels and low temperatures.
- ☞ Concretes with up to 70% GGBS will achieve sufficient strength within one day of casting to allow removal of vertical formwork without mechanical damage.

### **Effects of PFA and GGBS on Early-Ages Engineering Properties of Portland Cement Systems**

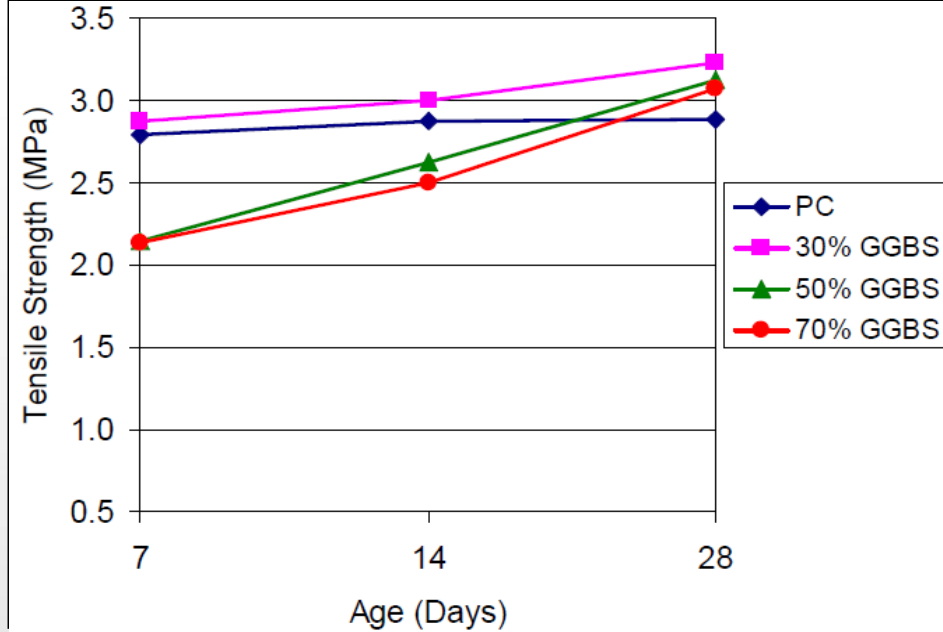
Xiangming Zhou, Joel R. Slater, Stuart E. Wavell, Olayinka Oladiran

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## COMPRESSIVE STRENGTH

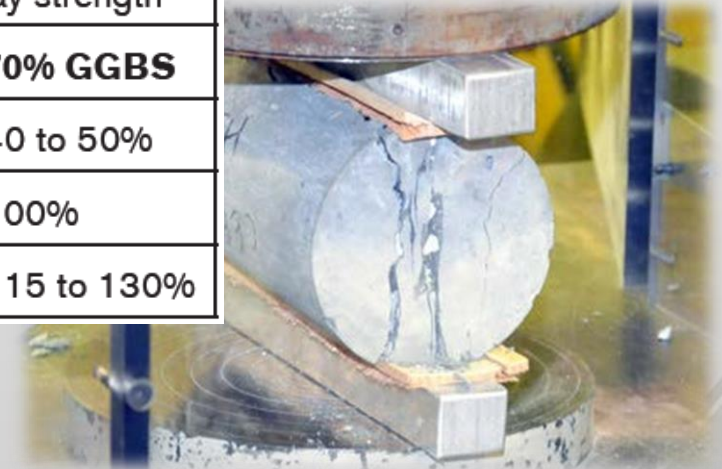
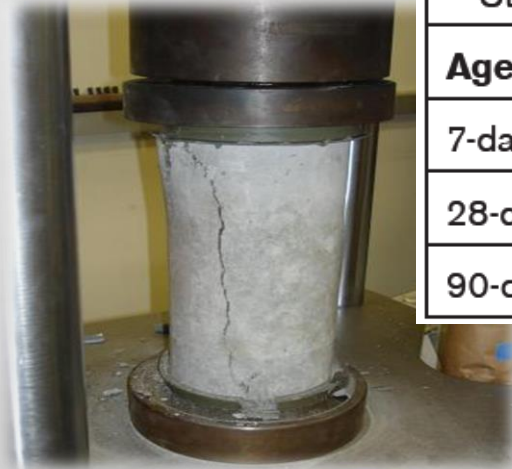


## TENSILE STRENGTH



Strength achieved as percentage of 28-day strength

| Age     | 0% GGBS     | 50% GGBS    | 70% GGBS    |
|---------|-------------|-------------|-------------|
| 7-days  | 75%         | 45 to 55%   | 40 to 50%   |
| 28-days | 100%        | 100%        | 100%        |
| 90-days | 105 to 110% | 110 to 120% | 115 to 130% |

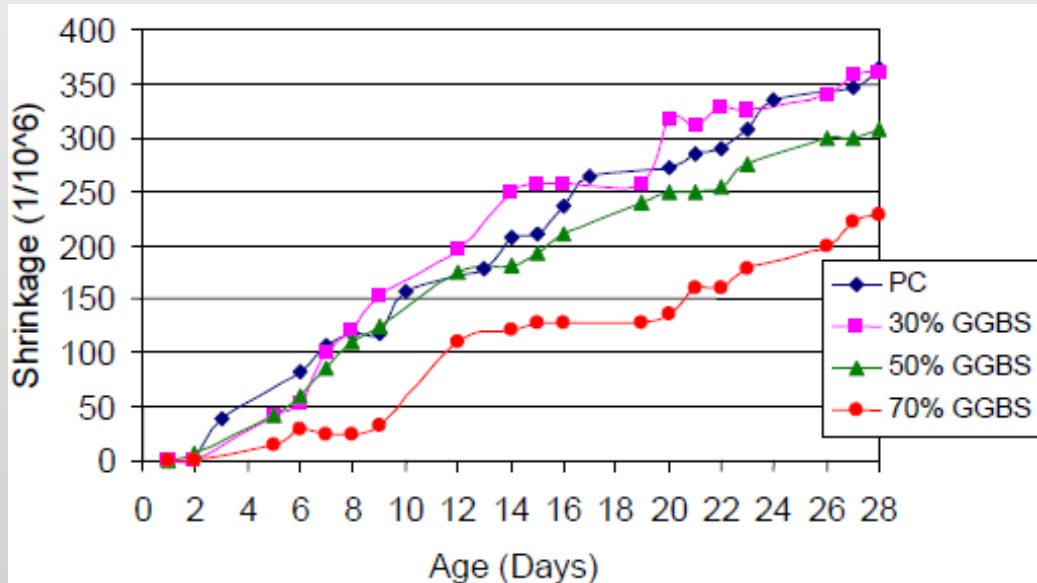




# DRYING SHRINKAGE

The drying shrinkage is an ever lasting process when concrete is subjected to drying conditions. Volume change is one of the most detrimental properties of concrete, which affects the long-term strength and durability.

