By: Dr. Shamshad Ahmad

LECTURE NO. 10 & 11 (Part II)

MINERAL ADMIXTURES

Objectives:

- **To introduce the mineral admixtures**
- **To explain in detail fly ash and silica fume used as mineral admixtures**

INTRODUCTION

- **Nowadays it is a normal practice to use blended cements for producing a durable and economical concrete and to save the energy and to reduce the environmental pollution.**

- **These blended cements are obtained by intergrinding or blending Portland cement with particular mineral admixtures.**

- ***Pozzolanic materials* (i.e., natural pozzolana or artificial pozzolana such as fly ash, silica fume) and *ground granulated blast furnace slag (GGBS)* are among the most widely used mineral admixtures for manufacturing the blended cements.**

By: Dr. Shamshad Ahmad

SOURCES AND CHARACTERISTICS

Natural pozzolana:

- **Obtained by grinding the sediments of volcanic eruptions**
- **Contains mainly silica**
- **Example: Italian pozzolana, which was used by the Romans.**

Fly ash (FA) also called as pulverized fly ash (PFA):

- **Obtained from thermoelectric power plants**
- **Contains mainly the silica and a small percentage of alumina with a negligible amount of lime**
- **Fineness in the range of 300 to 600 m^2/kg, which is about same as the fineness range of Portland cements**

Silica fume (SF) also called as microsilica, etc:

- **Obtained from the industries manufacturing ferro-silicon alloys**
- **Contains mainly the silica**
- **Has fineness very high, about 100 times more finer than common Portland cements**

Ground granulated blast furnace slag (GGBS):

- **Obtained in huge quantities from the blast furnaces used for production of pig iron in the iron industries**
- **Contains all the main components of Portland cement (i.e., lime, silica, and alumina), thus behaves like a cement**

By: Dr. Shamshad Ahmad

DIFFERENCE BETWEEN POZZOLANA AND GGBS

- A pozzolanic material is defined as a siliceous or siliceous and aluminous material without considerable lime, which in itself possesses little or no cementing property

whereas

- A GGBS, containing lime, silica, and alumina, has a similar behavior as a Portland cement.

therefore,

- Pozzolanic materials may only be used as admixtures for cement
- GGBS having self-cementing charecteirstics and thus, may either be used alone as a binder or may be used as admixture for cement.

By: Dr. Shamshad Ahmad

EFFECTS OF MINERAL ADMIXTURES ON DURABILITY

Effect on Microstructure of Hydrated Concrete

- **The reaction between silica (from a mineral admixture) and lime (from a Portland cement) results into the formation of a secondary C-S-H, as follows:**

  C_3S (of Portland cement) + H → C-S-H (primary) + CH (lime)

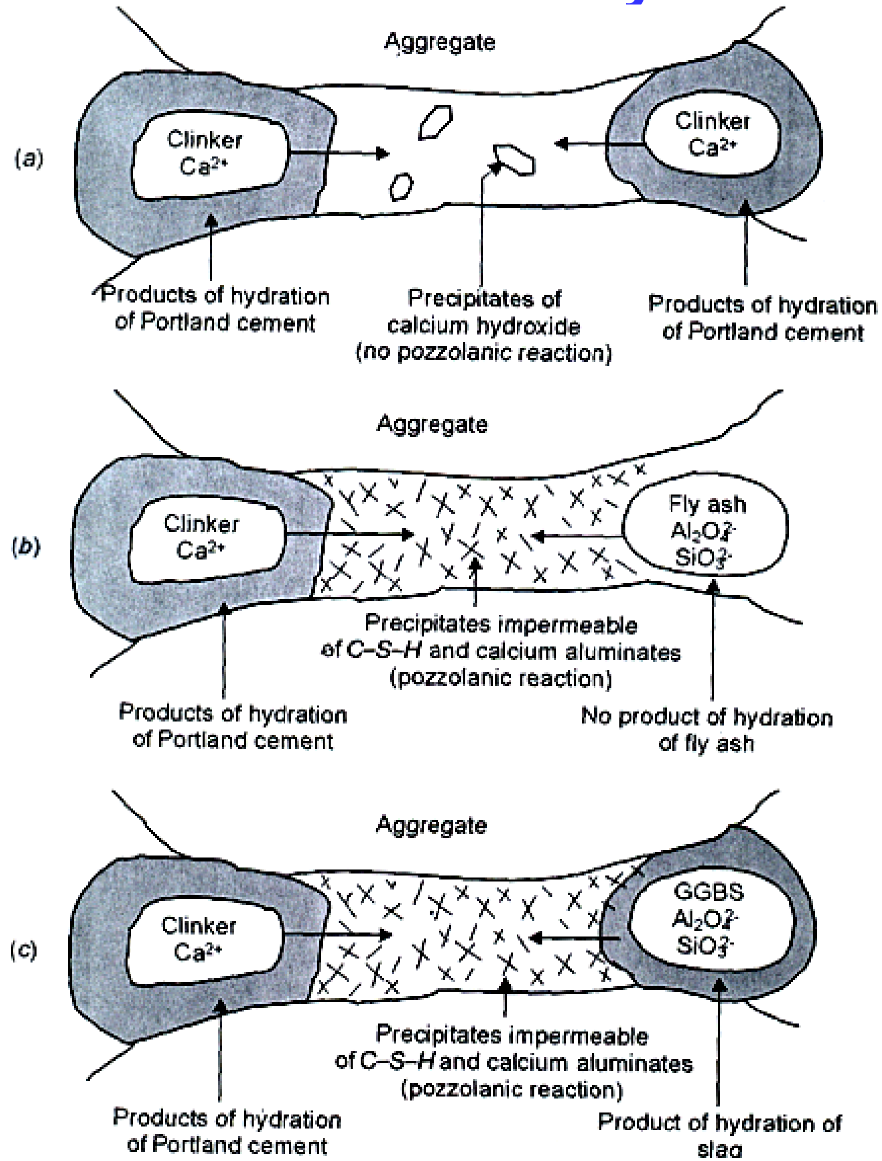
  S (present in Pozzolana or GGBS) + CH (lime liberated from PC) +H → C-S-H (secondary)

- **The *additional C-S-H gel*, produced as a result of above secondary hydration reaction, makes the pore structure of concrete denser, as shown in the following figure, thereby *reducing the penetration and diffusion of concrete by the aggressive agents*.**

