CHAPTER – 2

LITERATURE REVIEW

2.1. INTRODUCTION

In the cement industry the use of pozzolanic materials is attaining paramount importance due to their beneficial effect on various properties of the cement. In this context, by using the pozzolana material in the cement, the cement production companies are releasing different cements, under various brands, such as Portland Pozzolana Cement (Fly ash based (IS 1489 Part I)), Portland Pozzolana Cement (calcinated clay based(IS 1489 Part II)) etc.

The researchers/scientists in Civil Engineering are also looking to develop the strength of the cement and concrete to higher side when compared to available cements. In these situations, the research is focused on the use of pozzolana materials in the existing cements. In the present investigation, the available Portland pozzolana cement (fly ash based) available in the market and silica fume blended with PPC were used for experimental work. In this connection, a brief review has been presented about the above cited cements in the following sub sections.

2.2. BLENDED CEMENTS

Evidence of the first blended cements dates back to Roman times, when volcanic ash was used in a crude blend with slaked lime to give the user a product that developed higher early strength than the usual slaked lime as well as significant durability. Evidence of this can be seen in the Aqueducts and the Colosseum in Rome. The area in Italy where the volcanic ash was discovered is called Pozzuola, hence the term for a reactive substance being called a pozzolan. Some academics have assumed that the Roman Empire discovered the process of cement manufacturing, which was lost with the decline of this empire and rediscovered in the nineteenth century in Britain. In truth, it is more likely that the lime the Romans calcined (burnt) for the purpose of slaking approached an argillaceous lime in chemical composition
and hence had to be milled rather than naturally slaked. When mixed in the normal manner with water, this product showed large early strengths and was probably the first cement made.

A mixture of Portland cement and other material such as granulated blast-furnace slag, pozzolan, hydrated lime, etc., combined either during or after the finish grinding of the cement at the mill. ACI 116, Cement and Concrete Terminology1, defines blended cements as hydraulic cements "consisting essentially of an intimate and uniform blend" of a number of different constituent materials. They are produced by "intergrinding portland cement clinker with the other materials or by blending Portland cement with the other materials or a combination of intergrinding and blending."

Concrete can be produced with blended cement containing slag plus other cementitious materials (most commonly fly ash or silica fume) added at the batch plant. These are considered ternary systems. Ternary systems can be designed to attain performance characteristics that may be difficult to achieve in a binary system.

There are a number of systems that are used to make blended cements. Some systems are capable of "on-demand" blending, while others may blend the materials in a fixed percentage into a storage silo. All of the systems meter the constituent products in the desired proportions, and then blend them to a uniform mixture. In most cases proportions can be adjusted to produce blends that optimize the desired properties in concrete.

### 2.2.1 Fly-ash based PPC

Fly ash is the ash precipitated electro-statically from the exhaust fumes of coal fired power station. In India nearly 70 million tons of fly ash is being produced every year while a very small quantity is used in manufacturing of cement. It is an eco-friendly product. The fly ash particles are spherical and are generally of higher fineness than cement so that the silica is readily available for reaction. As per IS 3812: 1981, the percentage of silica and alumina should be minimum 70% and maximum loss on ignition 12%. Much superior quality fly ash is available from thermal power plants than specified in IS code.
For every ton of cement that is produced approximately four hundred and forty kilograms of carbon dioxide is emitted, this results from the conversion of calcium carbonate to calcium oxide. The use of fly ash or slag results in a net reduction of the amount of cement used and a corresponding reduction in the amount of carbon dioxide emitted. The consistent requirement of the ash distributor to maintain the level of carbon in ash to below five percent will ensure that the ash producer achieves increased burning efficiency and results in increased life of ash dams.

In the past the major benefit has always been that the net cost of the cement has been reduced and this has always been the argument for the use of pozzolans. The ratification and adoption of the Kyoto protocol with regard to carbon dioxide emissions has made the use of pozzolans a requirement and in some countries the use of pozzolans is legislated for environmental protection and structural longevity. The demand for pozzolan is steadily increasing worldwide and is being viewed as a resource rather than as a waste material.

Though blended cement with fly ash is ideally suitable under aggressive condition, it is necessary that quality of fly ash is properly evaluated, as quality of Fly ash available at most of the places is doubtful. Use of inferior quality of Fly ash with cement, may affect corrosion resistant properties adversely. Thus, it is necessary that quality of Fly ash is evaluated by reputed laboratory. It should be tested for chlorides, sulphate, alkalinity and heat of hydration as per IS : 3812. The quality of fly ash to be blended with cement and the concrete made out of it should be approved for corrosion resistant properties by reputed organization like Central Electrochemical Research Institute (CECRI), Central Building Research Institute (CBRI), Central Road Research Institute (CRRI) etc.

Fly-ash based PPC is made by intergrinding high strength clinker with specially processed fly ash. This imparts a greater degree of fineness to Fly-ash based PPC cement, improved workability properties while mixing, and makes concrete more corrosion resistant and impermeable. All of this makes for better long term strength
and improved corrosion resistance and therefore, greater life for constructions. Fly-ash based PPC is eco-friendly cement.

Fly-ash based PPC easily replaces OPC and provides additional advantages for practically all types of construction applications - commercial, residential, bungalows, complexes, foundation, columns, beams, slabs and RCC jobs. It is especially recommended for mass concreting work, and where soil conditions and the prevailing environment take heavy toll of constructions made with ordinary cements.

Due to its inherent characteristics, Fly-ash based PPC makes very corrosion resistant concrete that is superior to concrete made with OPC. It is more impermeable to oxygen, CO₂, chlorides, etc. Leaching of alkalis is reduced and the alkaline environment around steel is maintained.

The blended cements are manufactured by adding pozzolanic or cementitious materials like fly ash or ground granulated blast furnace slag (GGBFS) or condensed silica fumes (CSF) to Portland cement clinker and Gypsum. Alternatively, these pozzolanic and cementitious materials can be introduced into Portland cement concrete during concrete making operations.

2.2.2. Advantages of concrete made from blended cement

Blended cements can be produced to provide the benefits in performance that are also available when slag cement is used as a separate component of the concrete mix. By varying the proportions of the blend, attributes such as sulfate resistance and resistance to alkali silica reaction can be attained with blended cement. A blend designed for a specific project requirement can also be produced. For concrete producers, blended cement may allow them to take advantage of the benefits of slag cement despite storage constraints.
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2.2.3. Strength development

The 28 days and later compressive strengths are same as for OPC. However, the rate of gain of strength up to 7 days is slower, due to heat of hydration being low. The drop in early strength should not be considered as sign of poor quality as this is often accompanied by enhancement of other properties.

2.2.4. Curing

Curing is a very important stage in the life of a conventional concrete, it becomes a critical factor in concrete containing blended cement. A good curing method is essential, because blended cement hydrates slower than OPC. It is potentially more vulnerable to drying conditions, thus the wet curing requirements, which is the most neglected activity in the fields, is very important. The curing method and period must be specified.

2.2.5. Bleeding

The Pulverised Fuel Ash (PFA), Ground Granulated Blast Furnace Slag (GGBFS), Silica fumes being finer than OPC, less bleeding is observed. The freshly placed concrete is very stable, being very cohesive and having strong internal cohesion. This has a negative effect in the form of plastic shrinkage.

2.2.6. Workability
The workability increases, and thus water content can be reduced by about 3%. The ‘ball bearing’ action of cementitious particles improves the workability. Silica fumes demand high water due to higher fineness. The problem is circumvented by the addition of suitable super plasticizers.

The engineering benefits likely to be derived from the use of mineral admixtures (blended cements and cement + mineral admixtures can be used interchangingly) in concrete are improved resistance to thermal cracking because of lower heat of hydration, enhancement of ultimate strength, reduction in permeability due to pore refinement, and a better durability to chemical attacks such as chloride, sulphate water, soil and alkali-aggregate expansion.

2.2.7. Temperature rise

In large concrete pours like bridges, foundations and water retaining structures, it is vital to minimize the rise of early age thermal cracking by controlling the temperature rise caused by hydration. One method of doing this is by use of concrete containing blended cements.

