



## EFFECT OF SILICA FUME AND BENTONITE ON STRENGTH AND DURABILITY OF HIGH PERFORMANCE CONCRETE

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### Abstract

The project's work focuses on the strength of concrete and sulfate resistance to concrete, which is considered to be one of the major phenomena in the durability of concrete technology leading to deterioration. The main variable is the weight conversion of cement from silica fume replacing 10%, bentonite 20% and silica fume + bentonite 20%. In the presence of silica fume, the superplasticizer is also used to improve performance and make the concrete usable. A batch of concrete with a proper mix layout and a high strength of 6000 psi was prepared portion of the lot was tested for 28 days and a portion was repeatedly subjected to wetting and drying in a sulfate rich environment, 50 g / l Na<sub>2</sub>SO<sub>4</sub> solution. The quality of the concrete was evaluated using a 20 day ultrasonic pulse rate test, which showed a significant improvement in the resistance to sulfate attack by the cylinder produced by silica fume. Ordinary concrete cylinders were greatly affected when taking sulfate. The same concrete cylinder was tested for compressive strength with a universal tester and showed a surprising loss of strength of the normal concrete cylinder, while the silica fumed and bentonite concrete cylinders showed a slight loss of strength. The main conclusions from this project are that the use of silica fume improves the performance of concrete in a sulphate -rich environment, but strength cannot be changed as desired.

## **INTRODUCTION**

### **1.1 BACKGROUND**

The external sulfate attack is a chemical reaction that causes the sulphate-rich conditions to expand and decompose the concrete. Cracks occur on the surface of the material due to the differential expansion between the outer layer in which the reaction takes place and most of the material that remains largely intact. Assessing the laboratory's resistance of the concrete to sulphate attack is often difficult and usually requires a long time (Harbor 1982: Clifton et al., 1999), so great efforts have been made to develop a microstructure that can predict the concrete behavior of the sulfate attack. The external sulfate attack is a chemical reaction that causes the sulphate-rich conditions to expand and decompose the concrete. Cracks occur on the surface of the material due to the differential expansion between the outer layer in which the reaction takes place and most of the material that remains largely intact. Assessing the laboratory's resistance of the concrete to sulphate attack is often difficult and usually requires a long time (Harbor 1982: Clifton et al., 1999), so great efforts have been made to develop a microstructure that can predict the concrete behavior of the sulfate attack.

### **1.2 OBJECTIVES**

- I) developing a concrete mix with a maximum compressive strength of 6000 psi (in a dose of 1.5 to 2% super plasticizer)
- ii) Investigation of the effects of a 10% replacement of concrete weight by silica fume on the strength and durability of concrete sulphate attacks.
- iii) Investigate the effects of 20% of the concrete weight on the bentonite resistance and sulphate resistance of the concrete.
- iv) Investigate the effects of 20% concrete replacement on gassing with bentonite, silica and sulphate by weight.

## **2 CHAPTER NO.2**

### **LITERATURE REVIEW**

#### **2.1 INTRODUCTION TO HPC** **DEFINITION**

HPC is defined a concrete meeting special combination of performance and uniformity requirements that cannot be always achieved using conventional constituents and normal mixing placing and curing practices

## **2.2 HISTORICAL PERSPECTIVE:**

It is fair to say that the compressive strength of commercially produced concrete has increased from approximately 5,000 to 14,000 psi in the last 40 years. In the 1950s, the yield was so high that precast concrete with 5,000 psi was considered high strength. The story of True, the Washington State Department of Highway. Specified 6000 psi of concrete for pre stressed beams to allow members of the highway department in the country to lose weight. At the end of the 1980s, very high strength concrete was produced in other parts of North America. One of the most resistant concrete used to date in large commercial applications has been to achieve a compressive strength of 19,000 psi at 58-story Union Square in Seattle.