By: Dr. Shamshad Ahmad

EFFECTS OF MINERAL ADMIXTURES ON DURABILITY

Effect on Microstructure of Hydrated Concrete



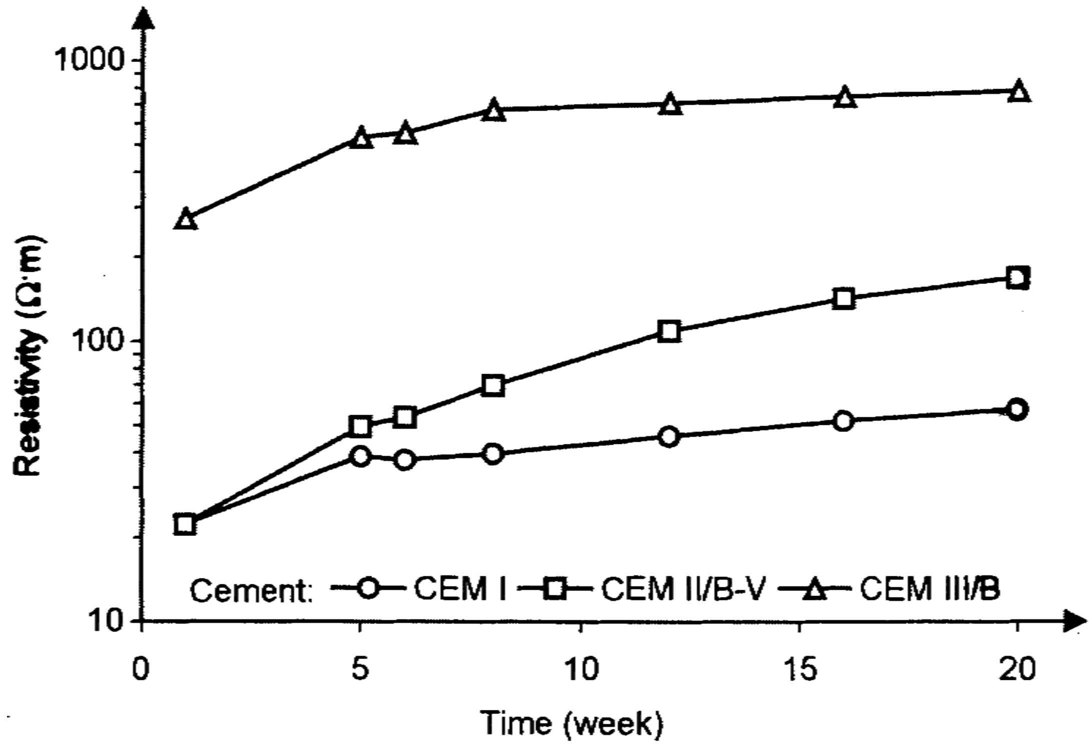
Microstructure of hydration of Portland cement (*a*), and cements with addition of fly ash (*b*) and blast furnace slag (*c*)

By: Dr. Shamshad Ahmad

EFFECTS OF MINERAL ADMIXTURES ON DURABILITY

Effect on Resistivity of Concrete

- **The resistivity of concrete made using the mineral admixtures is found to be significantly higher than that of ordinary Portland cement concrete, thereby reducing the rate of reinforcement corrosion.**
- **This is due to the achievement of a dense microstructure of concrete made using a mineral admixture.**



Effect using the mineral admixtures on resistivity of concrete

w/c = 0.45, 2% chloride mixed-in

CEM I: OPC; CEM II/B-V: PFA cement; CEM III/B: GGBS cement

By: Dr. Shamshad Ahmad

EFFECTS OF MINERAL ADMIXTURES ON DURABILITY

Effect on Chloride Diffusivity of Concrete

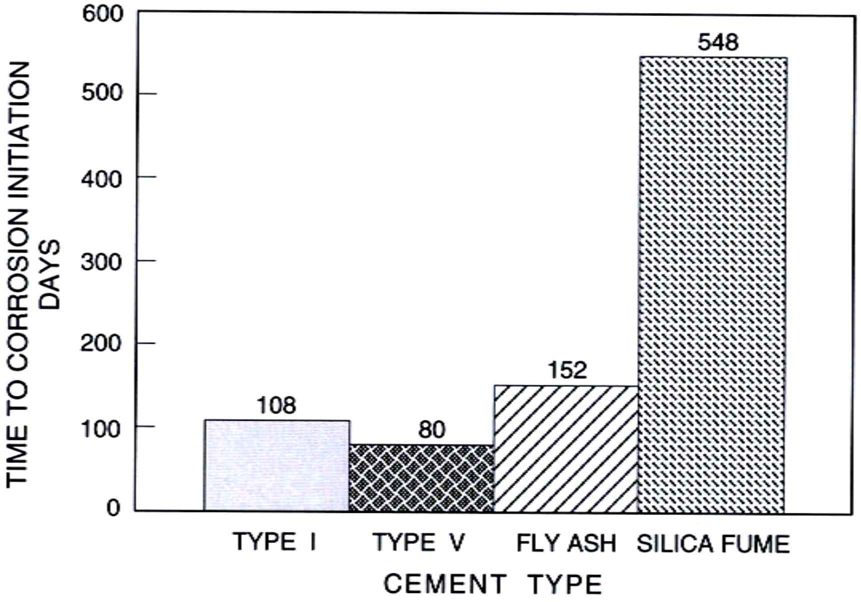
- **Diffusivity of chloride ions in *PFA concrete* is reported to be about *2 times lesser* and in *GGBS concrete 8 times lesser* as compared to the OPC concrete, at a typical w/c ratio of 0.5.**

- **10% addition of silica fume is reported to reduce the coefficient of chloride diffusion from 227×10^{-13} m^2/s *to* 22×10^{-13} m^2/s**