2.2.8. Chloride resistance

Blended cement concretes have a higher resistance to the penetration of chlorides. The diffusivity is substantially reduced in case of blended cement. This is due to two mechanisms. Firstly, the incorporation of slag reduces the permeability of the concrete and secondly the hardened paste of slag cement bind greater amounts of chlorides than that of OPC, resulting in much lower portion of free chlorides in the pore solution.

2.2.9. Protection to steel corrosion

The blended cement concrete is more resistant to Chloride penetration and thus provides protection in coastal areas against corrosion many more times than OPC concrete.
2.2.10. Sulphate resistance

Blended cement with slag content more than 50%, exhibits better sulphate resisting properties. Depending upon the severity of the exposure to sulphate, limitations are placed on C₃A content in cement.

2.2.11. Alkali-silica reaction

Blended cement with high slag is a safe cement system for the use with reactive aggregate.

2.3. SILICA FUME

The American Concrete Institute (ACI) defines silica fume as very fine non-crystalline silica produced in electric and arc furnaces as a byproduct of the production of elemental silicon or alloys containing silicon (ACI 116R). It is usually a gray coloured powder somewhat similar to Portland cement or some fly ashes.

The high amount of silica present, the super fineness, the high specific surface area upto 20000 m²/kg are the main characters of silica fume which impart high strength to concrete with enhanced qualities when mixed as a partial replacement to cement thus achieving economy.

Silica fume is thus found a place to be in the group of pozzolanic admixtures and made a way for the research community to develop high strength concretes of the order up to M50 or more.

2.3.1. Physical Properties

A typical silica fume exhibits most particles smaller than 0.5 microns in diameter with particles ranging in size from 0.001 to 0.3 microns with an average diameter of 0.10 microns. Silica fume is generally 50 to 100 times smaller than the
average cement. The particles surface area range from 17000 m$^2$/kg to 2500 m$^2$/kg although 20000m$^2$/kg seems to be the most common for the commercial silica fume in concrete. The specific gravity of silica fume ranges between 2.2 – 2.5 which is less than that of Portland cement.

2.3.2. Specific surface

Specific surface is the total surface area of a given mass of a material because the particles of silica fume are very small, the surface area is very large we know that water demand increases for sand as the particles become smaller, the same happens for silica fume. A specialized test called the bet method or nitrogen adsorption method must be used to measure the specific surface of silica fume.

2.3.3. Physical contribution

Adding silica fume bring millions of millions of very small particles to a concrete mixture. Just like fine aggregate fills in the space between coarse aggregate particles, silica fume fill in the space between cement grains.

2.3.4. Chemical contributions

Because of its very high amorphous silicon dioxide content, silica fume is very reactive pozzolanic material in concrete. As the Portland cement begins to react chemically, it releases calcium hydroxide. The silica fume reacts with this calcium hydroxide to form additional binder material called calcium silica hydrate, which is very similar to the calcium silicate hydrate formed from the Portland cement. It is largely this additional binder that gives silica-fume concrete it’s improved harden properties.

2.3.5. Chemical and Mineral Composition

The high silica content makes it an efficient pozzolana which can react with ordinary Portland cement to create secondary cementing material in hydrating
concrete. Silica fume acts in two major ways in concrete as a pozzolana and as a filler material.

First due to its high pozzolanicity, it contributes to the following hydration reaction between ordinary Portland cement and water by reacting with the calcium hydroxide to produce additional gel.

\[
\text{OPC + Water } \rightarrow \text{ CSH gel + Calcium Hydroxide}
\]

\[
\text{CSF + Calcium Hydroxide + Water } \rightarrow \text{ CSH Gel}
\]

Calcium silicate hydrate gel is the glue that binds the aggregates together and gives concrete its strength. Second, due to their extreme fineness, the Condensed Silica Fume (CSF) particles as a filler, reduce the porosity resulting indelible concrete with less permeability

\section*{2.3.6. Application of Silica Fume}

The quest for developing high strength and ultra high strength concretes and also the special purpose concretes with certain special characteristics for use under special circumstances is increasing from time to time. The usual ultimate utility / strength / durability parameter of normal cement concrete needs certain modifications. The special characteristics of silica fume viz., super fineness, high silica content gave the scope for enhancing the normal cement concrete when mixed with cement as a partial replacement. The excessive cohesiveness and excellent sulphate resistance of silica fume mixed concrete as of greater importance in shotcrete applications Silica fume is generally more efficient in concrete having higher W/C ratios.

Because of very high silica content and super fineness its reactivity is more. As a result it contributes to strength improvement. Ultra high strength concrete of the order of 70 to 120 N/mm² is now possible for field placeable concrete with silica fume admixture. Such high strength concrete has increased modulus of elasticity, lower creep and drying shrinkage.
2.4. WATER AND ITS QUALITY

Water from ground, lakes and rivers contains chlorides, sulphates and bicarbonates of calcium and magnesium. Higher concentrations of these affect the formation of strength causing hydrated compounds during hydration. Pure water from condensation of fog or water vapour, and soft water from rain or from melting of snow and ice, may contain little or no calcium ions. When these waters come in contact with Portland cement paste, they tend to hydrolyze or dissolve the calcium-containing products. Once the contact solution attains chemical equilibrium, further hydrolysis of the cement paste would stop. However, in the case of flowing water (natural or treated polluted water from industries) or seepage under pressure, dilution of the contact solution will take place, thus providing the condition for continuous hydrolysis. In hydrated Portland cement pastes, calcium hydroxide is the constituent, which because of its relatively high solubility in pure water (1230 mg/l), is most susceptible to hydrolysis. Theoretically, the hydrolysis of the cement paste continues until most of the calcium hydroxide has been leached away, this exposes the other cementitious constituents to chemical decomposition. Eventually, the process leaves behind silica and alumina gels with little or no strength. Biczok, (1967) showed in his results from two investigations, the strength loss from Portland cement pastes by leaching of lime.

Besides loss of strength, leaching of calcium hydroxide from concrete may be considered undesirable for aesthetic reasons. Frequently, the leachate interacts with CO₂ present in air and results in the precipitation of white crusts of calcium carbonate on the surface. This phenomenon is known as efflorescence.

2.4.1 Quality of mixing water

Impurities in water may interfere with the setting of the cement, may adversely affect the strength of the concrete or cause staining of its surface, and may also lead to corrosion of the reinforcement. For these reasons, the suitability of water for mixing and curing purposes should be considered. Clear distinction must be made between the effects of mixing water and
the attack on hardened concrete by aggressive waters. Some of the latter type of water may be
harmless or even beneficial when used in mixing (Steinour, 1960).

In many specifications, the quality of water is covered by a clause saying that water
should be fit for drinking. Such water very rarely contains dissolved solids in excess of 2000
ppm, and as a rule less than 1000 ppm. For a water/cement ratio of 0.5, the latter content
corresponds to a quantity of solids representing 0.05 percent of the weight of cement, and any
effect of the common solids would be small. There is, however, one situation when drinking
water is unsuitable as mixing water; this is when there is a danger of alkali aggregate reaction
and the water has a high concentration of sodium or potassium.

While the use of potable water is generally safe, water not fit for drinking may often
also be satisfactorily used in making concrete. As a rule, water with pH of 6.0 to 8.0 (Mc Coy,
1978), which does not taste saline or brackish is suitable for use, but dark colour or bad smell
do not necessarily mean that deleterious substances are present (Mc Coy, 1956). A simple
way of determining the suitability of such water is to compare the setting time of cement and
the strength of mortar cubes using the water in question with the corresponding results
obtained using known “good” water or distilled water, there is no appreciable difference
between the behaviour of distilled and ordinary drinking water. A tolerance of about 10
percent is usually permitted to allow for the chance variations in strength (Steinour, 1960); an
appendix to BS 3148-1980 also suggests 10 percent. Such tests are recommended when water
for which no service record is available contains dissolved solids in excess of 2000 ppm or, in
the case of alkali carbonate or bicarbonate, in excess of 1000 ppm. When unusual solids are
present a test is also advisable.