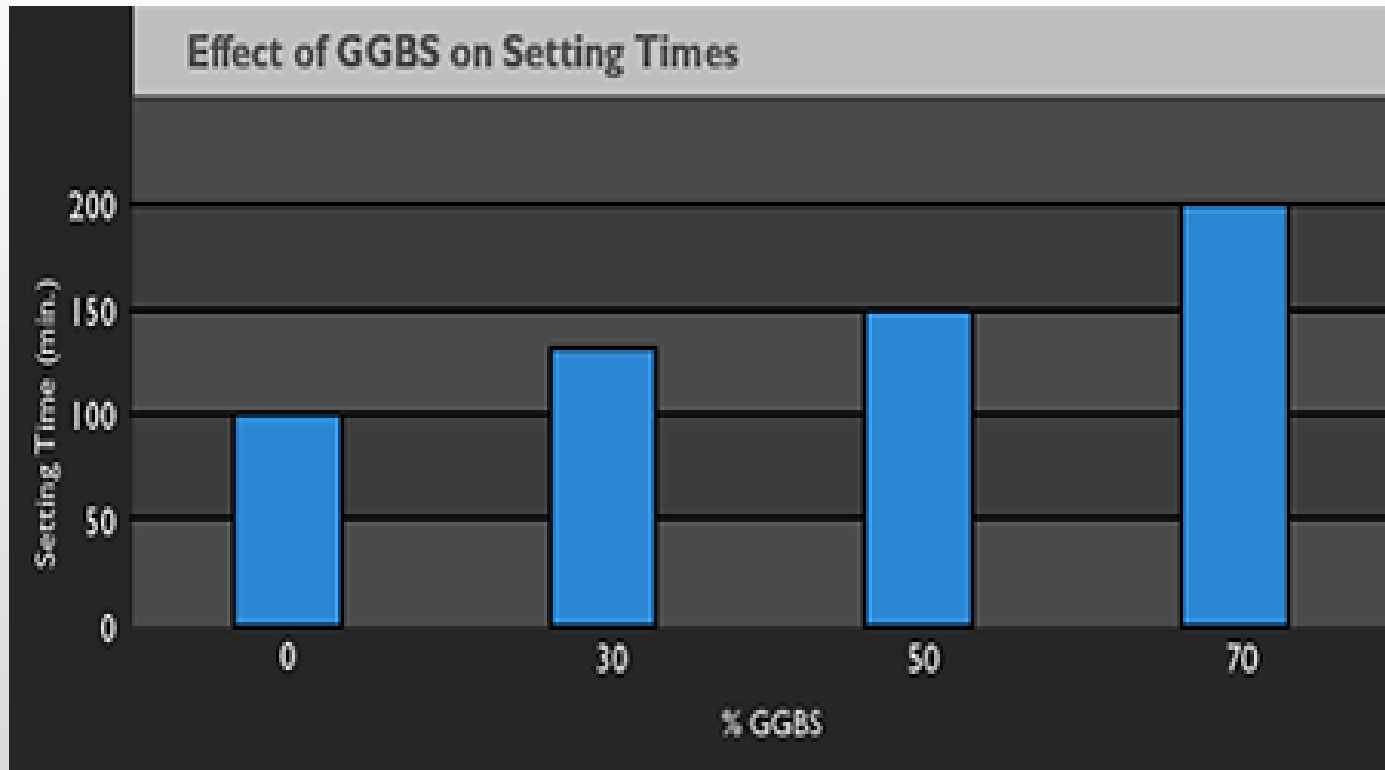
- ✓ Partially replacing GGBS reduced drying shrinkage of concrete.
- ✓ As the replacement level increased, shrinkage will decreased.
- ✓ Can minimize the early age crack.



## 4.3.2 EFFECT ON SETTING TIME

- GGBS concrete requires longer setting times than Portland cement concrete.
- Probably due to the smooth and glassy particle forms of GGBS.
- 40 to 50%: extended by one to two hours
- 50% GGBS setting time maybe extended past three hours.
- GGBS <30% : NO SIGNIFICANCE

## 4.3.3 EFFECT OF GGBS ON SETTING TIME

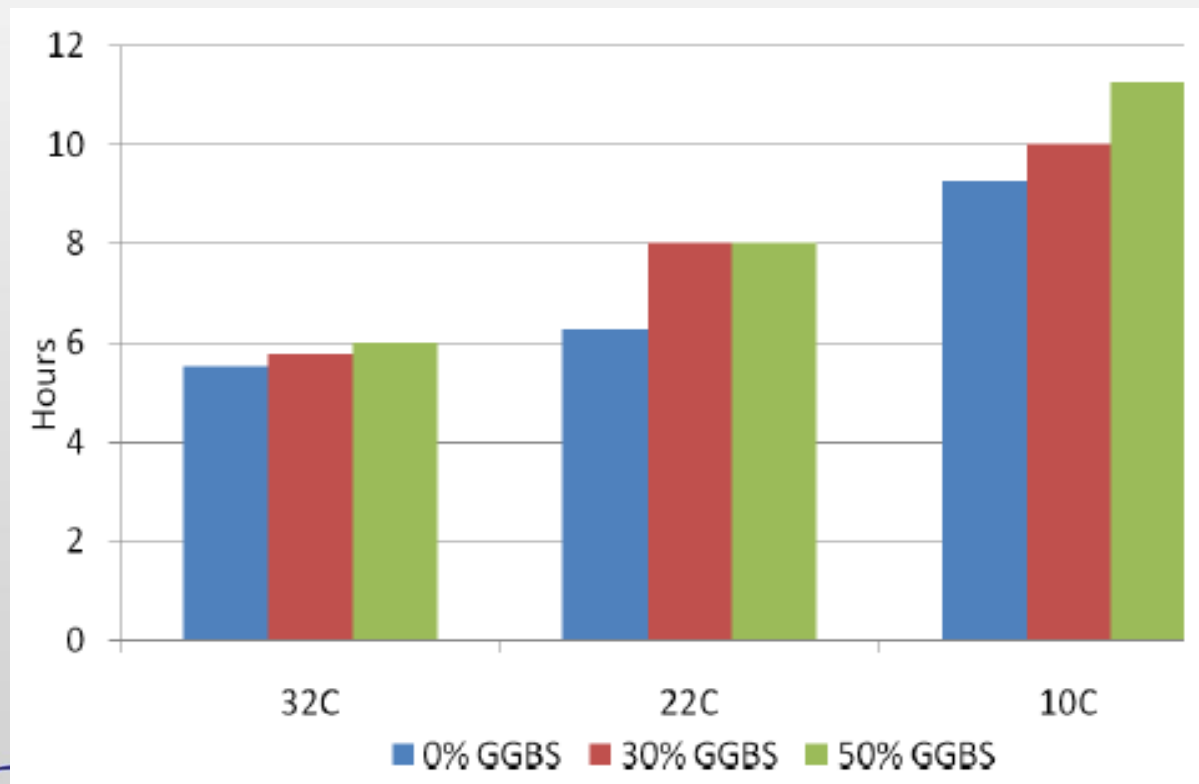


# CONTINUE...

- Longer setting times can have the advantage of allowing concrete to be worked for longer periods.
- Allow time delays, including;
  - delays in transport
  - Delay in mixing and using concrete.
  - reduce the risk of cold joints in larger concrete pours.