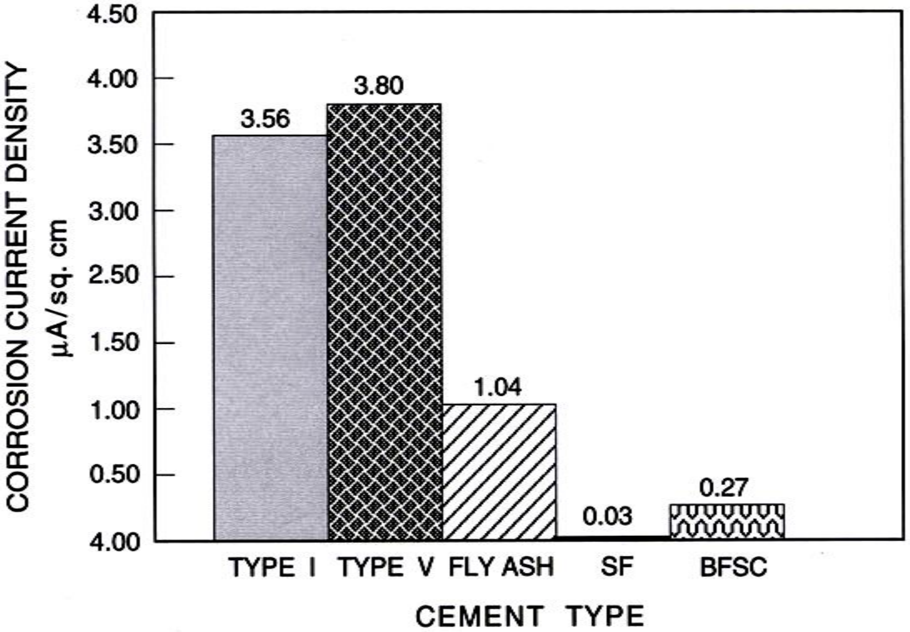
By: Dr. Shamshad Ahmad

EFFECTS OF MINERAL ADMIXTURES ON DURABILITY

Effect on Resisting Reinforcement Corrosion



Time to initiation of reinforcement corrosion in plain and blended cement concrete specimens



Corrosion current density on steel in plain and blended cement concretes, after 425 days.

PRACTICAL DOSAGES OF THE MINERAL ADMIXTURES

- **The activities of pozzolanic materials depend on the silica content and fineness of a mineral admixture.**
- **The amount of a mineral admixture should be proportioned to the amount of CH (lime) produced in the hydration of Portland cement. Any excess addition of the mineral admixture will not react and thus will behave as an inert material.**
- **The amount of *fly ash* addition to Portland cement generally ranges from *20 to 40% (very commonly 20%)* of the total cement content.**
- ***Silica fume* is usually added in the range of *5 to 10% (very commonly 7%)* of the total cement content.**
- **In order to achieve an optimal densification of concrete the *GGBS* content should be *higher than 65%*.**

FURTHER DETAILS ABOUT FLY ASH AND SILICA FUME USED AS CONCRETE ADMIXTURES

By: Dr. Shamshad Ahmad

FLY ASH: Introduction

- **Fly ash particles are typically *spherical*, ranging in diameter from less than 1 μm to more than 1 mm, the majority being less than 45μm**
- **Specific surface, already mentioned earlier, ranges from 300 to 600 m^2/kg**
- **The specific gravity of fly ash generally ranges from 2.2 to 2.8**
- **The characteristics of fly ash vary and depends on the following two factors:**
  - ***Collection method from flue gases (has effect on physical property i.e. fineness)***
    - **As a general rule, fly ash extracted at the *mechanical collectors* is coarser than that collected at the *electrostatic precipitators***
  - ***Type of coal (has effect on chemical property)***
    - **Fly ash produced from the combustion of *bituminous coals contains low lime* (< 10%) and such low-lime fly ash is classified as: Class F (low-lime fly ash)**
    - **Fly ash produced from the combustion of *sub-bituminous or lignite coals contains high lime* (> 10%) and such high-lime fly ash is classified as: Class C (high-lime fly ash)**

By: Dr. Shamshad Ahmad

FLY ASH: Reactivity

- **The reactivity of silica from fly ash with $Ca(OH)_2$ from the primary hydration of the Portland cement, results into formation of secondary C-S-H gel improving the quality of concrete**
- **Reactivity of fly ash is affected by the following factors:**
  - **The chemical and phase composition of both fly ash and cement**
  - **The alkali-hydroxide concentration of the reacting system**
  - **The morphology of fly ash particles**
  - **The development of heat during the early stages of the hydration process**
  - **The fineness of both the fly ash and cement**
  - **The reduction in mixing water requirement when using fly ash**
- **Since reactivity of fly ash varies with the variation of the above factors, the following quality of concrete should be investigated through trial mixtures before accepting a fly ash as mineral admixture:**
  - **Workability**
  - **Strength**
  - **Durability (permeability and diffusivity)**

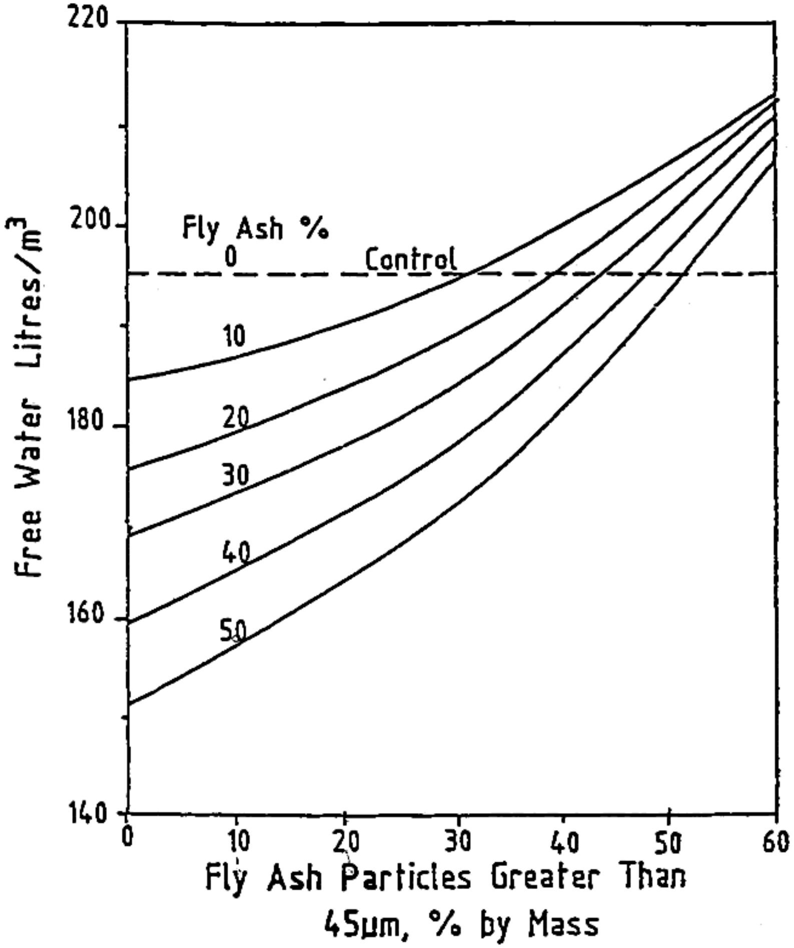
By: Dr. Shamshad Ahmad

FLY ASH:
Effect of Fly ash on Concrete Properties

1. Workability and Bleeding

- Improvement in workability due to more paste available for lubricating the aggregates

- The spherical shape of fly ash particles enhance the lubrication effect thereby permitting the water in the concrete to be reduced for a given slump, as shown in the following figure:

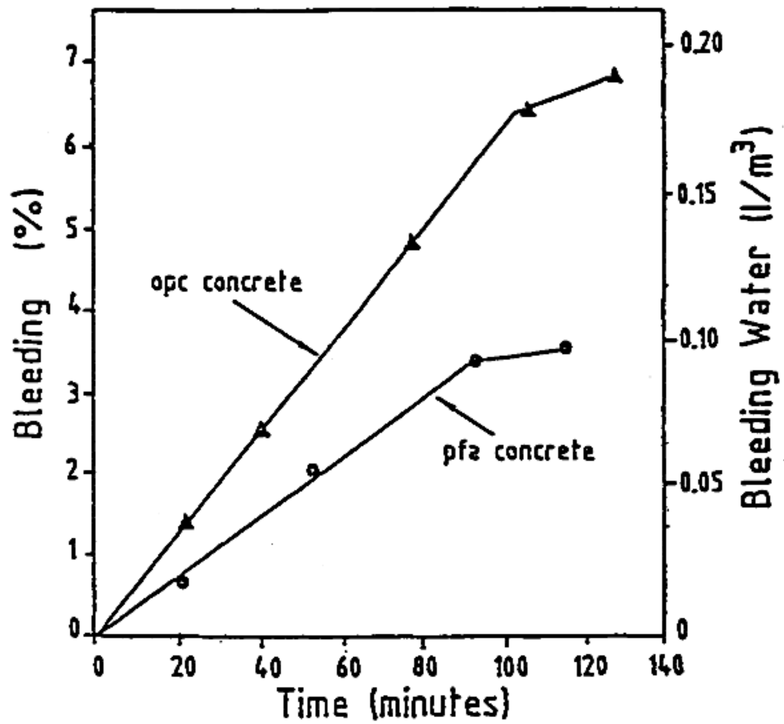


By: Dr. Shamshad Ahmad

FLY ASH:
Effect of Fly ash on Concrete Properties

1. Workability and Bleeding-----contd.

- **Water reduction and lubrication due to fly ash addition increases the solid to liquid ratio in the concrete mixture thereby resulting in particulate packing reducing bleeding of concrete, as shown in the following figure:**



Effect of Fly Ash on Bleeding in Concrete

By: Dr. Shamshad Ahmad

FLY ASH:
Effect of Fly ash on Concrete Properties

2. **Setting time**
   - The use of fly ash retard the time of setting of the concrete (i.e. more setting time in a fly ash concrete)
   - Class F fly ash generally extends the time of setting, while Class C fly ash may extend, reduce or may have no significant effect on setting time

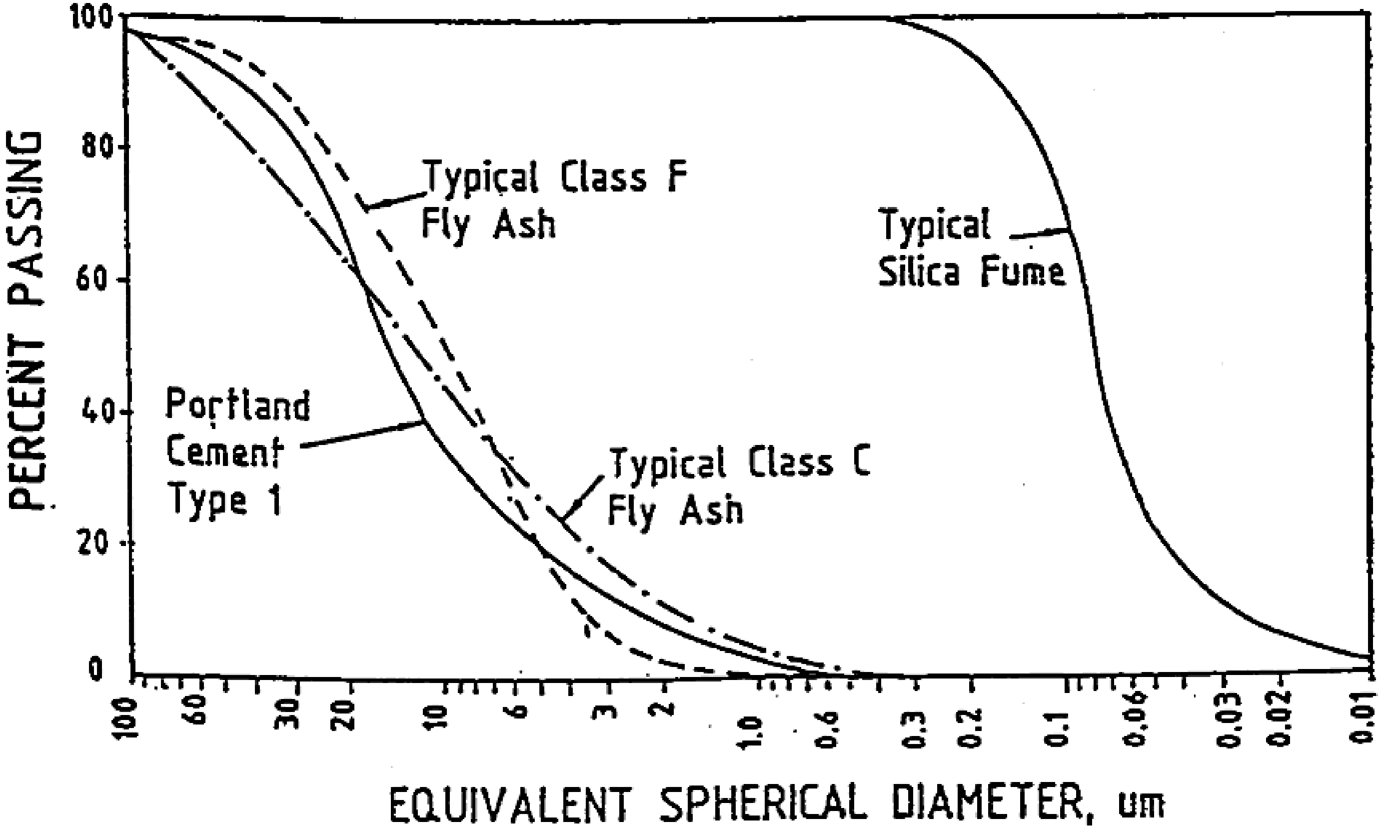
3. **Finishability and Pumbability**
   - Finishability and pumpability of a fly ash concrete are found to be greatly improved due to increased amount of the paste

4. **Permeability and Diffusivity**
   - Although lately (after about 28 to 60 days of water curing), the permeability and diffusivity of fly ash concrete is found to be much lower than that of the plain Portland cement