Since it is undesirable to introduce large quantities of silt into the concrete, mixing
water with a high content of suspended solids should be allowed to stand in a settling basin
before use; a turbidity limit of 2000 ppm has been suggested (U.S. Bureau of Reclamation,
1975). However, water used to wash our truck mixers is satisfactory as mixing water,
provided of course, that it was satisfactory to begin with. ASTM Standard C 94-78a allows the use of wash water. Clearly, different cements and different admixtures should not be involved.

Brackish water contains chlorides and sulphates. When chloride does not exceed 500 ppm, or SO$_3$ does not exceed 1000 ppm, the water is harmless, but water with even higher salt contents has been used satisfactorily (Building Research Station, London, 1956). The appendix to BS 3148-1980 recommends limits on chloride and on SO$_3$ as above, and also recommends that alkali carbonates and bicarbonates should not exceed 1000 ppm. Somewhat less severe limitations are recommended in American literature (Mc Coy, 1956).

Sea water has a total salinity of about 3.5 percent (78% of the dissolved solids being NaCl and 15% MgCl$_2$ and MgSO$_4$), and produces a slightly higher early strength but a lower long-term strength; the loss of strength is usually not more than 15% (Abrams, 1924) and can therefore often be tolerated. Some tests suggest the sea water slightly accelerates the setting time of cement, others (Thomas and Lisk, 1970), a substantial reduction in the initial setting time but not necessarily in the final set. Generally the effects on setting are unimportant if water is acceptable from strength consideration.

Water containing large quantities of chlorides (e.g., sea water) tends to cause persistent dampness and surface efflorescence. Such water should, therefore, not be used where appearance of the concrete is important, or where a plaster-finish is to be applied (Lea, 1956 & Anderson, et al., 1985).

When reinforced concrete is permanently under water, either sea or fresh, the use of sea water in mixing seems to have no defects (Shalon and Raphael, 1959). However, in practice it is generally considered inadvisable to use sea water for mixing unless this is unavoidable (Lea, 1956).

Sand dried out in sea water may contain a large amount of salt, but if sand dredged from the sea is washed in sea water and is allowed to drain, and fresh water is used as mixing
water, then the salt content represents no more than 1 percent of the total weight of water (National Sand and gravel Association, 1959 & Cohen and Mather, 1991). The British code of Practice for the Structural Use of Concrete CP 110: 1972 specifies the maximum total chloride ion content (as a percentage weight of cement) arising from all sources including aggregate is as follows: 0.1 for prestressed concrete made with sulphate resisting or super sulphate cement and 0.35 for all other concrete containing metal. American Concrete Institute suggests the following limit to the total (i.e. from all sources) soluble chloride ion concentration as a percentage of weight of cement to 0.06 for prestressed concrete, and 0.10 to 0.15 for other concretes. Only concrete that will be permanently dry is exempt from this limitation. In view of the above rules, it is necessary to determine the chloride content even of those admixtures in which calcium chloride is only a minor component.

Natural waters that are slightly acidic are harmless, but water containing humic or other organic acids may adversely affect the hardening of concrete; such water, as well as highly alkaline water, should be tested. The effects of different ions vary, as shown by Steinour (1960).

All cements containing lime are susceptible by acids. In acidic solutions, where the pH is less than 3.5, erosion of the cement matrix will occur. Moorland waters with low hardness, containing dissolved carbon dioxide and with pH values in the range of 4-7 may be aggressive to concrete. The pure water of melting ice and condensation contain carbon dioxide and will dissolve calcium hydroxide in cement causing erosion. In these situations the quality of concrete assumes a greater importance. (John Newman and Ban sang Choo, 2003)

Iron or organic matter may cause staining, particularly if water flows slowly over concrete and evaporates rapidly (U.S. Army Corps of Engineers, 1954).

Thus, the role of chemical impurities of the industrial effluents is very deleterious even in hydrolysis. Hence the need to study the role of chemical impurities in the mixing water on hydration of cement and thus on the properties of concrete is more pronounced now.
The water during the preparation of concrete usually comes from two sources, namely added water and moisture in the aggregates. Most specifications on quality of water for use in concrete concentrate on the added water, even though the moisture contained in the aggregates (sand and gravel) can be anything from 10 to 20 percent of the total water used for mixing. However, its quality is usually ignored with the expectation that added potable water would dilute any contaminant.

Natural water contains dissolved and suspended substances of organic and mineral origin. These enter with atmospheric precipitation and from soils with which water comes into contact in underground streams or in surface water bodies (rivers, lakes etc.). Moreover, water is polluted with the metabolites of aquatic plants and animals and the products of their decay. Contamination of industrial effluents to both surface and underground waters would also occur at localized situations.

The substances contained in natural waters can be divided into the following groups.

a) Suspended substances.

b) Colloids, molecular and ion-dispersed substances.

Suspended and colloidal substances are generally absent in ground water. The presence of these substances in surface waters can be removed by conventional water treatment systems. The molecular substances present in water include Sodium (Na⁺), Potassium (K⁺), Calcium (Ca⁺⁺) and Magnesium (Mg⁺⁺) as cations and Chloride (Cl), Sulphate (SO₄⁻), Bicarbonate (HCO₃⁻) and Carbonate (CO₃⁻⁻) as anions. All these are inorganic substances are in highly dissolved state. These can’t be removed by ordinary conventional water treatment systems.

The presence of dissolved inorganic substances in ground waters is mostly through mineral origin and would be expected in varied concentrations geographically. Literature on the quality of different waters indicates that the water may contain salts of Sodium,
Potassium, Calcium and Magnesium. The Tab. 2.1 lists out the range of these substances in mg/l present in different waters (James, 1988).

In view of the fact that the natural water changes both in physical and chemical characteristics, there is need to assess the effect of quality of water on setting times, soundness and strength development of concrete structures.

Table 2.1 List of inorganic substances (mg/l) present in different waters.

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Salt water</th>
<th>Sea water</th>
<th>Rain Water</th>
<th>River water</th>
<th>Ground water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cl</td>
<td>18980</td>
<td>2.1</td>
<td>8.7</td>
<td>605.0</td>
</tr>
<tr>
<td>2</td>
<td>Na</td>
<td>10560</td>
<td>1.2</td>
<td>9.3</td>
<td>857.0</td>
</tr>
<tr>
<td>3</td>
<td>Mg</td>
<td>1270</td>
<td>0.1</td>
<td>5.6</td>
<td>194.0</td>
</tr>
<tr>
<td>4</td>
<td>Ca</td>
<td>400</td>
<td>1.3</td>
<td>18.0</td>
<td>424.0</td>
</tr>
<tr>
<td>5</td>
<td>K</td>
<td>380</td>
<td>0.2</td>
<td>2.3</td>
<td>9.5</td>
</tr>
</tbody>
</table>

2.4.2. Standards for water for concrete mix

Water, being the most abundant solvent, may contain any number of impurities that are soluble in water even in very large concentration. Water available in the arid regions or the regions which are susceptible to saline water intrusion may contain very high amounts of Sodium Chlorides, sometimes even up to 20,000 mg/l. Some uncontaminated natural waters are found to be acidic due to the presence of carbon dioxide in solution. Mixing water sometimes contains industrial wastewater, which mainly consists of inorganic salts like Manganese, Tin, Zinc, Copper and Lead are known to be deleterious.

A search of literature indicates that constituents of water have both positive and negative effects on the quality of concrete.
Many research workers have investigated the suitability of water for mixing concrete. An overview of some of the available literature on the effect of quality of water upon the cement mortar and concrete is presented below.

Using a large number of waters, many of which were highly unpotable, Abrams (1924) cast concrete cylinders and tested them in compression at ages up to twenty eight months and found that despite the wide variation in the origin and types of waters used, most of the samples gave good results in concrete and none caused unsoundness. The few waters that Abrams reported as unsuitable contained, with one exception, total dissolved solids exceeding 6000 mg/l. The solitary exception was a highly carbonated mineral water with only 2140 mg/l of total solids.