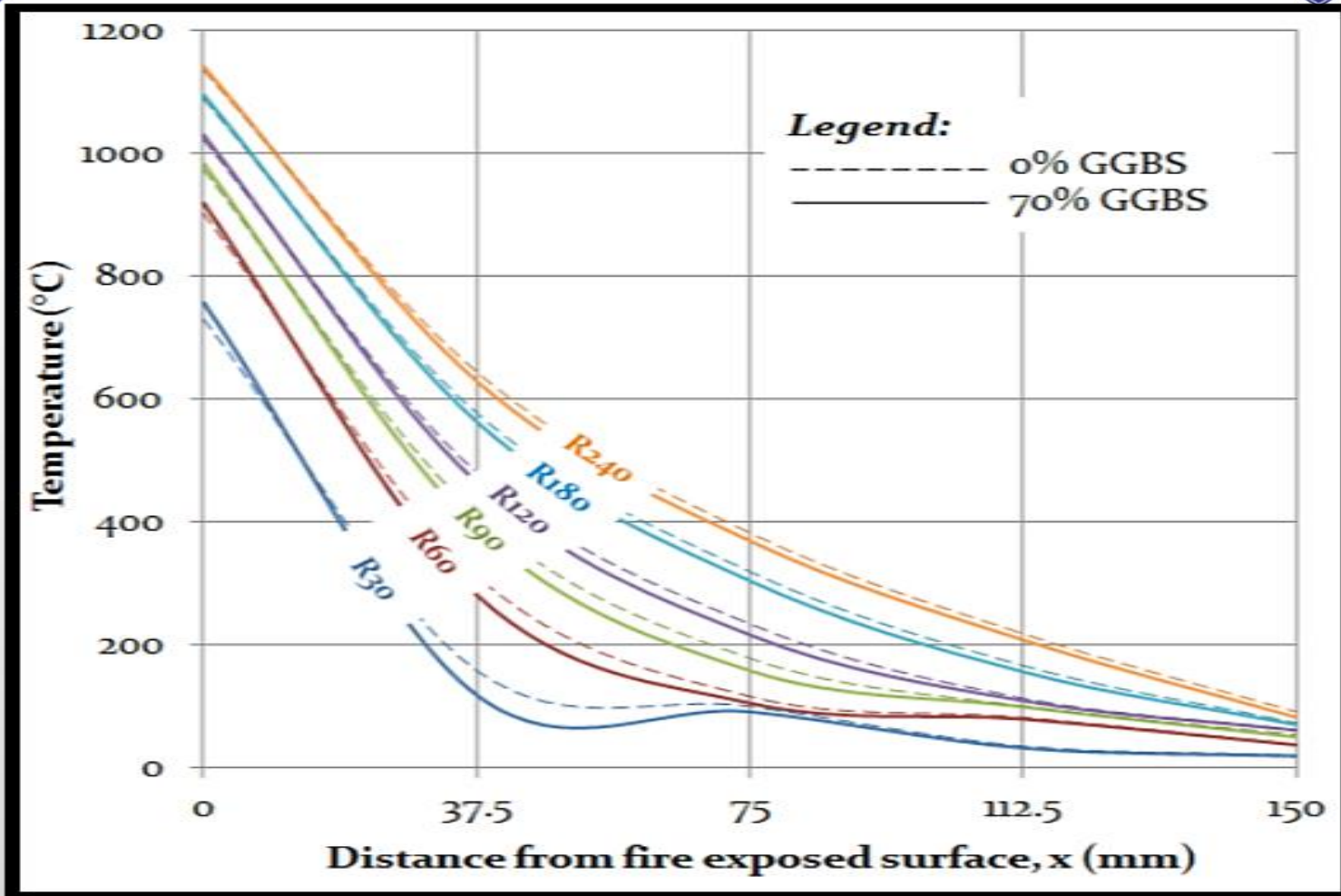
## 4.3.4 SETTING TIME IN COLD CONDITION

- Initial set of all concretes including GGBS CONC. is extended in cold conditions.



## 4.3.5 EFFECT ON FIRE RESISTANCE

- The behavior of concrete structures at elevated temperatures is predicting the safety of structures in **RESPONSE TO CERTAIN ACCIDENTS OR PARTICULAR SERVICE CONDITIONS**
- Exposure to high temperatures can degrade **CONCRETE PERFORMANCE**
- Lower transfer of heat exhibited by GGBS concrete **IMPROVES PERFORMANCE** in terms the separating function and could allow a **5% reduction** in the thickness of reinforced concrete separating elements
- With the addition of GGBS into concrete, **HYDRATION** product  $\text{Ca(OH)}_2$  is generally **REDUCED** compared with concrete made with 100% OPC, thus **IMPROVING THE PERFORMANCE OF RESISTING FIRE DAMAGE.**



## 4.3.6 EFFECT ON DURABILITY

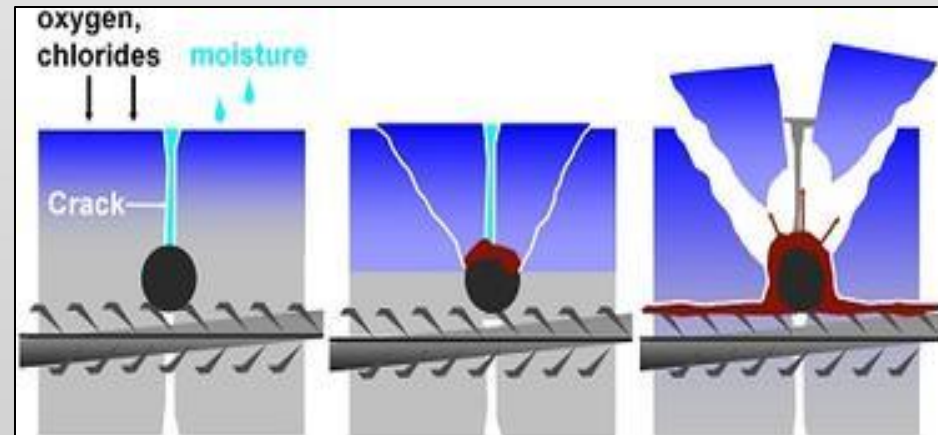
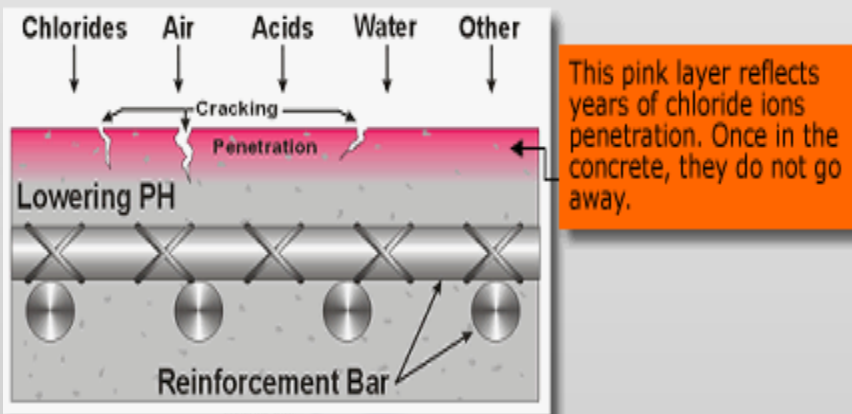
GGBS is effective in preventing all these forms of deterioration :