By: Dr. Shamshad Ahmad

SILICA FUME: Introduction

- **Silica fume particles are typically *spheroidal* (*increasing lubrication of aggregates*) and *glassy (increasing reactivity with cement)***
- **Silica fume particles are found with an average size of 0.1 μm (about 100 times finer than those of PC), as shown in the following figure:**



SILICA FUME: Introduction

- **Due to the very fine size, silica fume is a very good *filler***
- **Specific surface, already mentioned earlier, is very high about 20000 m^2/kg**
- **The specific gravity of silica fume is generally 2.2**
- **The silica fume contains about 85% amorphous silica which make silica fume a *super-pozzolanic material***

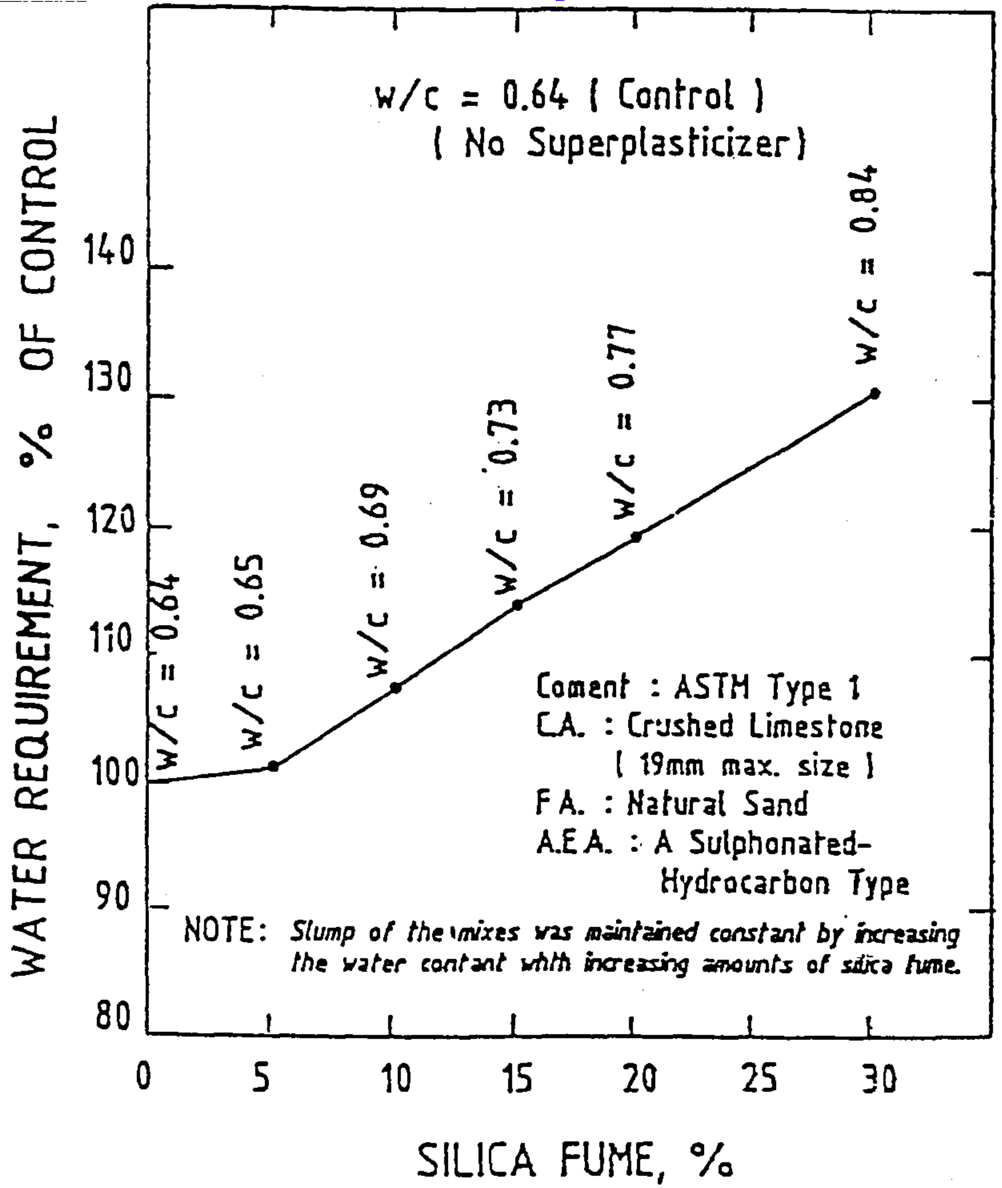
By: Dr. Shamshad Ahmad

SILICA FUME:

Effect of Silica fume on Concrete Properties

1. Water Demand

- Due to spherical shape of the particles of silica fume, like fly ash, there is decrease in the water demand in silica fume concrete
- However, due to high specific surface area of the particles of silica fume the water demand increases, giving a *net effect of increased water demand* compared to Portland cement concrete *with the same level of workability*
- Therefore, superplasticizers should be used in silica fume concrete to reduce the water demand