Calcium Chloride is placed in the mixing water to serve as an accelerator in the hardening of the concrete. The addition of Calcium Chloride appears to increase the rate at which the heat is evolved from all cements tested and in general gives an increase of about 4 cal. per gm. of cement in 24 hrs. It decreased the time of set of the 11 commercial cements and increased the flow of concrete mix and the strength of the resulting concrete at all ages up to 90 days (Rapp and Wells, 1962).

Sodium Benzoate has been used as corrosion inhibitor to protect the steel in R.C.C. Tests have proved that the addition of 2 per cent Sodium Benzoate reduces the compressive strength of concrete of 34.5 MPa by 3.4 MPa, but has little effect on any other property (Lewis et al., 1956)

Steinour (1960) has investigated the effect of sea water upon concrete and found that sea water containing up to 3.5% (35,000 ppm) dissolved solids can make good concrete, provided the Tricalcium Aluminate (C₃A) level of the Portland cement is about 8 percent. It was also found that although seawater may give enough early strength, its use often results in reduced strength at latter ages.
The engineering properties of cement mortar and concrete specimens prepared by using a mixture of treated effluent and potable water in various proportions were studied in Qatar, an arid region where fresh water resources are scarce. The total dissolved solids, chloride and Sulphate content in the mixing water containing up to 40% treated effluent lie within the threshold limit for mixing water in concrete mixing. About 90% of the compressive strength is retained in the cement mortar and concrete specimens when the proportion of treated effluent does not exceed 20% in the mixing water. The tensile strength, as well as the ratios of compressive strength to tensile strength and setting time for the cement mortar were found to be within the limits prescribed by British Standard Code of practice 12 and 3148, BSI, London, 1978 and 1980 (El-Naway, et al., 1991).

The products of the reaction, gypsum and calcium sulfoaluminate, have a considerably greater volume than the compounds they replace, so that the reaction with the sulphates lead to expansion, strength loss, cracking, spalling and ultimately brings about complete mechanical disintegration. Magnesium sulphate attack on Portland cement-based materials is considered to be among the most damaging forms of attack on their integrity (Bonen, 1993).

Kotaiah and Kumara Swamy (1993) had conducted various studies and came out with a list of impurities with their tolerable levels in the mixing water, which can be seen in Tab. 2.2.

It is generally accepted that sulphate attack of hydrated cement takes place by the reaction of sulphate ions with calcium hydroxide and calcium aluminate hydrate to form gypsum and ettringite. It has been suggested that the influence of sulphate ions on the deterioration of concrete may vary depending on the type of cation (i.e. Na⁺, Ca²⁺ and Mg²⁺) as well as the concentration of sulphates in the solution (Toril and Kawamura, 1994).

The amount of Tricalcium aluminate in the concrete mixture affects the sulphate resistance. To produce concrete with improved sulphate resistance, the amount of calcium
hydroxide and calcium aluminate hydrate must be kept to a minimum (Mangat and Khatib, 1995).

As per IS 456 – 2000 specifications, water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances which may be deleterious to concrete or steel. As a guide, the following concentrations represent the maximum permissible values.

a. To neutralize 100 ml. Sample of water, using phenolphthalein as an indicator, it should not require more than 5 ml. of 0.02 normal NaOH. The details of test are given in 8.1 of IS 3025 (Part 22)
b. To neutralize 100 ml. Sample of water, using mixed indicator should not require more than 25 ml. of 0.02 normal H$_2$SO$_4$. The details of test are given in 8.1 of IS 3025 (Part 23)
c. Permissible limits for solids shall be as given in Table 1 of IS 456 – 2000.

Tab.2.3 presents permissible maximum limit for solids in the mixing water. Shetty (2000) also had listed out various impurities and their maximum permissible limits in mixing water so as to get proper mix without any deleterious effect. Tab. 2.4 is presented below which gives the tolerable limits of impurities in mixing water.

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Parameter</th>
<th>Tolerable concentration (ppm or mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PH</td>
<td>6 to 8</td>
</tr>
<tr>
<td>2</td>
<td>Acidity (as CaCO$_3$)</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>Alkalinity (as CaCO$_3$)</td>
<td>250</td>
</tr>
<tr>
<td>4</td>
<td>Organic Solids (Algae, Humus etc)</td>
<td>200</td>
</tr>
<tr>
<td>5</td>
<td>Inorganic Solids</td>
<td>3,000</td>
</tr>
<tr>
<td>6</td>
<td>Sulphates</td>
<td>500</td>
</tr>
<tr>
<td>Sl.No</td>
<td>Parameter</td>
<td>Tested as per</td>
</tr>
<tr>
<td>-------</td>
<td>----------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>i)</td>
<td>Organic</td>
<td>IS 3025 (Part 18)</td>
</tr>
<tr>
<td>ii)</td>
<td>Inorganic</td>
<td>IS 3025 (Part 18)</td>
</tr>
<tr>
<td>iii)</td>
<td>Sulphates (as SO3)</td>
<td>IS 3025 (Part 24)</td>
</tr>
<tr>
<td>iv)</td>
<td>Chlorides (as Cl)</td>
<td>IS 3025 (Part 32)</td>
</tr>
<tr>
<td>v)</td>
<td>Suspended matter</td>
<td>IS 3025 (Part 17)</td>
</tr>
</tbody>
</table>

Table 2.3 Permissible limits for solids
Table 2.4 Tolerable concentrations of some impurities in mixing water (Shetty, 2000)

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Impurity</th>
<th>Tolerable concentration (mg/l or ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sodium &amp; Potassium Carbonates and Bicarbonates</td>
<td>1,000 (total). If this is exceeded, it is advisable to make tests both for setting time and 28days strength</td>
</tr>
<tr>
<td>2</td>
<td>Chlorides</td>
<td>10,000</td>
</tr>
<tr>
<td>3</td>
<td>Sulphuric anhydride</td>
<td>3,000</td>
</tr>
<tr>
<td>4</td>
<td>Calcium chloride</td>
<td>2% by wt. Of cement in non-prestressed concrete</td>
</tr>
<tr>
<td>5</td>
<td>Sodium Iodate, Sodium phosphate, sodium arsenate, Sodium borate</td>
<td>Very low</td>
</tr>
<tr>
<td>6</td>
<td>Sodium Sulphide</td>
<td>Even 100 ppm warrants testing</td>
</tr>
<tr>
<td>7</td>
<td>Sodium hydroxide</td>
<td>0.5% by wt. of cement, provided quick set is not induced.</td>
</tr>
<tr>
<td>8</td>
<td>Salt and suspended particles</td>
<td>2,000. Mixing water with a high content of suspended solids should be allowed to stand in a settling basin before use.</td>
</tr>
<tr>
<td>9</td>
<td>Total dissolved salts</td>
<td>15,000</td>
</tr>
</tbody>
</table>
Organic material 3,000. Water containing humic acid or such organic acids may adversely affect the hardening of concrete. 780 ppm of humic acid is reported to have seriously impaired the strength of concrete. In the case of such waters therefore, further testing is necessary.

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>Shall not be less than 6</th>
</tr>
</thead>
</table>

2.5. LITERATURE REVIEW ON CEMENT AND CONCRETE

Yogendran et al. (1987) studied the properties of improving the high strength and some other properties of concrete by incorporating silica fume and super plasticizer. They studied the efficiency of silica fume in improving the properties of concrete and compared at medium and very low water cement ratios. They concluded that the optimum replacement of cement by silica fume for high strength concrete in the 28 days compressive strength range of 50 to 70 MPa is seen to be nominally 15 percent for a water cementitious ratio of 0.34. The compressive strength of mixes with a W/C ratio of 0.34 was maximum at 15% silica fume replacement at all ages.

ACI Committee 226 (1987), in their report has described about the physical and chemical properties of silica fume and gives possible application and limitations of its use in concrete. Silica fume, because of its extreme fineness and high silica content, is highly effective pozzolanic material. The main contribution of silica fume to concrete strength development at normal curing temperature takes place from about 3 to 28 days. They reported that silica fume with high range water reducers has been used to produce very high strength concrete. Compressive strengths of the order of 100 MPa and higher have also been reported.
Rachel Detwiler and Kumar Mehta (1989) conducted compression tests on cylinders of size 10 x 20cm and concluded that the silica fume concrete showed the greatest improvement in strength due to the combination of cement hydration and the pozzolanic reaction between 7 and 28 days.