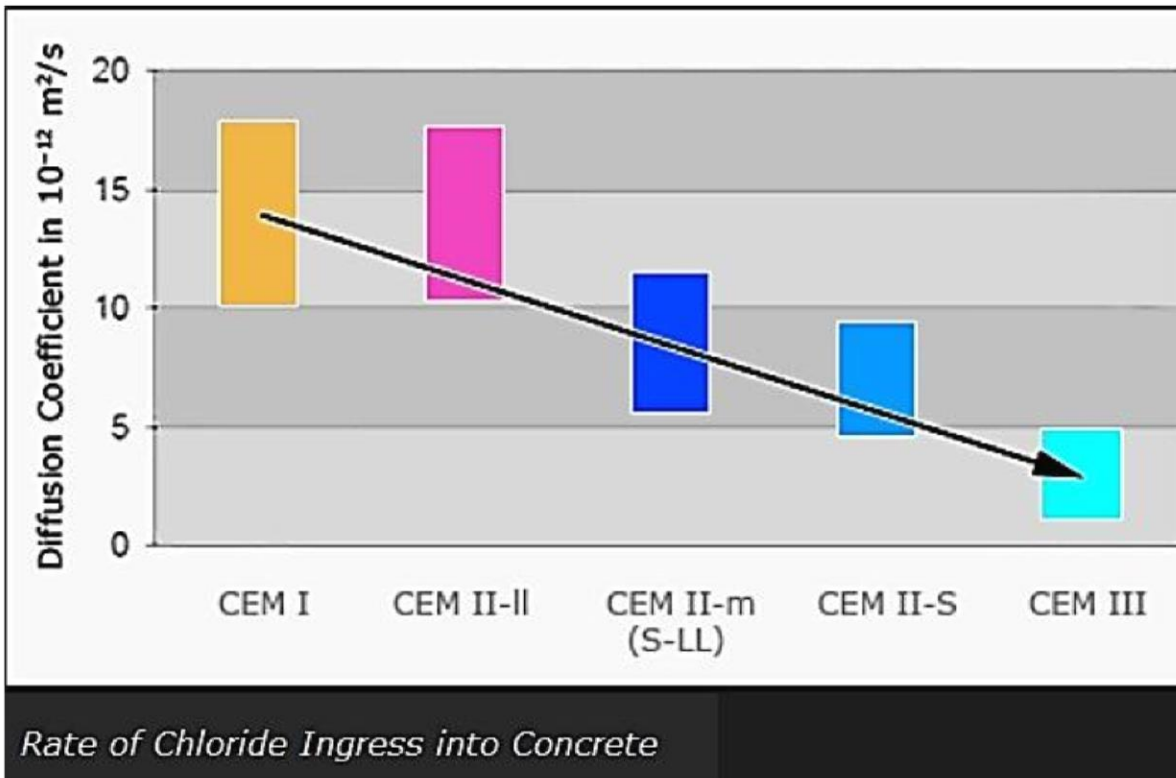
- i. Chloride penetration
- ii. Sulphate attack
- iii. Alkali-silica reaction (ASR)



# Resistance to Chloride Penetration

- Chloride penetration **can cause severe damage from corrosion and expansion** of any embedded metal reinforcing.
- GGBS concrete has lower of chloride diffusivity as the penetrating chlorides and **more effectively** than Portland cement.
- **Lower permeability** of GGBS concrete limits ingress of chlorides.
- GGBS is so superior to Portland cement in preventing chloride penetration that certain specifies require that GGBS be included in concrete mixes whenever any reinforcing is present.





### Info

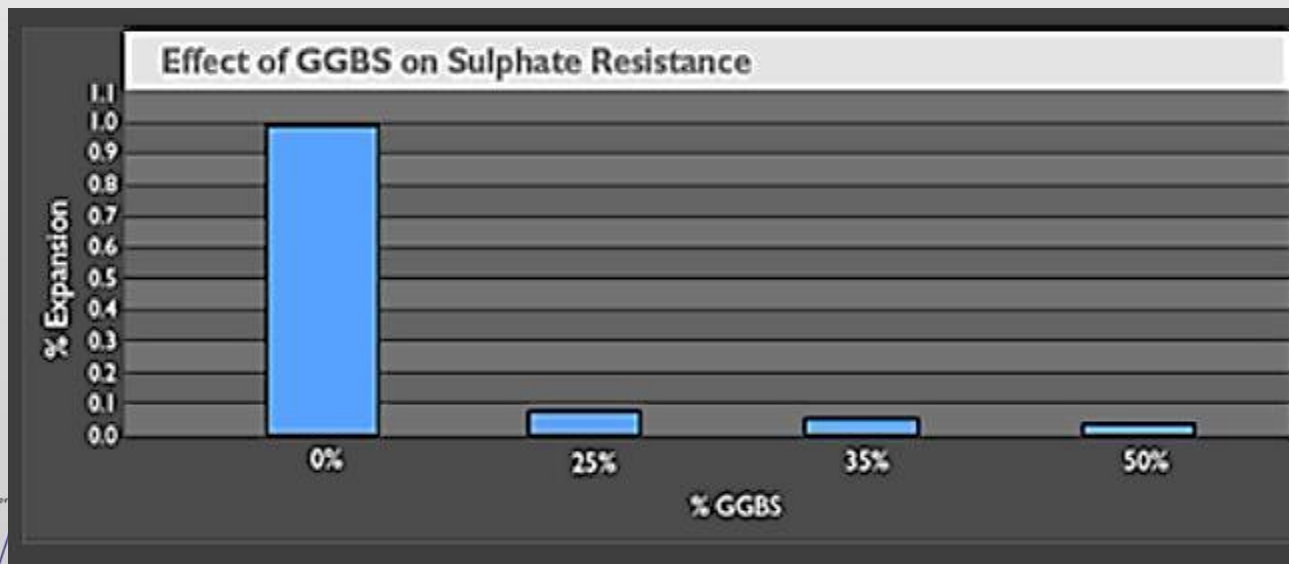
- GGBS is being used in Greystones harbour and many other marine projects around Ireland.
- GGBS has been specified in all the basement structures in the Dublin Docklands to increase the resistance to attack by salts.

| % GGBS | Cement Type | Diffusion Coefficient ( $10^{-12} \text{ m}^2/\text{s}$ ) |
|--------|-------------|---|
| 0      | CEM I       | 7-18  |
| 0      | CEM II/A    | 7-17  |
| 10-35  | CEM II/B    | 5-10  |
| 35-65  | CEM III/A   | 2-5   |
| 66-80  | CEM III/B   | 0.9-3.5   |

# Resistance to Sulphate Attack

**SULFATE ATTACK** processes decrease the durability of concrete by changing the chemical nature of the cement paste, and of the mechanical properties of the concrete.