By: Dr. Shamshad Ahmad

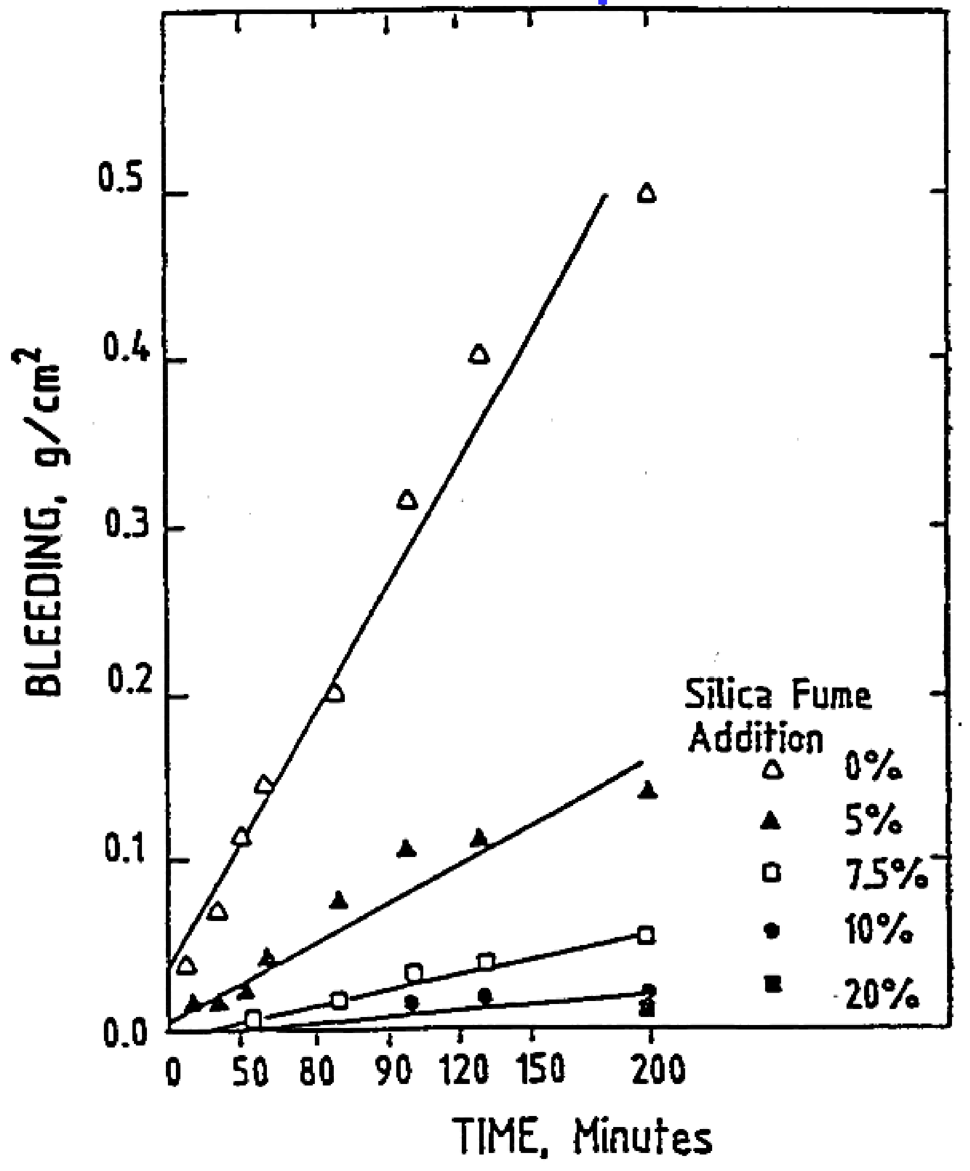
SILICA FUME:

Effect of Silica fume on Concrete Properties

2. Bleeding

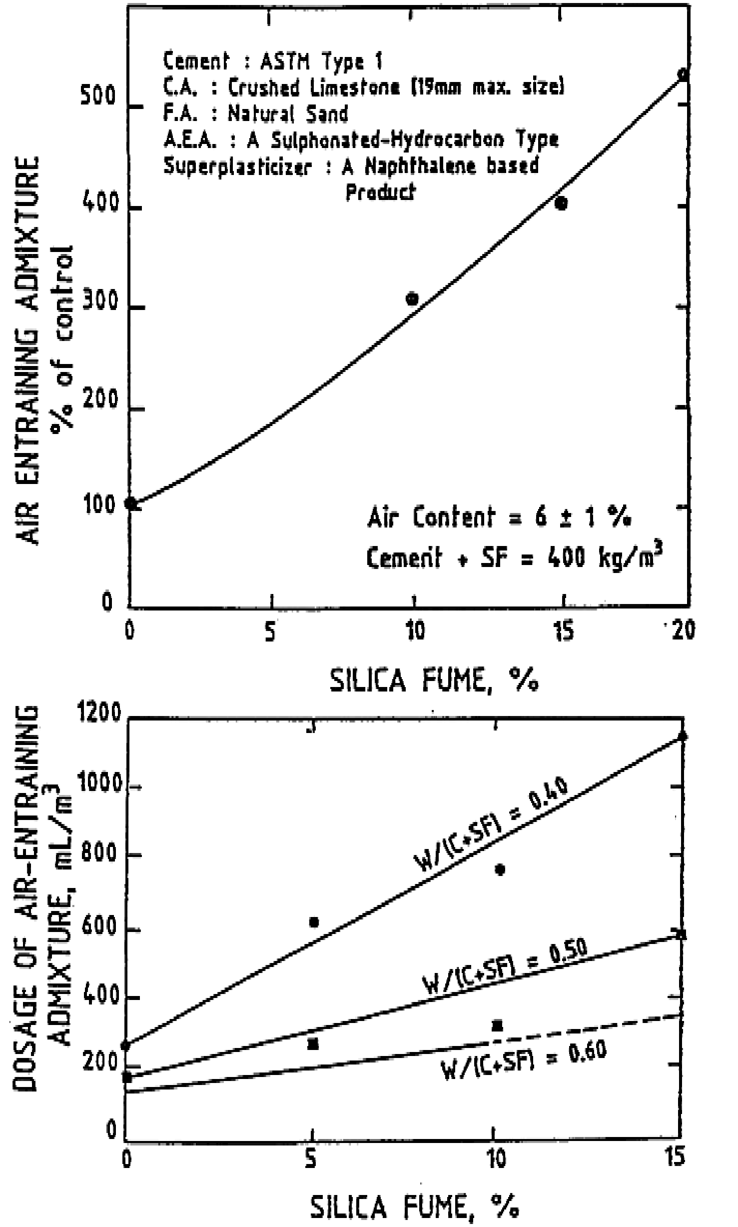
The extremely fine silica fume particles attach themselves to the cement particles, reducing the channels for bleeding

The following figure shows the significant reduction in bleeding with increasing silica fume content



SILICA FUME: Effect of Silica fume on Concrete Properties

3. **Dosage of air-entraining admixture** increases with increase in silica fume addition, as shown in the following figure:

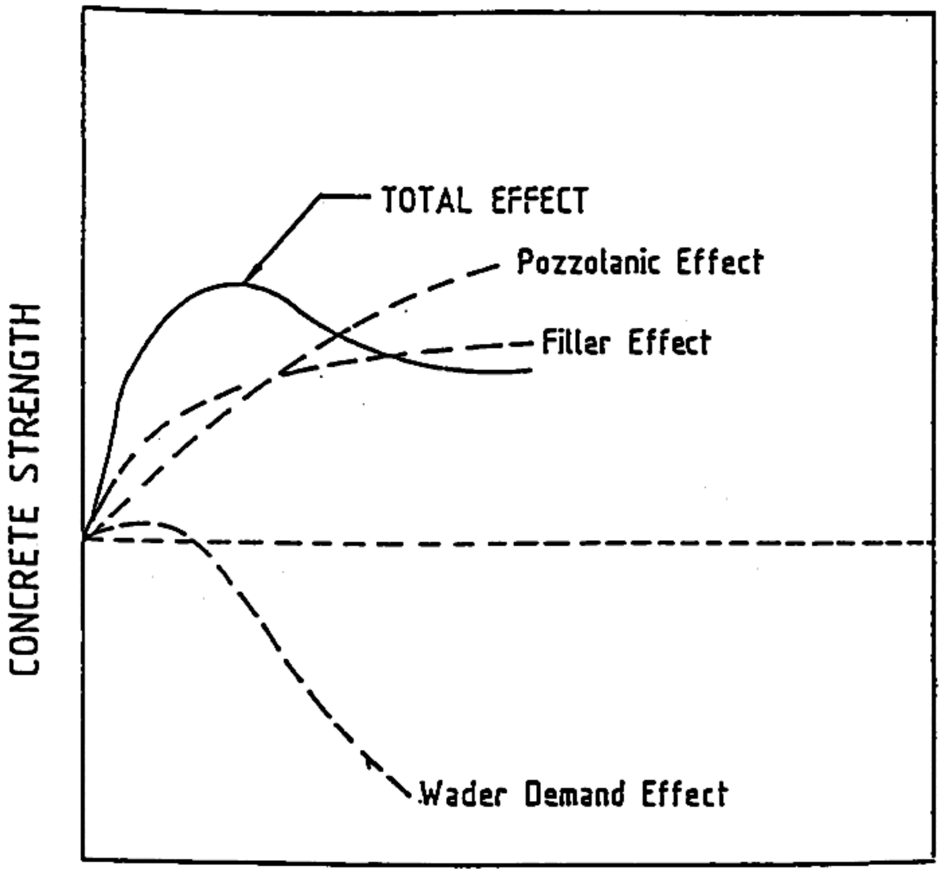


Effect of Silica Fume on Dosage of Air-Entraining Admixture

By: Dr. Shamshad Ahmad

SILICA FUME: Effect of Silica fume on Concrete Properties

4.Strength of concrete increases with increase in silica fume addition, as shown in the following figure:

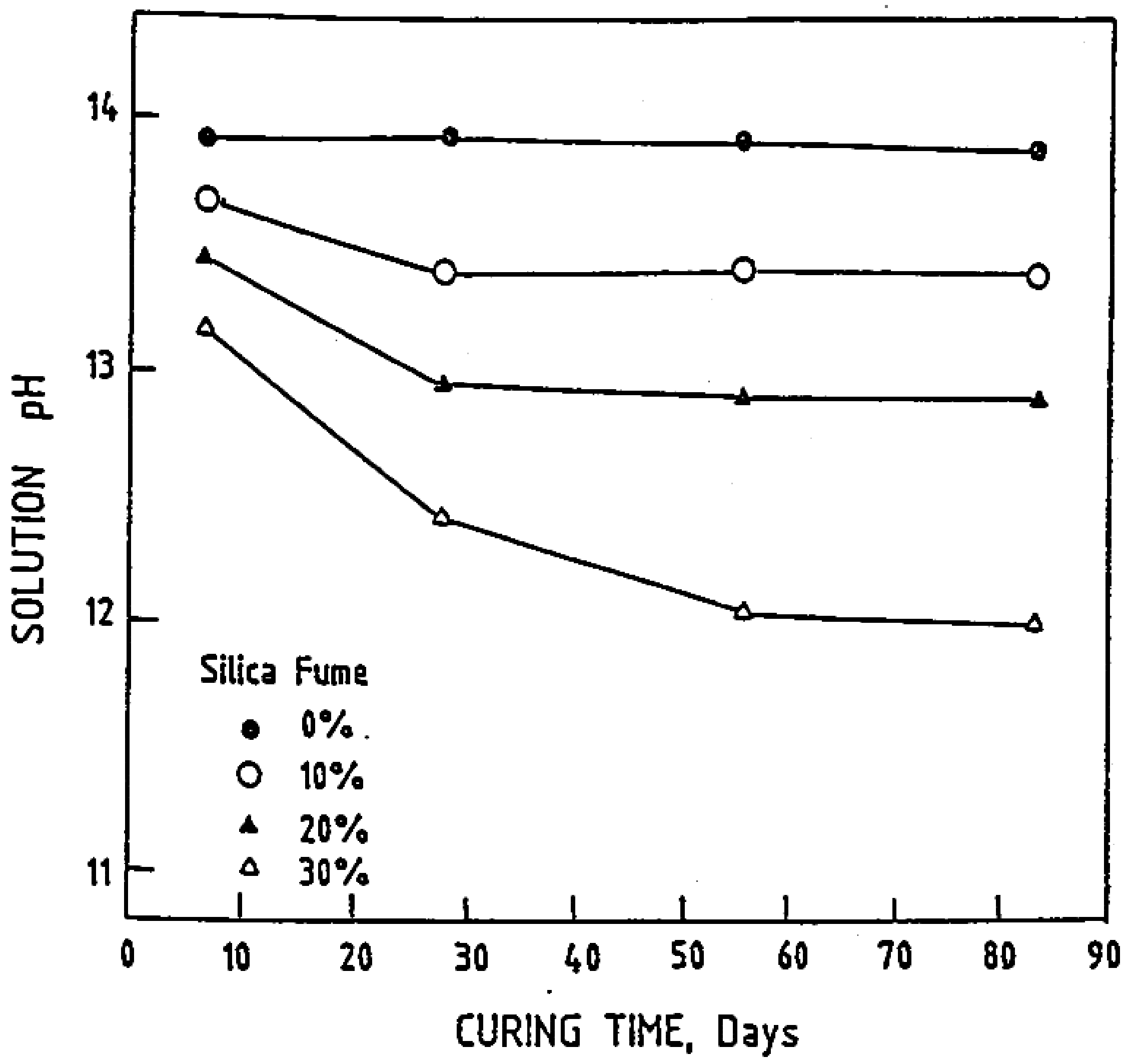


Effect of Silica Fume on Compressive Strength of Concrete

By: Dr. Shamshad Ahmad

SILICA FUME: Effect of Silica fume on Concrete Properties

5. **pH of pore solution in concrete decreases with increase in silica fume addition, as shown in the following figure:**