The compressive strength originally specified for the structure was 14,000 psi after 28 days. Tests have shown that a modulus of elasticity of this ladder required concrete with a desired compressive strength of the order of 19,000 psi. The Burj Khalifa skyscraper is the tallest building in the world with more than 150 floors and concrete with a specified compressive strength of 11,600 psi. Architecture,

## **2.3 PROPERTIES OF AGGREGATE IN HPC:**

Although common aggregates are used in the manufacture of Hpc in high strength concrete, the strength of coarse aggregate particles themselves can be crucial. As a result, the strength of the source rock is important, but the binding strength of the aggregate particles can also be a limiting factor. Good quality aggregates should be used to ensure a good bond between the coarse aggregate particles and the matrix. These particles should have approximately equal dimensions. Fine aggregates should be rounded and uniformly classified, but instead of being coarse, since the rich mixtures used in HPC have a high content of fine aggregates. Large aggregate particles are not desirable

## **2.4 HIGH PERFORMANCE CONCRETE COMPOSITION & FEATURES**

The composition of (HPC) is almost identical to that of conventional concrete concretes (CCC), because of the low proportion of cement in water, the presence of pozzolans and chemical additives, HPC generally presents many characteristics that distinguish them from the CCC. Practical considerations, in concrete structures, in addition to the final strength, the rate of development of resistance is also very important. High performance concrete usually contains pozzolanic and chemical additives. As a result, the

hydration rate of cement and the rate of development of HPC resistance are quite different from those of conventional cement (CCC).

The **proportioning (or mix design)** of normal strength concretes is based primarily on the w/c ratio 'law' first proposed by Abrams in 1918. For **high strength concretes**, however, all the components of the concrete mixture are pushed to their limits. Therefore, it is necessary to pay careful attention to all aspects of concrete production, i.e., **selection of materials, mix design, handling and placing**.

## **2.5 COMPOSITION OF HPC**

The most common **composition of high performance concrete** as supplementing cementations materials or **mineral admixtures** is:

1. Silica Fume
2. Fly Ash
3. GGBFS (Ground granulated blast furnace slag)

## **2.6 SILICA FUME IN HPC**

Silica smoke is a waste product in the production of silicon and silicon alloys. Silica vapor is available in a variety of forms, the most commonly used in a condensed form. In industrialized countries, it is already available mixed with cement.

It is possible to produce high-strength concrete without fumed silica with a compressive strength of up to 98 MPa. However, silicic acid vapor becomes essential beyond this level of strength. With silica fume it is easier to make HPC for thicknesses between 63 and 98 MPa.

## **2.7 FLY ASH IN HPC**

Fly ash, of course, has been used extensively in concrete for many years. Unfortunately, fly ash is much more variable in its physical and chemical properties than silicic acid fumes. Most flashes give strengths of not more than 70 MPa. Therefore, for higher strengths, silica fume must be used in conjunction with fly ash. For high strength concrete fly ash is used at dosage rates of 15% of the cement content.

## **2.8 GROUND GRANULATED BLAST FURNACE SLAG (GGBFS) IN HPC:**

Sags are good for use in HSC at dosage rates between 15-30 %. However, for high strengths, in excess of 98Mpa