- Sulphates react with tri-calcium aluminate ( $C_3A$ ) and calcium hydroxide ( $Ca(OH)_2$ ) to form an expansive compound called secondary ettringite.
- The use of GGBS in concrete gives greatly increased resistance to attack by sulfates.

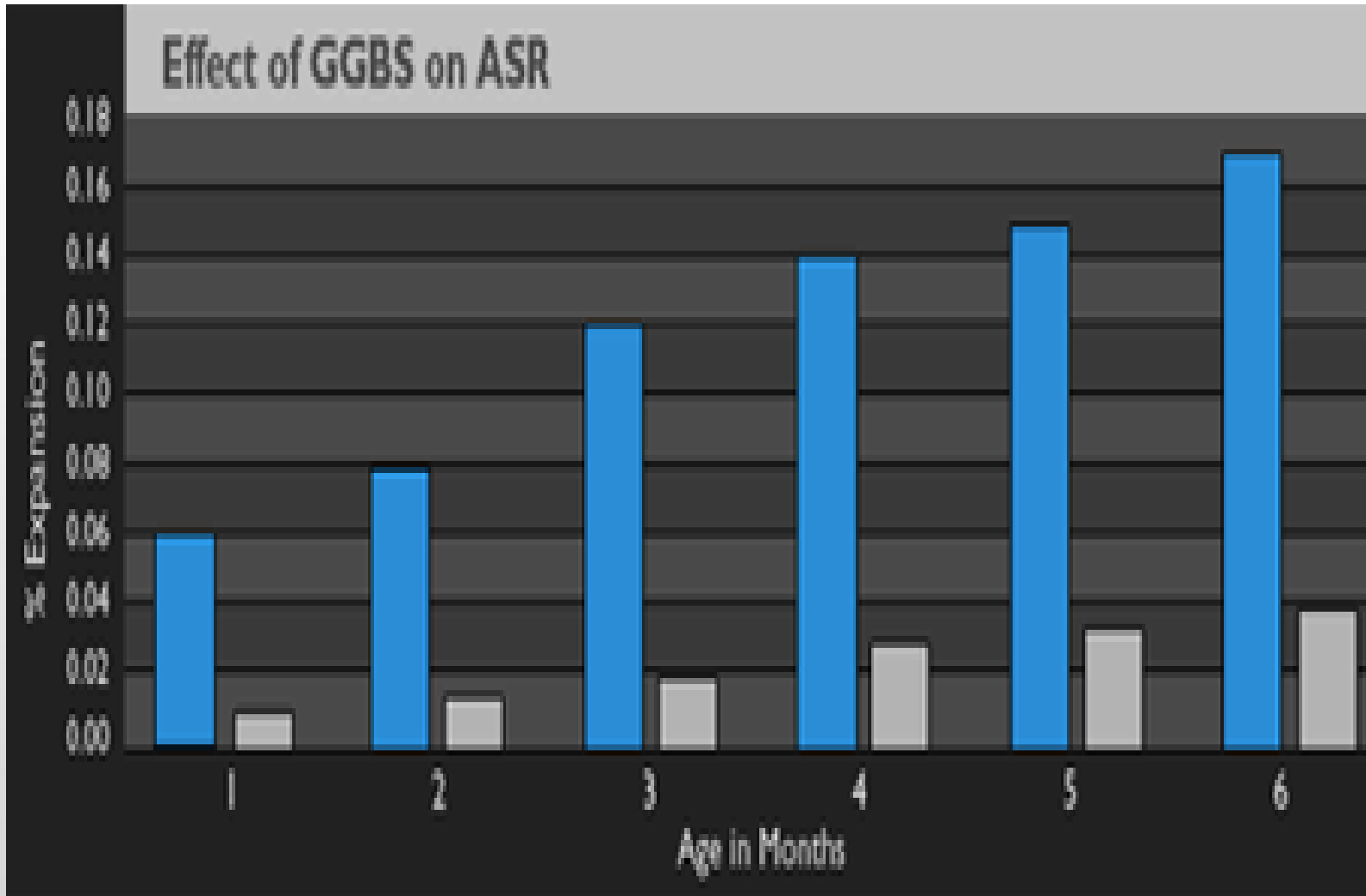


## Resistance to **Alkali-silica reaction (ASR)**

- Alkali ions (sodium and potassium) are present in Portland cement. They are readily soluble in water and are released into the pore solution of concrete when the cement hydrates.
- Here they can slowly react with certain types of silica in the aggregate to produce an alkali-silicate gel.
- In wet conditions this gel **can absorb water**, swell and exert sufficient pressure to crack the concrete.
- In some cases the resultant cracking is sufficient to **endanger structural integrity**.



- Addition of appropriate percentages of GGBS is an effective means of minimizing the risk of damaging ASR.
- Practice in specifying the level of GGBS varies from country to country. In the UK there is general acceptance that a **50% GGBS replacement** will be effective against ASR. A number of favorable factors contribute to this good performance by GGBS:
  - i) GGBS **reduces the alkalinity** of the concrete, and thus the alkali-silica ratio.
  - ii) GGBS **reduces mobility of alkalis** in the concrete.
  - iii) GGBS **reduces free lime** in the concrete (regarded as an important factor for alkali silica reaction).



## 4.3.7 CONCLUSION

- Replacement materials should have similar properties or better than existing material.
- So that it can prove the improvement performance in terms of concrete strength and durability.
- High quality of GGBS concrete is depends on proper proportion of replacement materials.