Akthem et al (1992) have studied the effects of silica fume and super plasticizer on viscosity, bleed, setting time strength and shrinkage of the grout. Experimental programs were conducted on 50mm grout cubes to know the compressive strength. The compressive strength of the grout is a property that relates directly to the structure of the cement paste. They concluded that setting times are delayed by temperature. The addition of silica fume can help offset this trend to a limited extent. Unconfined compressive strengths were found to be very high for all mixes incorporating silica fume (i.e. about 100 MPa). Shrinkage strains were low for all grout mixes studied.

Per Fidjestol (1993) reported about the usage of silica fume in concrete. As per his report Norwegian Directorate of Roads requires that concrete for bridges contain upto 5 percent silica fume. The purpose of this requirement is to ensure good compaction of the concrete, high chloride resistance and good strength. Finally he concluded that silica fume concrete has gained increasing acceptance for use in high performance concrete.

Durekovic (1994) studied the porosity characteristics under the influence of silica fume and super plasticizer. Porosity was investigated in cement pastes with a water to solid ratio of 0.28 and cured at normal temperature. Samples with and without superplasticizer admixture were prepared using an OPC in which 0, 5, 10 & 15% of weight was replaced by condensed silica fume. He concluded that the most
obvious i.e. increase of the median pore size was detected at the age of 3 years in the blend with 15% of CSF.

Xie et al. (1995) investigated the mechanical properties of three high strength concretes containing silica fume designed for 60, 90 and 120 MPa. They conducted tests on compressive cylinder, split tensile and triaxial compression test for concretes having strengths 60, 90 & 120 MPa. It was concluded that although the tensile strength and fracture energy increase with an increase in compressive strength, high strength concrete is less ductile than normal concrete in both tension and compression. It was also concluded that confinement of concrete will increase the maximum and residual compressive strength significantly and also improve the durability of concrete.

Wild et al (1995), has studied the factors influencing strength development of concrete containing silica fume. Experiments were conducted on condensed silica fume concrete with a range of fume contents and cured at two temperatures (20°C and 50°C) for periods upto 91 days. Strength development and relative strength are considered in relation to temperature, cement hydration and pozzolonic action. They concluded that at early ages curing temperature has little effect on the strength of the control concrete and at extended curing periods strengths of 50°C cured concrete tend to be less than those of 20°C cured concrete. They suggested that this loss in strength is due to coarsening of calcium hydroxide crystals particularly at interfacial zones. But curing temperature does however have a very substantial effect on the strength of CSF concrete at early ages principally as a result of the increased rate of reaction of CSF with calcium hydroxide, the ultimate strengths are similar. Also, there is a continuous increase in relative strength with CSF content at both curing temperatures and the magnitudes of these increases are similar at both temperatures.
Swee liang Mak and Kazuyuki Torii (1995) investigated the strength development of high strength concretes with and without silica fume under the influence of high hydration temperatures. They concluded that high early age temperatures significantly accelerate 7–day strength of a high strength silica fume concrete with no significant increase in strength thereafter when compared to concrete cured at standard temperature. The stagnated strength development of a silica fume high strength concrete is consistent with the rapid stabilization of non evaporate water content as well as reduction in concrete humidity at very early ages due to self-desiccation.

Zhou et al. (1995) investigated the fracture properties of high strength concrete with varying silica fume content and aggregates. They studied about the fracture mechanics of high strength concrete with compressive strength in the range of 80 to 115 MPa. Silica fume contents of 10% and 15% cement replacement were used along with 10mm gravel, 10mm crushed lime stone and 20mm crushed limestone. They concluded that increasing the silica fume content from 10% to 15% cement replacement has more effect on compressive strength of concretes with higher water binder ratio.

ACI Committee 234 (1995) in its report describes the physical and chemical properties of silica fume, effects of silica fume on the properties of fresh and hardened concrete and applications of silica fume concrete. They reported that concrete containing silica fume shows significantly reduced bleeding. This effect is caused primarily by the high surface area of the silica fume to be wetted, there is very little free water left in the mixture for bleeding. The static modulus of elasticity of silica fume concrete is apparently similar to that of Portland cement concrete of similar strength. They also reported that the main contribution of silica fume to concrete
strength development at normal curing temperatures takes place from about 3 to 28 days. At 28 days the compressive strength of silica fume concrete is always higher and in some instances significantly also.

Ganesh Babu and Surya Prakash (1995) reported about the efficiency of silica fume in concrete. They reported that the overall efficiency factor of SF can be assessed in two parts (I) “general efficiency factor” – a constant at all the percentages of replacement and (ii) “percentage efficiency factor” varying with the replacement percentage. They concluded that the “general efficiency factor” (Ke) was found to be 3.0 at all replacement percentages for 28 day cube compressive strengths. The percentage efficiency factor Kp is ranging from 2.28 to 0.37 and overall efficiency ranging from 6.85 to 1.11 respectively for percentages replacements varying from 5 – 40%.

Odd Gjorv (1995) investigated about the effect of condensed silica fume on steel corrosion in concrete. He reported that with the presence of large amount of CSF, the passivity of embedded steel will not be destroyed. He concluded that upto 20% replacement of OPC with CSF will not reduce the PH of the pore solution to more than 12.5. Even at 30% replacement, the PH will not drop below 11.5, which is considered to be a threshold value for maintaining the passivity of embedded steel. If properly dispersed CSF is combined with a low w/c ratio and proper curing, it appears that concrete structures with an excellent performance can be constructed even in the most aggressive and hostile environment.

Houssam Toutanji and Tahar Korchi (1995) have investigated the influence of silica fume on the compressive strength of cement paste and mortar. Experiments were conducted to find compressive strengths of silica fume cement paste and mortar were evaluated at various water cementitious ratios. Five different water cementitious
ratios 0.22, 0.25, 0.28, 0.31 and 0.34 and two contents of silica fume, 16% and 25% by weight of cement were used. Super plasticizer was used to increase workability. Compression strength was evaluated by testing cubes 51 x 51 x 51mm under servo hydraulic controlled testing machine. From past research they reported that the optimum silica fume content should be 15%. They concluded that the replacement of cement by silica fume, regardless of w/c ratio, along with the use of a sufficient amount of super plasticizer, increases the strength of mortar. Strength increases with increasing silica fume content. Silica fume has no strengthening effect on the strength of phase.

Mohammad Shamim Khan and Michael Ayers (1995) studied about minimum length of curing of silica fume concrete. In experimental investigation they carried out tests on minimum length of curing of silica fume concrete and compared with that of plain Portland cement concrete and fly ash concrete. They replaced cement by silica fume by 5%, 10%, 15% and 20% of total cementitious material along with one plain Portland cement concrete mix and one fly ash concrete mix. They concluded that the minimum length of curing for specific SF concrete is approximately 3 days compared to 3.75 day for plain concrete mix and that for a 15% class fly ash concrete mix being 6.5 days.

Houssam (1995) evaluated the compressive strengths of silica fume cement paste and mortar at various water cement ratios. Superplasticizer content was adjusted for each mix to ensure that no segregation would occur. They found that the replacement of cement by silica fume, regardless of w/c ratio, along with superplaticiser, increases the strength of mortar. Strength increases with increasing silica fume content. This can be attributed to the improved aggregate-matrix bond associated with the formation of less porous interfacial zone and a better interlock between the paste and aggregate.
Pavla Halamickova et al (1995) had studied the effect of the sand content on the development of pore structure, the permeability to water, and the diffusivity of chloride ions on Portland cement mortars. Mortars of two water-to-cement ratios and three sand volume fractions were cast together with pastes and tested at degrees of hydration ranging from 45 to 70%. An electrically-accelerated concentration cell test was used to determine the coefficient of chloride ion diffusion while a high pressure permeability cell was employed to assess liquid permeability. The coefficient of chloride ion diffusion varied linearly with the critical pore radius as determined by mercury intrusion porosimetry while permeability was found to follow a power-law relationship vs. this critical radius. The data set provided an opportunity to directly examine the application of the Katz-Thompson relationship to cement-based materials.