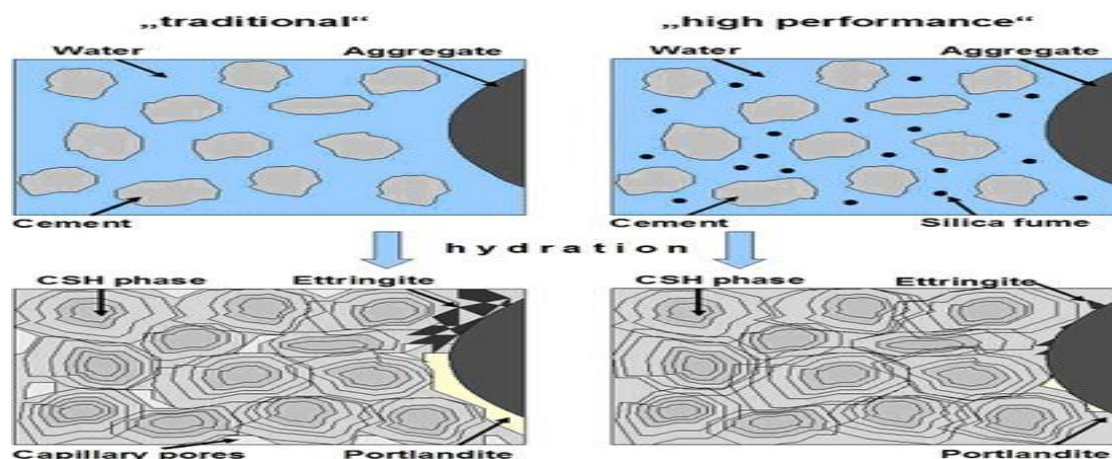


Figure 2.1 composition of HPC

## 2.9 ADVANTAGES OF HIGH PERFORMANCE CONCRETE (HPC)

The benefits of using high strength and high performance concrete often outweigh the increase in material costs. The following main advantages can be achieved.

1. Reduction of the size of the bar, which leads to an expansion of the base area / effective area and a direct saving of the volume of concrete saved.
2. Deadweight reduction and DL superimposed with associated savings through smaller foundations.
3. Reduction of the formwork area and costs while shortening the shoring and stripping time due to a high resistance gain at an early age.
4. Construction of high-rise buildings with associated savings in housing costs in metropolitan areas.
5. Longer spans and fewer beams with the same load.
6. Reduction of the axial shortening of the pressure support elements.
7. Reduction in the number of columns and support bases due to the increase in separation widths.
8. Reduce the thickness of floor panels and beam sections, which are an important component of the weight and cost of most constructions.
9. Superior long-term performance under static, dynamic and fatigue loads.
10. Low creep and shrinkage.
11. Higher stiffness due to a higher modulus  $E_c$ .
12. Increased resistance to freezing and thawing, chemical attack and significantly improves long-term stability and crack propagation.
13. Maintenance and repairs reduced.
14. Lower depreciation than fixed costs.

## **2.10 CURING OF HIGH PERFORMANCE CONCRETE**

High performance concrete has a very low water / cement ratio and better particle distribution due to the use of mineral additives, resulting in significantly fewer pores per unit volume of cementitious materials in the mix than the CCC. The filling of the holes with the hydration product in the HPC is much faster than that of the conventional concrete, because the smaller pores require fewer hydration products to fill. Therefore, moisture loss due to capillary action is stopped earlier in the case of HPC versus CCC under the same curing conditions. The moisture loss of HPC was mainly observed up to the first 24 hours. Due to the very low water / cement ratio and the use of superplasticizer, the hydration rate of early stage HPC is higher than that of conventional concrete, which leaves hydration potential in the longer term.

Therefore, it was found that the curing time after initial moisture protection had little effect on the long-term chlorine permeability of micro-silica's or HPC fly ash. All of this indicates that the cure time required for high performance computing is lower than for the CCC.

The duration of wet curing is important for the removal of HPC, which is not the case with conventional concrete. The curing method has a similar effect on HPC for concrete shrinkage and shrinkage, which are again influenced by the type and duration of curing. Hardening is the most complex part of building structures with HPC. For a given level of workability, HPC contains less water than conventional cement concrete, sometimes less than the minimum required for complete hydration and automatic drying. As a result, the early loss of concrete moisture has adverse effects on the durability and long-term properties of the concrete. Therefore, protection against moisture loss due to fresh HPC is crucial for the development of strength, the prevention of plastic shrinkage cracks and durability.