## 4.4 Effect of silica fume on the concrete properties



## 4.4.1 Introduction

- What is silica fume?
  - Silica fume is a by-product of the manufacture of silicon metal and ferro-silicon alloys.
  - Silica fume is a highly reactive pozzolana that converts all or most of the liberated calcium hydroxide to C-S-H
  - *pozzolanic ash* is a siliceous or siliceous and aluminous material which reacts with calcium hydroxide in the presence of water at room temperature.
  - Silica fume can either be added separately at the concrete mixer, where they are referred to as 'additions' or else be incorporated into a factory-produced composite cement

## COMPATIBILITY WITH ADMIXTURES

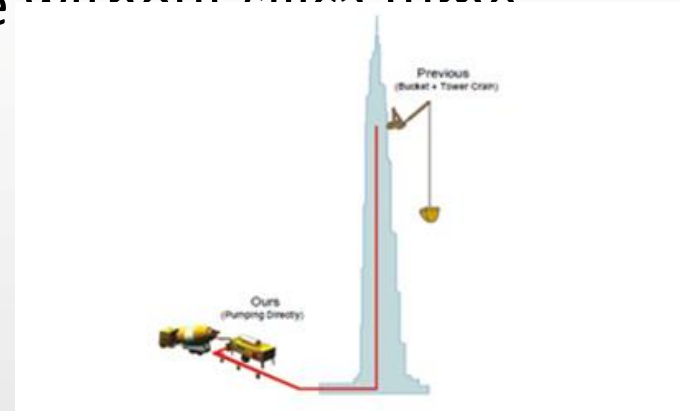
- Generally chemical admixtures can be used with silica fume in the same way as for conventional concretes.
- Silica fume is normally used with a super-plasticiser or high range water reducing agent (HRWRA) to maximise the full strength producing potential.

## WATER DEMAND

- The water demand of concrete containing silica fume increases with increasing amounts of silica fume and should contain a high range water reducing admixture to achieve a maximum improvement in strength and durability.

## WORKABILITY/CONSISTENCE

- Fresh concrete containing silica fume is more cohesive and less prone to segregation than concrete without silica fume
- Silica fume addition has been used to assist in pumping long distances, especially vertically.



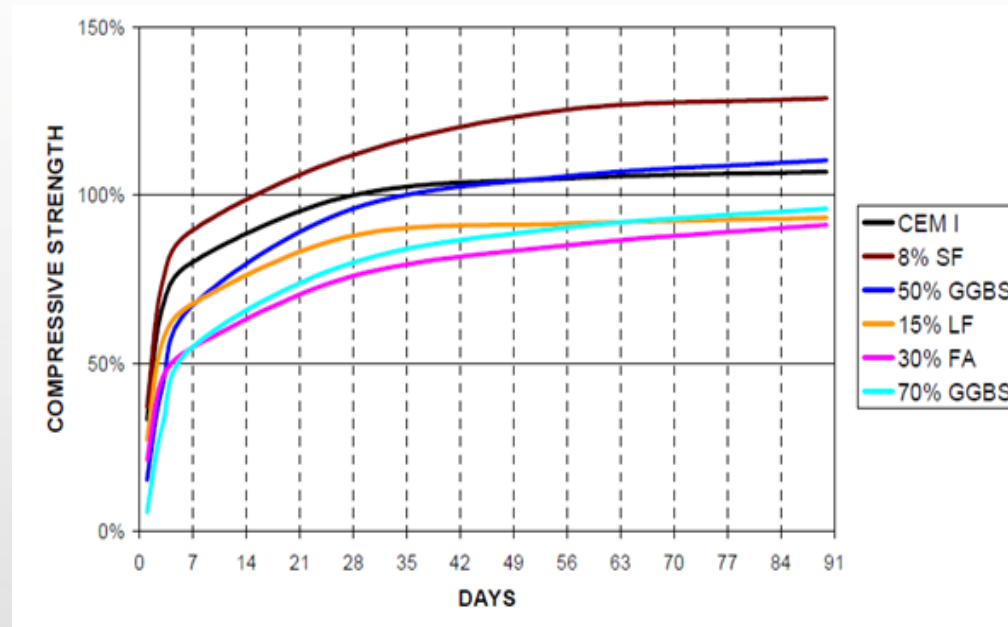
## BLEEDING

- Concrete containing silica fume shows significantly reduced bleeding. As silica fume dosage is increased, bleeding will be reduced.
- \This effect is caused primarily by the high surface area of the silica fume to be wetted

## SENSITIVITY TO CURING

- Concrete stiffens and hardens through the hydration reaction between cement and water.
- To obtain the full benefits of silica fume concrete, proper curing procedures must be followed. Because concrete containing silica fume shows significantly reduced bleed (as dosage is increased) there is very little free water left in the mixture for bleeding.
- Experience shows that under conditions of fast evaporation (wind and sun), curing measures must be taken immediately after placing the concrete.

# EFFECT ON CONCRETE STRENGTH



Indicative Strength Development (at fixed w/c and relative to the 28-day strength of CEM I)

Notes:

1. The relative strengths are indicative and will vary significantly, with mix design and materials
2. At fixed w/c, the workability/consistence will vary, according to the water-demand
3. This graph is derived from experience and data contributed by the authors of CSTR74

- Concrete made with silica fume follows the conventional relationship between compressive strength and w/c but strength is increased at a given w/c ratio when silica fume is used. High early compressive strength (in excess of 25N/mm<sup>2</sup> at 24 hours) can be achieved
- With proper concrete design, very high 28-day strengths can be produced, using normal ready-mixed concrete plants

## TENSILE STRENGTH

- The tensile (flexural) strength of concrete increases with compressive strength, with the tensile strength being typically only about 10% of the compressive strength.
- Compared with CEM I concrete the ratio of tensile strength tends to be slightly lower for silica fume concrete.
- As the compressive strength of silica fume concrete increase, the tensile strength also increases, but at a gradually decreasing ratio

## EFFECT ON CONCRETE DURABILITY

- Silica fume can produce **very large reductions in water permeability** of up to one order magnitude or more, depending on the mix design and dosage of silica fume.
- The reduction in the size of capillary pores increases the probability of transforming continuous pores into discontinuous ones.
- Because capillary porosity is related to permeability, the permeability to liquids and vapours is thus reduced by silica fume addition.



## PROTECTION TO EMBEDDED STEEL (CARBONATION)

- Steel embedded in concrete is protected against corrosion by the alkalinity of the cement paste.
- Despite any reduction in calcium hydroxide, resulting from the incorporation of silica fume, the pH of the cement paste remains at an adequately high level to protect steel.
- Carbonation can reduce the alkalinity and protection to the steel.
- Silica fume concrete tends to show greater carbonation than CEM I mixes of equivalent 28 day strength.

## PROTECTION TO EMBEDDED STEEL (CHLORIDES)

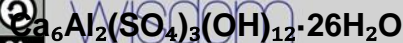
- If chloride permeates the concrete to the depth of the reinforcement it can initiate corrosion of the steel.
- Concrete made with silica fume is generally substantially more resistant to chloride diffusion than CEM I concrete and for reinforced concrete structures exposed to chlorides, its use will give enhanced durability.

## SULFATE RESISTANCE

- Sulfate attack of concrete occurs through both chemical and physical processes.
- Two main reactions are involved, these being the reaction of sulfate ions with hydrated calcium aluminates forming *ettringite*, and the combination of sulfate ions with free calcium hydroxide forming *gypsum*.