Saad et al. (1996) investigated the effect of temperature on physical and mechanical properties of concrete containing silica fume. In their experimentation the cement has been partially replaced by silica fume. The heat treatment was varied from 100°C to 600°C by increments of 100°C temperature for three hours without any load. They concluded that the addition of silica fume to ordinary concrete leads to the consumption of Ca(OH)_2 obtained during cement hydration and specimens made with 10% silica fume posses the highest compressive strength values at all temperatures of thermal treatment as more CSH is formed with stronger binding forces. They also reported that the replacement of OPC by 10% silica fume by weight improved the compressive strength by 64.6% but replacement of OPC by silica fume by ratios 20 and 30% improved the compressive strength by only 28% at 600°C. This could be attributed to the additional tober morite gel (CSH phase) which formed due to the reaction of silica fume with Ca(OH)_2.

Saad et al. (1996) investigated the effect of silica fume on the phase composition and microstructure of thermally treated concrete. They investigated
experimentally the change occurring in the phase composition and micro structure of concrete pastes containing silica fume after heat treatment. The investigation was performed by x ray diffraction analysis. They concluded that concrete specimens containing 10% silica fume are stable for thermal treatment upto 300°C and the increase of silica fume by 20% & 30% leads to appearance of micro cracks after thermal treatment at 105°C and later enlarged to 600°C.

Jianyong Li and Tian Pei (1997) investigated the effect of slag and silica fume on mechanical properties on high strength concrete. They studied on properties like compressive strength, split tensile strength and rupture strength of high strength concretes. They replaced cement by slag and silica fume up to 25% by weight. Compressive strength and split tensile strength are conducted on cube specimen of size 10 x 10 x 10 cm and for testing rupture strength they used prism specimen of size 10 x 10 x 40 cm. At 3, 7 and 28 day the specimen were tested for mechanical properties. They concluded that the appropriate dosage of slag and silica fume are both 10 – 15% of total weight of bonding materials in concrete along with super plasticizer shall evidently improve the compressive strength, split tensile and rupture strength. They also reported that the compressive strength develops faster than the split tensile strength and rupture strength.

Fu et al. (1997) investigated the effects of silica fume, Latex, MethylCellulose and carbon fibres on the thermal conductivity and specific heat of cement paste. As thermal conductivity and specific heat properties relevant to various applications of concrete, low thermal conductivity is desirable for buildings and high thermal conductivity for floors and drive ways with embedded heaters. For designing a concrete mix it is better to have desired values of thermal conductivity and specific heat. They used latex (20 – 30% by weight of cement), methyl cellulose Co. 4 – 0.8%
by weight of cement) and silica fume (15% by weight). They concluded that replacement of above send materials were effective for decreasing the thermal conductivity of cement paste by 46% mainly due to low conductivity of these admixtures. They also reported that silica fume was most effective for increasing the specific heat by 9%.

Ozgur Eren and Tahir Celik (1997) in their study the influence of silica fume on the properties of HSFRC were investigated by using silica fume of two different percentages and three different hooked-end fibers namely, 30/0.50, 60/0.80 and 50/0.60 length/diameter (mm/mm). Fibers were added to concrete in three different volume percentages of 0.5, 1.0 and 2.0 by volume of concrete. The results indicated that there is a linear function between compressive strength and volume percentage of fibers. It was also found that although silica fume has an effect on compressive strength, volume percentage and aspect ratio of steel fibers has little effect. The addition of 10% silica fume with fiber volume of 1% and aspect ratio of 60 to plain concrete caused a maximum increase of 28.27% in compressive strength. Plain concrete with fiber volume of 2% and aspect ratio of 75 causes a decrease of 40.69% in compressive strength.

Omar Saeed Baghabra Al-Amoudi (1998) studied the performance of cement paste, mortar and reinforced concrete specimens made with plain and blended cements in magnesium sulfate, sodium sulfate and mixed-sulfate environments was evaluated for a period of up to 44 months. Based on the data developed in this investigation, he has concluded that Blended cement concrete mixtures exhibited an advanced stage of deterioration when compared to plain cement mixtures in magnesium-rich sulfate environments. Silica fume concrete mixtures performed better than fly ash and blast-furnace slag ones, the worst performance being that of BFS cement. The mode of deterioration in magnesium-based sulfate exposures was characterized by spalling and softening, akin to the
eating away of the hydrated cement paste and the progressive reduction of it to a cohesionless granular mass, leaving the aggregate exposed. Despite the advanced deterioration observed in the silica fume reinforced concrete specimens, its dense microstructures preserved the passivity of the reinforcing steel, even after an exposure period of 44 months. Blended cements, particularly those made with silica fume and blast furnace slag, performed much better than plain cements in sodium sulfate environments in terms of both strength reduction and expansion. Comparison of the weight loss data of concrete cylinders with the reduction in strength of small mortar cubes prepared with the same water-to-binder ratio and exposed to the same mixed-sulfate environment indicated the possibility of predicting the performance of concrete structures made with blended cements only. The use of silica fume cement concrete, with the application of a good quality water-resistant epoxy-based coating on the exposed members, appears to be the rational approach to protecting reinforced concrete structures from both sulfate attack and reinforcement corrosion in sulfate environments.

Vladimir Zivica (1999) conducted a study on the acidic resistance of cement-based materials prepared with chemically modified silica fume (MSF). MSF seems to be a highly effective hardening accelerator of materials based on combinations of Portland cement and basic blast furnace slag and on this slag alone. Besides the mechanical properties chemical resistance is a very important engineering property of concretes. Based on the observation of changes of chemical composition, pore structure and mechanical properties of the test specimens, a high acidic resistance was found on the cement-based materials when MSF was applied. The obtained results showed significantly increased acidic resistance of the composites that were based on combinations of Portland cement and basic blast furnace slag, and this slag alone under the application of chemically modified silica fume (MSF). A very positive engineering property of the composites was reached with MSF. It is quite evident that usual acidic degradation under the application of MSF was significantly eliminated. The obtained results show that MSF enables the possibility of a significant solution of general insufficient acidic resistance of the cement-based materials.
Macías et al (1999) studied the durability of ordinary Portland cement and ground granulated blast furnace slag pastes in buffered acetic/acetate medium (pH 4.5) by means of the Köch-Steinegger test. Results has shown that flexural strength measurement is not a good parameter to evaluate the degradation degree of cement paste in acid medium because two effects take place with opposite consequences on flexural strength as a result of acid attack: a densification of the cement paste in the specimen core and a degradation of the outer surface with loss of resistance.

Roberto et al. (1999) investigated the effect of super plasticizer and silica fume on heat of hydration of mortar mixtures with low water cementitious materials ratio. Experiments were conducted on replacement of cement by 0, 5 and 10% by weight of cement and 0, 0.8 and 1.6% of superplasticizer by cement mass, while a constant w/c ratio of 0.33 was used. They concluded that silica fume accelerated early cement hydration, at low levels of addition of silica fume, the heat generated from the pozzolanic reaction surpassed the decrease in heat liberation resulting from a reduction in cement hydration whereas at higher levels of silica fume replacement the result is reversed.

Nicole et al. (2000) investigated the effect of silica fume and Rice Husk ash on Alkali Silica reaction. The alkali – silica reaction occurs between the alkaline hydroxides in cement paste and reactive minerals in the aggregate produce an expansive gel that may cause cracking and displacement in concrete structures. The replacement of 15% of either silica fume or rice husk ash produce the least expansion and reduce the cracking that commonly develops in mortars with reactive aggregates.

Pinto et al. (2000) investigated the combined effects of silica fume, super plasticizer and temperature on setting behaviour. They reported that the mortar temperature greatly affect the setting behaviour. The effect of mixture composition on time of initial set varied with temperature. The duration of the time period between
initial and final was strongly influenced by temperature. This can be controlled by reducing cement content and adding super plasticizer and silica fume which accelerates setting time.