Again, the wet curing of the HPC cannot be done at an early stage, as this would increase the water / binder ratio adjacent the exposed surface, which would lead to a deterioration in concrete quality. One study found that moisture loss by HPC was highest within 24 hours of placement. HPC's fresh concrete mix is more cohesive and bleeding is much lower than CCC's. The rinse water evaporates quickly, making HPC more susceptible to plastic shrinkage cracks. The critical time to form plastic shrinkage cracks is around the initial setting time. Therefore, plastic shrinkage cracks under curing conditions characterized by high temperature, low humidity and high wind can be a very serious problem, accelerating the evaporation of water from fresh concrete. Therefore, to solve this problem, the curing process must start immediately after the introduction of the new HPC. Wet hardening, when applied immediately after the concrete is applied to control plastic shrinkage cracks as in the CCC, would also adversely affect the quality of the surface layer of the concrete. Hardened concrete. , If wet hardening is performed before the final setting of the concrete, the hardening water dilutes the cement paste near the surface, thereby increasing the W / C ratio. As a result, the strength and impermeability properties of

concrete are greatly impaired. Therefore, the HPC must be cured early without applying water directly to the exposed surface of the fresh concrete. This requires a complete cure of the HPC, which is divided into two stages. For this reason, hardening of HPC is generally done in two steps: primary curing and wet curing. Water is not used directly during initial drying. The start time of the two cure phases and their duration depend on the initial and final setting time of the concrete. It is difficult to establish a general maturation specification that applies to all weather conditions and all types of structural elements. The moisture loss of fresh HPC is dependent on ambient conditions, wind speed, temperature and humidity as well as the area / volume ( $s / v$ ) ratio. Structural geometry, reinforcement structure and design methods affect the initial hardening process.

## **2.11 SILICA FUME**

### **2.11.1 DEFINITION**

Silica fume is also called micro silica. It is a very small (small) pozzolanic material composed of amorphous silica produced by electric arc furnaces, such as the production of elemental silicon or ferrosilicon silica fume that can be used in various cementite products, such as concrete and mortar, as well as in the application of ceramic and rubber polymers.

### **2.11.2 WORKING OF SILICA FUME**

In cement compounds, the silicic acid vapor acts on two levels. The first is a chemical reaction called "pozzolan" reaction. Hydration (mixing with water) of Portland cement produces many compounds, including calcium silicate hydrates (CSH) and calcium hydroxide (CH). It is known that CSH gel is the source of resistance in concrete. When silica fume is added to the fresh concrete, it reacts chemically with the CH to produce additional HSC. This reaction has two advantages. Higher resistance to compression and chemicals. The bond between the concrete paste and the coarse aggregate in the critical interface area increases significantly, resulting in compressive strengths in excess of 15,000 psi. The additional CSH produced by fumed silica is more resistant to aggressive chemical attack than the weaker CH.

The second function exerted by fumed silica in cement compounds is a physical function. As silica fumes are 100 to 150 times smaller than cement particles, the voids created by the open water in the matrix can be filled. This characteristic, called particle packing, refines the microstructure of concrete and creates a much denser pore structure. The impermeability increases considerably because fumed silica reduces the amount and size of capillaries that would normally introduce contaminants into the concrete. Therefore, fumed silica is not only firmer, it lasts longer because it is more resistant to aggressive environments. As a filler and pozzolan, the double effect of silica fume on cement compounds is manifested throughout the hydration process.

### **2.11.2 CHARACTERISTICS OF SILICA FUME**

#### **PHYSICAL PROPERTIES**

Diameter is about 0.1 micron to 0.2 micron

Surface area about 30,000 m<sup>2</sup>/kg

Density varies from 150 to 700 kg/m<sup>3</sup>

When its density is about 550 kg/m<sup>3</sup> it is the best suited as concrete additive

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#### **CHEMICAL COMPOSITION**

- Contains more than 90 percent silicon dioxide
- Other constituents are carbon, Sulphur and oxides of aluminum, iron, calcium, magnesium, sodium and potassium
- Advantages of silica fume
- Silica fume improves the properties of fresh and hardened concrete
- Fresh concrete made with silica fume is more cohesive
- Silica fume reduces segregation and bleeding
- Silica fume improves the durability of concrete
- Lack of bleeding allows a more efficient finishing process