Ettringite is a hydrous calcium aluminium sulfate mineral with formula:



Gypsum is a soft sulfate mineral composed of calcium sulfate dihydrate, with the chemical formula



- Silica fume is very effective in reducing or preventing the attack from sodium sulfate.
- The primary mechanism by which silica fume improves sodium sulfate resistance is by reduction of permeability, and it may be augmented by reduced calcium hydroxide contents due to pozzolanic reaction.
- Performance of silica-fume concrete exposed to ammonium sulfate is mixed
- Performance when exposed to magnesium sulfate is less than that of paste without silica fume

## RESISTANCE TO ACIDS

- All types of cement are susceptible to attack by acids and, in highly acid solutions (e.g. pH less than 3.5), dissolution of the cement matrix and subsequent loss of integrity of concrete will occur.
- silica fume will increase the resistance of concrete to dilute acids and chemical attack through reduced permeability and through reduced content of calcium hydroxide.
- Silica fume concrete is not completely impervious to all aggressive chemicals, especially in the case of concentrated acid attack on the surface
- at a low w/c, silica-fume concrete can be used effectively to prevent significant damage by many types of chemical attack including sewage and outfall pipes.

# ABRASION RESISTANCE

- Numerous factors influence the abrasion resistance of floor slabs, the most significant being curing, strength class and trowelling intensity.
- Silica fume will increase the abrasion-erosion and abrasion resistance of concrete through increased strength of the matrix and the improved bond between matrix and aggregates.

# EFFECT ON CONCRETE'S PHYSICAL PROPERTIES

## Colour

- ❖ Most silica fumes range from light to dark grey. Because  $\text{SiO}_2$  is colourless, the colour is determined by the non-silica components, which typically include carbon and iron oxide.
- ❖ In general, the higher the carbon content, the darker the silica fume.
- ❖ The carbon content of silica fume is affected by many factors relating to the manufacturing process, such as: use of wood chips versus coal, and the type of product (metal alloy) being produced.

## Elastic Modulus

- ❖ silica fume usually increase the ultimate modulus, but the magnitude of the increase is generally not significant in terms of design.
- ❖ Several other researchers have reported that the static modulus of elasticity of silica-fume concrete is apparently similar to that of concrete without silica fume of similar strength



## EFFECT ON ENVIRONMENTAL IMPACTS

Significant reductions in environmental impacts occur for GGBS, fly ash and silica fume, because:

- their manufacture does not require the quarrying of virgin minerals
- their use in concrete avoids them being disposed of to landfill
- they use much less energy in their manufacture than CEM I.

# Conclusion

- Cement replacement up to 10% with silica fume leads to increase in compressive strength.
- The use of micro silica in high strength concrete leads to economical and faster construction.

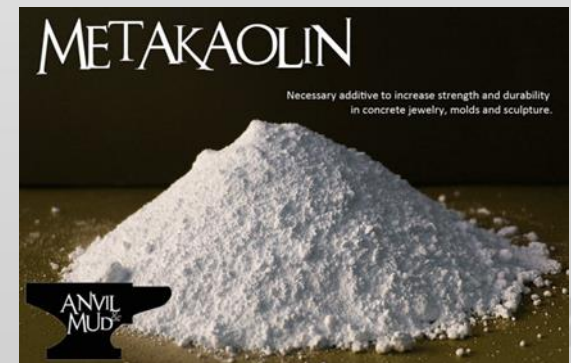


## 4.4 Effect of Metakaolin the concrete properties

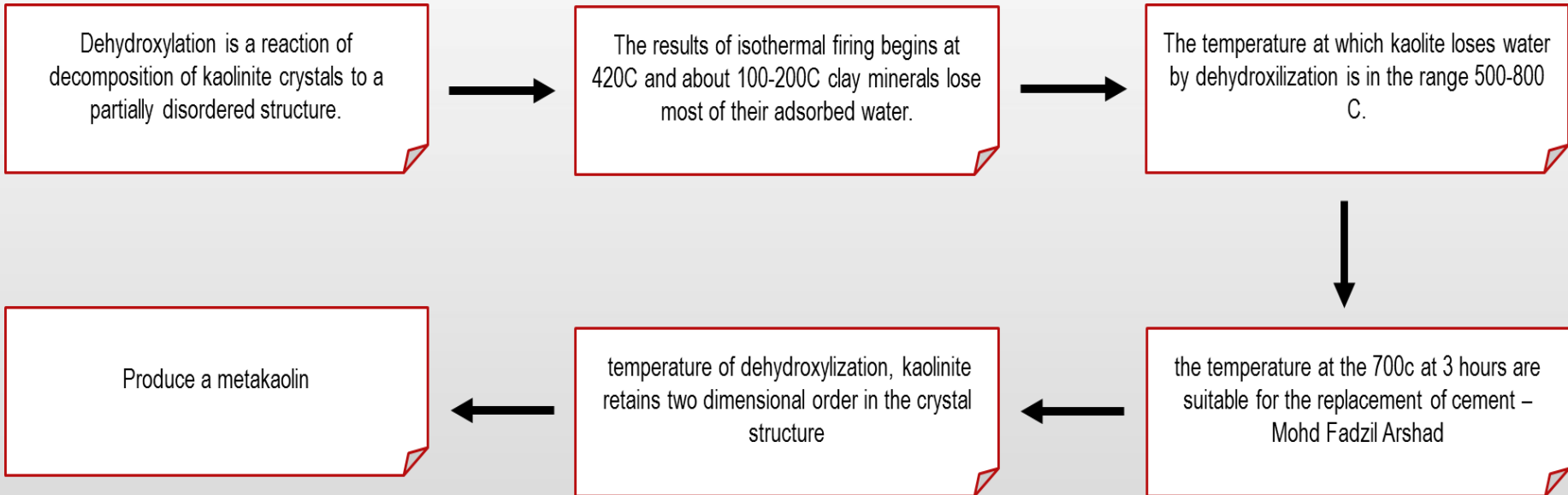
# INTRODUCTION

## DEFINITION

- **Kaolin is a fine , white, clay mineral**
- **Kaolins are classifications of clay minerals, which like all clays, eg: layer silicate mineral.**
- **Calcination of clay mineral (kaolin) at moderately-high temperature (650-800C)**
- **Burning at higher temperature will cause recrystallization into quartz**