Zelic et al (2000) using differential scanning calorimetry (DSC), the rate of calcium hydroxide (CH) formed during hydration has been determined quantitatively and the percentage of reaction of hydration has been calculated. The kinetic analysis was used to obtain parameters, which were employed to find out the influence of the silica fume content on the reaction rate constant value. The reaction stages have been analysed and explained by kinetic terms. The delay in CH formed during hydration between 8 and 10 h from the beginning of hydration has been noticed and a mechanism has also been discussed. The investigations have shown that the addition of silica fume of more than 8 mass% reduced the duration of the phase boundary interaction as a rate-determined process resulting in the fast diffusion rate-determining process. The pozzolanic reaction between silica fume and CH formed during hydration is occurring after three days of hydration.

Kakali et al (2000) studied the effect of calcium carbonate on the hydration products of C₃A, C₃S and cement. Pastes made from C₃A and C₃S containing 0%, 10%, 20% and 35% w/w of chemical grade CaCO₃, as well as pastes made from Portland cement containing 0%, 10%, 20% and 35% w/w limestone, were examined after 1, 2, 7 and 28 days of hydration. The hydration products in C₃S and C₃A pastes containing CaCO₃, as well as in limestone cement pastes, were identified by means of powder diffraction. The effect of calcium carbonate on the hydration procedure was also recorded. It was concluded that in pastes containing CaCO₃, either as a chemical reagent or as a limestone constituent, the ettringite's transformation to monosulfate is delayed, while calcium aluminate monocarbonate is preferably formed instead of monosulfate even at early ages. In addition, the hydration of C₃S is accelerated and formation of some carboxylate is observed.

Puertas et al (2000) had studied the activation of fly ash / slag pastes with NaOH solutions. The parameters of the process studied were: activator concentration (NaOH 2 and
10 M), curing temperature (25°C and 65°C), and fly ash / slag ratios (100/0, 70/ 30, 50/ 50, 30/ 70, and 0/ 100). The equations of the models describing the mechanical behaviour of these pastes have been established as a function of the factors and levels considered. The ratio of fly ash / slag and the activator concentration always resulted to be significative factors. The influence of curing temperature in the development of the strength of the pastes was lower than the contribution due to other factors. At 28 days of reaction, the mixture 50% fly ash /50% slag activated with 10 M NaOH and cured at 25°C, developed compressive mechanical strengths of about 50 MPa. The nature of the reaction products in these pastes has been studied by insoluble residue in HCl acid, XRD, FTIR and MAS NMR. It has been verified that slag reacted almost completely. It has also been determined that the fly ash was partially dissolved and participates in the reactive process, even in pastes activated at ambient temperature. The main reaction product in these pastes was a hydrated calcium silicate, like CSH gel, with high amounts of tetracoordinated Al in its structure, as well as Na ions in the interlayer spaces. No hydrated alkaline aluminosilicates with three - dimensional structure characteristics of the alkaline activation of fly ashes were formed

Brough et al (2000) had investigated hydration of alkali-activated slag cements in the presence of heavy contamination with chloride. Reference samples were made by activating slag with sodium silicate solution. It was found by them that sodium chloride accelerates setting times at low addition levels up to 4% by weight. It was also found that mechanism of hydration is not significantly altered by the presence of NaCl.

Shannag (2000) used various combinations of a local natural pozzolan and silica fume to produce workable high to very high strength mortars and concretes with a compressive strength in the range of 69-110 MPa. The mixtures were tested for workability, density, compressive strength, splitting tensile strength, and modulus of elasticity. It was found that the natural pozzolan and silica fume combinations can be used to produce high to very high strength concretes in the range of 69-85 MPa 28-day compressive strength, with medium workability, using total cementitious contents between 400 and 460 kg/m³. The author had concluded that a high to very high strength mortars and concretes with 15%
natural pozzolan and 15% silica fume by weight of cement can be produced and marketed to provide technical and economical advantages in special local uses.

Pierre-Claude Aitcin (2000) in his review paper on “Cements of yesterday and today Concrete of tomorrow” has felt that it is very important to design concrete mixtures that keep their 28-day compressive strength over the life of the structure under its peculiar environmental conditions. He is also of the view that cement and concrete will have to evolve in the respect of the environment within a sustainable development perspective, which means that more mineral components will be blended with clinker and water/binder ratios will be lowered in order to increase the life cycle of concrete structures and lengthen as much as possible the use of hydraulic binders and aggregates.

Omar S. Baghabra Al-Amoudi (2002) reviewed the studies conducted at King Fahd University of Petroleum and Minerals (KFUPM) to assess sulphate attack on plain and blended cements exposed to aggressive environments in the laboratory and the field. It was found that the blended cements particularly those prepared with silica fume were observed to be highly resistant to Na$_2$SO$_4$ attack due to an interplay of several factors; the most important being the reduction in the portlandite (CH) produced by cement hydration and the densification of the microstructure of the hardened cement paste matrix.

Joana Roncero et al (2002) analysed the hydration characteristics of cement pastes with naphthalene, melamine and copolymerbased superplasticizers, using the techniques of X-ray diffraction (XRD) and nuclear magnetic resonance (NMR), up to the age of 28 days. The results indicate a significant influence of the superplasticizer on the growth rates of the hydrates and on the state of polymerization of the silicates.

Singh et al (2002) had studied Hydration of 10 wt.% rice husk ash (RHA)-blended Portland cement in the presence of 2 wt.% CaCl$_2$, 1 wt.% lignosulfonate (LS) and a mixture of the two admixtures by using different methods. Free lime determinations and differential thermal analysis have shown that CaCl$_2$ accelerates the pozzolanic reaction of Ca(OH)$_2$ and RHA. In the presence of mixture of two admixtures, lower amount of water was required for consistency of the paste. IR spectral studies have supported that the mixture of the two
admixtures act as a strong accelerator for cement hydration. The compressive strength was highest in the presence of a mixture of the two admixtures at 28 days of hydration. The admixtures did not prevent the deterioration of the blended cement in corrosive atmosphere.

Lee (2002) worked on the effects of inorganic salt addition towards the setting and rheological characteristics of the early pastes. It was found that Potassium salts retarded setting only to the cements, which used less sodium silicate in the initial solution for activation. However, its long-term effects still need to be identified. Potassium salts were found to delay setting only when the initial solution for solid activation was low in soluble silicate concentration. The anions of Cl\(^-\), CO\(_3\)^{2-} and NO\(_3\) could affect the alkaline solution to achieve the right composition and thus retard setting. Careful addition of inorganic salts hence can be used to modify the setting and rheological characteristics of alkali activated fly ash-based cements, which are vital for industrial applications.

Byung Hwan Oh et al (2002) investigated the resistance to chloride penetration of different types of concrete and to develop high performance concrete that has very high resistance to chloride penetration, and thus guarantee high durability. A large number of concrete specimens were tested by the Rapid chloride Permeability Test method. Major test variables included water to binder ratio, types of cement, type and amount of mineral admixtures (silica fume, fly ash and blast furnace slag), maximum size of aggregates and air entrainment. It was found that the concrete containing silica fume showed best performance among the specimens in the RCPT. This is because silica fume has finer particles than other cementitious materials and makes pore structure of concrete denser. Concrete containing fly ash also has shown good performance in the RCP test. It was found that the addition of fly ash greatly decreases the permeability of the concrete. It was also stated by the authors that air entrainment does not seem to have a great influence on the chloride permeability compared with water to binder ratio and mineral admixtures.

Marchand et al (2002) studied theoretical analysis of the detrimental influence of weak sodium sulfate solutions (Na\(_2\)SO\(_4\)) on the durability of concrete. It was
conducted using a numerical model that takes into account the coupled transport of ions and liquid and the chemical equilibrium of solid phases within the (partially) saturated system. Numerous simulations were performed to investigate the influence of various parameters such as water/cement (w/c) ratio (0.45, 0.65 and 0.75), type of cement (CSA Type 10 and Type 50), sulfate concentration (0–30 mmol/l of SO4) and the gradient in relative humidity across the material. All input data related to the properties of concrete were obtained by testing well-cured laboratory mixtures. Numerical results indicated that exposure to weak sulfate solutions can result in a significant reorganization of the microstructure of concrete. The penetration of sulfate ions into the material was not only at the origin of the precipitation of sulfate-bearing phases (such as ettringite and eventually gypsum) but also resulted in calcium hydroxide dissolution and C–S–H decalcification. Data also clearly emphasized the fact that w/c ratio remained the key parameter that controls the durability of concrete to sulfate attack.