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#### **DURABILITY OF SILICA FUME CONCRETE**

##### **RESISTANCE TO CHEMICAL ATTACK**

1. Silica fume checks sulfate attack by:
    - a) Being very fine, it reduces permeability and the entry of sulfate ions.
    - b) By consuming the calcium hydroxide in course of pozzolanic action, it checks conversion of mono-sulfo aluminate into ettringite.
  2. Resistance against Acidic Environment
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- a) Silica fume reacts with lime present in paste matrix. Lime is considered as a dangerous compound, as it reacts with various chemicals causing expansion.
- b) Silica fume mortar has a better pore structure which vastly reduces permeability.
- c) Addition of silica fume as a partial replacement of cement reduces C3A content of the paste. C3A is seemed to react with acids causing expensive products.

## **2.12 SUPER PLASTICIZER**

Superplasticizers are also known as high performance water reducers used as admixtures. It improves the flow properties of the suspension, for example in concrete applications. Their addition to concrete or mortar allows for a reduction in the proportion of water cement, which does not affect the functioning of the mixture, and allows the production of concrete and self-consolidating high-performance concrete. This effect significantly improves the performance of the freshly ground paste.

## **2.13 USE OF SUPER PLASTICIZER**

The use of superplasticizers becomes essential to design blends to achieve HPC. As you can see, the relationship w / binder has an important relationship for achieving resistance parameters. To achieve dense concrete with reduced permeability, plasticizers of the following types are commonly used: i) condensates of sulfonated melamine formaldehyde (SMF)

- i) Sulfonated formaldehyde naphthalene condensate (SNF)
- ii) Polycarboxylate Ether Superplasticizer (PCE) of the above types, the newest superplasticizer and most effective when based on SNF.
- iii) ASTM has also recommended the use of this type to achieve optimum benefits such as good processibility and minimum weight to binder ratio. About 2% by weight of the cementitious materials are normally used to achieve the required workability.

## **2.4 Bentonite**

Bentonite is a kind of clay, usually refined from volcanic ash. Its high absorbency makes it a useful substance for industrial applications. Although you can buy bentonite in the form of wet clay or gel-like substance, the most common, cheapest and most versatile form is powder. In concrete construction Sodium bentonite, a clay material, has gained popularity in recent years. The panel form is the choice of a growing number of architect and building. By collecting water, the clay becomes 15 times its initial volume and sinks into cracks and cavities. When it reaches its maximum volume, it remains permanently in these areas to protect itself from the water. The plate of a corrugated cardboard with a length of 4 x 4 feet, where the clay particles in the waves of the cardboard are retained. The panels can be nailed, fixed with a powder tool or simply suspended for horizontal applications.

Some water repellents are concerned about the use of bentonite panels. With other products, you can inspect the finished waterproofing application and verify seal integrity before filling. With the bentonite panels, the joint is not formed until the base fills and the water reaches the panel. Suppose something goes wrong? This is an annoying question for "traditional" waterproofing.

However, bentonite has advantages: it is safe for work, non-polluting, easy to apply and fast, and can continue even at low temperatures. A company manufactures a sheet membrane that uses a bentonite compound and butyl rubber.

## **2.14 SULFATE ATTACK IN CONCRETE**

Sulphate attack is a mechanism of chemical degradation in which sulphate ions attack the components of the cement paste. Water-soluble sulfated compounds, such as alkaline earth (calcium, magnesium) and alkali (sodium, potassium) sulphates, which can react chemically with the constituents of the concrete, are responsible for the sulphate-attacking compounds. Sulphate attack can take different forms. The chemical form of sulfate Atmospheric environment to which concrete is exposed

## **2.15 WHAT HAPPENS WHEN SULFATES GET INTO CONCRETE?**

When sulphate enter in to the concrete it makes ettringites.