# Process of Metakaolin



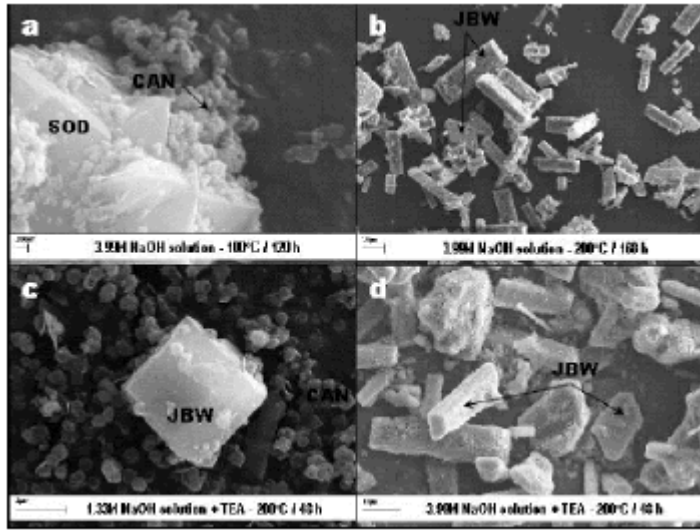
# PROPERTIES OF METAKAOLIN

## • PHYSICAL OF METAKOLIN

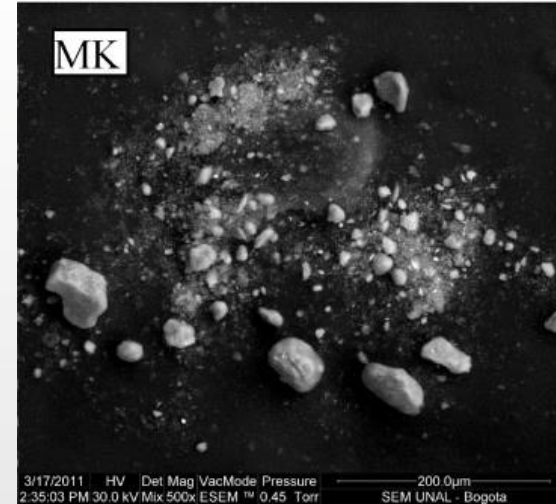
|                  |                           |
|------------------|---------------------------|
| Specific Gravity | 2.40 to 2.60              |
| Physical Form    | Powder                    |
| Color            | Off white, Gray to Buff   |
| Brightness       | 80-82 Hunter L            |
| BET              | 15 m <sup>2</sup> /gram   |
| Specific Surface | 8 – 15 m <sup>2</sup> /g. |

## • CHEMICAL OF METAKOLIN

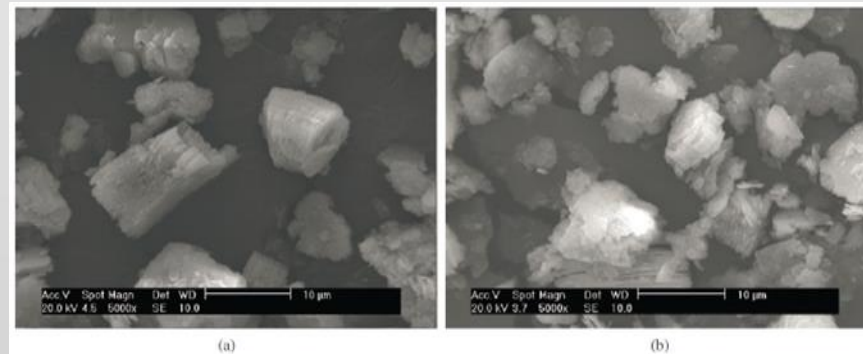
|                                |         |                   |         |
|--------------------------------|---------|-------------------|---------|
| SiO <sub>2</sub>               | 51-53 % | CaO               | < 0.20% |
| Al <sub>2</sub> O <sub>3</sub> | 42-44%  | MgO               | < 0.10% |
| Fe <sub>2</sub> O <sub>3</sub> | < 2.20% | Na <sub>2</sub> O | < 0.05% |
| TiO <sub>2</sub>               | < 3.0%  | K <sub>2</sub> O  | < 0.40% |
| SO <sub>4</sub>                | < 0.5%  | L.O.I.            | < 0.50% |
| P <sub>2</sub> O <sub>5</sub>  | < 0.2 % |                   |         |



Synthesis conditions for transformation of kaolinite into SOD-, CAN- and jbw-type structures



Scanning electron-micrograph cementitious material of Metakaolin



SEM image : a) Kaolin waste b) metakaolin waste material

# METAKAOLIN IN CONCRETE

**Reaction**

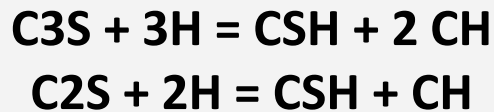
**Application / Usage**

**Advantages**



# REACTION

- Portland cement consists of about 80% calcium silicates:
- Tricalcium silicate(Alite)=(C3S) and diclcium silicate(belite)=(C2S)
- These will react with water according to the following reactions.



- The final structure consists of about 75% calcium silicate hydrate (CSH) and 25% hydrated lime (CH).
- The hydrated lime (ch) also called calcium hydroxide or portlandite will react with pozzolana, forming more csh-phases:



# APPLICATION / USAGE

**BRIDGE**

**DAMS**

**WATER  
RETAINING  
STRUCTURES**

**HIGH RISE  
BUILDINGS**

**HISTORICAL  
BUILDING**

**WAREHOUSES**



# ADVANTAGE

- **Facilitate finishing concrete surfaces by rubbing and smoothing**
- **reduces the amount of cement in the formation of concrete**
- **The strength and durability of concrete increases.**
- **Metakaolin reduces heat of hydration leading**
- **Metakaoline increases resistance to chemical attack**

# CASE STUDY

| Title & author   | Result  |
|--|---|
| <b>The Use of Metakaolin as Partial Replacemnet Substance in Concrete – Murali.G and Struthee P (2012)</b> | <ul style="list-style-type: none"><li>•The result showed that 7.5% of Metakaolin increased the compressive strength of concrete by 14.2%, the split tensile strength by 7.9% and flexural strength by 9.3%.</li></ul>   |
| <b>The Effect Of Metakaolin On Strength And Workability Of Concrete. - Paiva.H Et Al (2012)</b>            | <ul style="list-style-type: none"><li>•The experimental results showed that the use of Metakaolin decreased the workability and to get the required slump, High range water reducing admixtures (HRWRA) were essential.</li><li>•HRWRA resulted in deflocculation of Metakaolin particles and thus a well dispersion of Metakaolin particles were achieved.</li><li>•The work concluded that use of HRWRA was very essential in concrete containing fine particles like Metakaolin to achieve well dispersion and better results.</li></ul> |

| <b>Title &amp; author</b>   | <b>Result</b>  |
|---|--|
| <b>suitability of silica fume and metakaolin combination in production of concrete. - Vikas Srivastava et al (2012)</b> | <ul style="list-style-type: none"><li>•The optimum combined doses of silica fume and Metakaolin were found out as 6% and 15% (by weight) respectively.</li><li>•The 28th day compressive strength of concrete generally increased with the Metakaolin content for at all the Silica fume contents.</li></ul>   |
| <b>Studied The Reaction Between Metakaolin-ca(oh)2-water And Fly Ash- Ca(oh)2-water - Dojkov.I Et Al (2013)</b>         | <ul style="list-style-type: none"><li>•The reaction between Fly ash- Ca(OH)<sub>2</sub>-water was taking place at a moderate rate in the initial age as compared with Metakaolin-Ca(OH)<sub>2</sub>-water.</li><li>•The experimental results justified the possible combined use of Metakaolin-Fly ash-Portland cement in concrete industry.</li></ul> |