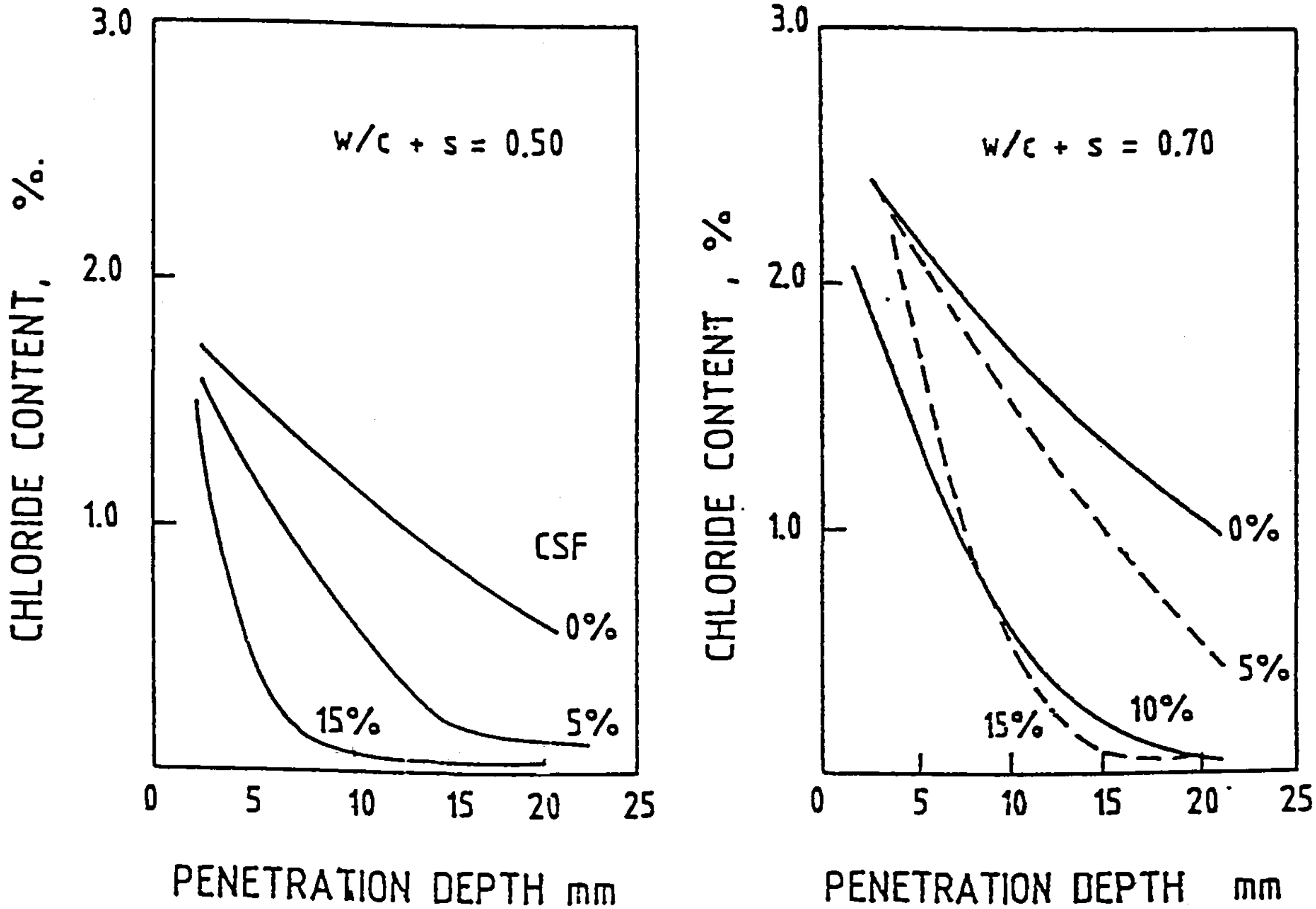


Effect of Silica Fume on the pH of Pore

By: Dr. Shamshad Ahmad

SILICA FUME: Effect of Silica fume on Concrete Properties

6. **Chloride penetration** in concrete decreases with increase in silica fume addition, as shown in the following figure:

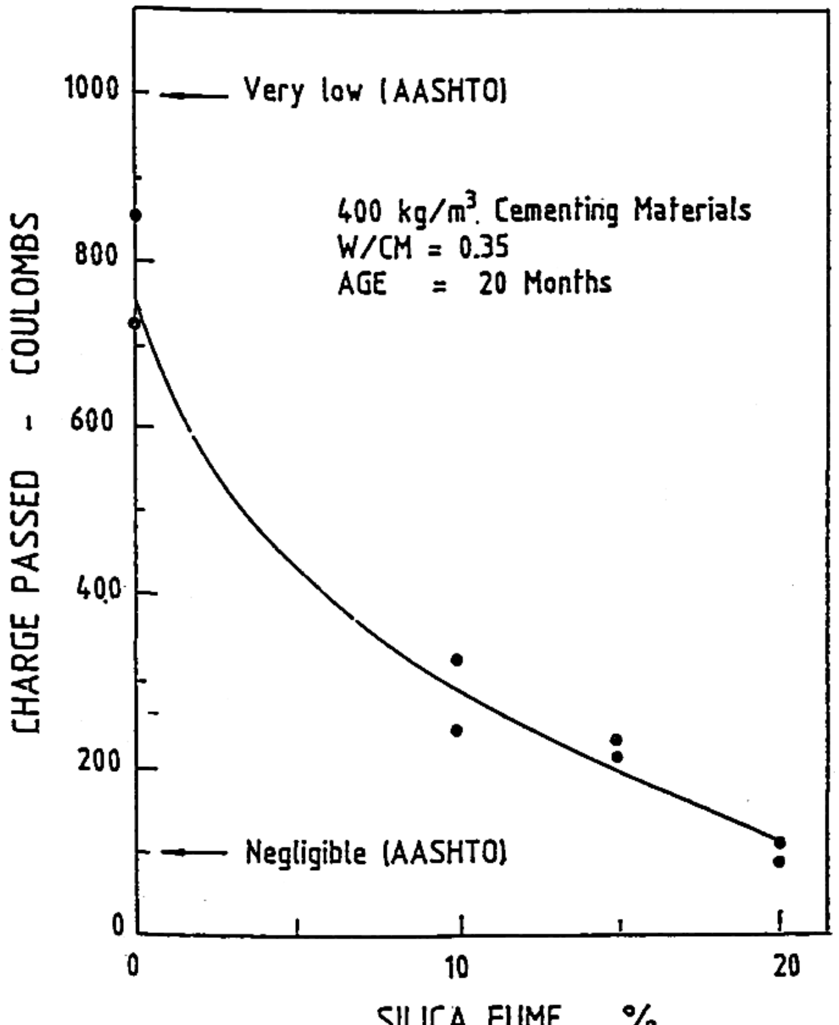


Chloride Penetration into Hardened Cement Paste
(Chloride Content in Percentage by Weight of Cement)

By: Dr. Shamshad Ahmad

SILICA FUME: Effect of Silica fume on Concrete Properties

7. **Chloride permeability** in concrete decreases with increase in silica fume addition, as shown in the following figure:



Effect of Silica Fume on Rapid Chloride Permeability (AASHTO T 277)