### **2.15.1 EXTERNAL SOURCES:**

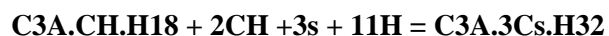
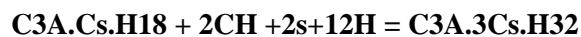
External sources of sulphates are more common and are usually the result of soils and sulphate-rich groundwater, or may be the result of atmospheric or industrial water pollution. The soil can contain excessive amounts of gypsum or other sulfates. Groundwater can be transported to concrete foundations, retaining walls and other underground structures.

## **INDUSTRIAL WASTE WATER**

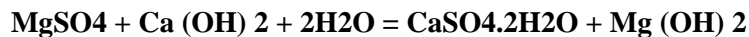
**Nature of reaction: (chemical, Physical) Sulfate attack** processes decrease the durability of concrete by changing the chemical nature of the cement paste, and of the mechanical properties of the concrete

## **CHEMICAL PROCESSES**

The sulfate ion + hydrated calcium aluminates and/or the calcium hydroxide components of hardened cement paste + water = ettringite (calcium sulpho aluminate hydrate)



The sulfate ion + hydrated calcium aluminates and/or the calcium hydroxide components of hardened cement paste + water = gypsum (calcium sulfate hydrate)



Two forms of Chemical reaction depending on

Concentration and source of sulfate ions .Diagnosis

Composition of cement paste in concrete.

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### **PHYSICAL PROCESS:**

The complex physico-chemical processes of "sulfate attack" are interdependent as is the resulting damage.

Physical sulfate attack, often evidenced by bloom (the presence of sodium sulfates  $\text{Na}_2\text{SO}_4$  and/or  $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ ) at exposed concrete surfaces.

It is not only a cosmetic problem, but it is the visible displaying of possible chemical and micro structural problems within the concrete matrix.

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**Both chemical and physical phenomena observed as sulfate attack, and their separation is inappropriate.**

## **3 DISCUSSIONS AND CONCLUSIONS**

In this article, we examine the effect of silica fume, bentonite and superplasticizer on concrete strength and durability. We use 12% fumed silica as a substitute for cement and 3% superplasticizer. We made 22 cylinders for normal concrete, 18 cylinders with silica fume, bentonite and fumed silica + bentonite for 7, 14, 28, 56 and 91 days, respectively, and we verified the resistance to pressure and the influence of silica fume. The results obtained are given above.

After carrying out the 20-day sulfate resistance test, the reduction in resistance was tested. The cylinders were sealed in Plaster of Paris and tested in Universal Testing Machine. When the results were compared with those obtained in the rebound hammer test, it was clearly shown that the concrete cylinders containing silica vapor showed a greater resistance to deterioration induced by sulphate attack, while the

concrete cylinders used lots were prepared showing a large reduction in resistance after exposure to the sulfate environment.

The quality of the concrete in terms of uniformity, frequency or absence of internal failures, cracks and segregation, etc., showing the level of work used, can be assessed using the recommendations presented below, developed to characterize quality. Concrete in structures in terms of ultrasonic pulse velocity. Finally, we found the following: silica fume, bentonite and superplasticizers can be used to prepare high performance concrete. The Super plasticizer is also used to achieve high strength and make the concrete more sustainable in silica fume locations. High compression is usually the first property associated with silica fume. The relationship between tensile strengths, flexibility and compression in silica fumes is determined in the same way as concrete strength. Tensile strength and flexibility strength is the result of increasing compressive strength by using silica fume. This plays an important role when silica fume concrete is used in bridge, floor and road projects.

After the 20 day sulfate resistance test was carried out, resistance testing was reduced. The cylinders were sealed in Paris plates and tested in a universal test machine. When the results were compared to the results obtained in the rebound test, it was clearly demonstrated that concrete cylinders containing silica vapor are more resistant to deterioration that stimulates sulfate attack, and batch bottles of concrete. They have been prepared to significantly reduce resistance after exposure to sulphate.

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