Al-Dulaijan et al (2003) conducted a study to evaluate the performance of plain and blended cements exposed to varying concentrations of sodium sulfate for up to 24 months. Four types of cements, namely Type I, Type V, Type I plus silica fume and Type I plus fly ash, were exposed to five sodium sulfate solutions with sulfate concentrations of 1%, 1.5%, 2%, 2.5% and 4%. These concentrations are representative of the sulfate concentration in highly saline soils. The results indicated reduction in compressive strength.

Shannag and Hussein (2003) prepared High-performance concrete mixes containing various proportions of natural pozzolan and silica fume (up to 15% by weight of cement) were prepared and stored in sodium and magnesium sulfate solutions, in Dead Sea and Red Sea waters. The progressive deterioration and the relative sulfate resistance of these mixes were evaluated through visual observations, ultrasonic pulse velocity measurements, and relative strength determinations. The investigation indicated that the concrete mix containing
15% natural pozzolan, and 15% silica fume showed the best protection in sulfates solutions and sea waters. It retained more than 65% of its strength after one year of storage in sulfates solutions and sea waters. The superior resistance of that mix against sulfate attack was attributed to the pore refinement process and further densification of the transition zone occurring due to the conversion of lime forming from the hydration of cement into additional binding material through lime-pozzolan reaction. Authors recommended the use of silica fume in combination with natural pozzolan for better performance in severe sulfate environments.

The strengths and chloride penetration resistance of a series of high performance concretes were measured after curing either at 23 deg C or accelerated by heating to 65 deg C by Hooton (2004). The results confirm that concretes containing silica fume or ternary blends of SF and GGBFS exhibit improved chloride penetration resistance compared to those of plain Portland cement concretes. Even Detwiler et al (1994) had investigated the effectiveness of using supplementary cementing materials to increase the chloride resistance and found that concretes containing supplementary cementing materials performed better than the Portland cement concretes.

Pruckner (2004) quantified the effect of different types of chloride source on the concrete corrosivity, different mortars with OPC and 0.50 w/c were prepared, and various amounts of CaCl$_2$, NaCl and NaOH were added to the fresh mixtures. The corrosivity was primarily tested by measurements of electrical resistivity and acid capacity. The paper summarized the results of the study regarding the effect of both the type and amount of chloride source on concrete corrosivity. It was seen that the effect of NaCl added to fresh cement mortar appeared to give much less corrosive conditions than that of CaCl$_2$. It was further observed that when CaCl$_2$ was added to the fresh mortar, the amount of dissolved hydroxyl ions or pH level was reduced and the acid capacity for Ca(OH)$_2$ or amount of Ca(OH)$_2$ was decreased. The acid capacity for CSH and/or Friedel’s Salt was increased. However, when NaCl was added to the fresh mortar, it was seen that the amount of dissolved
hydroxyl ions or pH level was increased, the acid capacity for Ca(OH)$_2$ or amount of Ca(OH)$_2$
was decreased, no change in acid capacity for CSH and/or Friedel’s salt was observed. It was
also observed that since concrete is more permeable than mortar for the same w/c ratio, the
observed effects of the various chloride additions would probably be even more distinct in
cement than in mortar. Therefore, it was felt that if NaCl or CaCl$_2$ is added to fresh concrete
as a chloride source for accelerated corrosion testing of embedded steel, the different effects
of these admixtures both on the chemical and physical properties of the concrete should be
considered.

Juenger et al. (2004) investigated the Alkali – silica reactivity of large silica
fume derived particles. Pozzolanic materials are commonly added to concrete to
reduce expansion due to alkali silica reaction. They reported that large particles of
silica fume may either decrease or increase expansion due to alkali – silica reaction in
mortar. Under the accelerated testing they reported that agglomerated silica fume
decreases expansion when used as a 5% replacement of reactive sand and when 5% of
sintered silica fume aggregates are replaced expansion may increase considerably.

Dotto et al. (2004) have investigated the addition of silica fume in concrete to
improve their performance in resisting concrete reinforcement corrosion. Experimental program on compressive strength, porosity, electrical resistivity and
polarization curves were carried out with different SF additions (0%, 6% and 12%)
along with different water – binder ratio (cement + SF) 0.50, 0.65 and 0.80. They
reported that the addition of 6% of silica fume increases the electrical resistivity of
cement by 2.5 times and 12% of SF increases it by 5 times which indicates that the
addition of SF can be effectively used in protection of steel reinforcement against
corrosion. The improved electrical resistivity and dense microstructure of concrete
yielded by the addition of silica fume are expected to be efficient on protecting steel
reinforcement from corrosion in concrete.
Mazloom et al. (2004) have investigated the effect of silica fume on mechanical properties of high strength concrete. Experimental work was carried on short and long term mechanical properties of high strength concrete containing different levels of silica fume. The percentages of silica fume replaced in cement were 0%, 6%, 10% and 15% and a fixed water/binder ratio of 0.35 was adopted. They concluded that the 28 day compressive strength and secant modulus improved with the addition of silica fume (0 – 15%). However, silica fume did not affect the total shrinkage, but as the proportion of silica fume increased the autogeneous shrinkage of high strength concrete increased and its drying shrinkage decreased. They also reported that the compressive strength of concrete mixtures containing silica fume did not increase after the age of 90 days.

Mohamed Heikal (2004) studied the effect of calcium formate (CF) as an accelerator on the properties of pozzolanic cement pastes. Three types of cements were used in this investigation. These cements were OPC and pozzolanic cements containing 80 mass% OPC and 20 mass% silica fume (SF) or 20 mass% ground clay bricks (GCB). The dosages of CF were 0.00, 0.25, 0.50, and 0.75 mass% of cement. The compressive strength, total porosity, and hydration kinetics such as free lime and combined water contents were investigated. The results obtained in this study has shown that the addition of CF shortens the initial and final setting times and increases the compressive strength and combined water content as well as gel/space ratio at all ages of hydration. On the other hand, it decreases the total porosity. CF activates the liberation of Ca(OH)$_2$ of OPC pastes. The free lime content of pozzolanic cement in the presence of CF increases up to 7 days, then decreases at the later ages of hydration.

Pengfei Huang et al (2005) investigated corrosion damage in three types of concrete (C25, C45, and C55), resulting from HCl with various contents, by comparing the mechanical properties of different types of concrete and their corrosion damage. The test samples that were cured for 360 days were exposed in an aggressive environment (with 5%, 10%, 15%,
and 20% HCl content, respectively) for 24 h. The mass loss, the dynamic modulus loss, the flexural strength, and the compressive strength were measured using a series of the etched samples. The results indicate that the mechanical properties of concrete were degraded with the increasing HCl content of the corrosion medium. The etched samples of both the high- (C55) and normal-strength concretes (C25) exhibited the similar degradation of compressive strength. The strength degradation was approximately described as an exponential function of HCl content. The experiments demonstrated that surface corrosion caused by HCl solution strongly affects the flexural and compressive strengths and the elastic modulus of concrete, and that the effect degree is an increasing function of the HCl content. The study revealed that the degradation of the flexural strength was more remarkable for the high-strength concrete than for the normal-strength concrete due to higher defect sensitivity in the high-strength concrete than in the normal-strength concrete. On the other hand, the loss of both the mass and the elastic modulus, caused by HCl corrosion, was in reverse proportion to the strength grade of concrete. The tests of the diffusion coefficient of chloride by using modified Nernst–Einstein method demonstrated that the greater mass loss occurred in the normal-strength concrete was due to higher chloride permeability in C25 concrete.

Juenger et al (2005) applied soft X-ray transmission microscopy to the examination of tricalcium silicates hydrating in a solution containing CaCl₂. It appears that CaCl₂ accelerates the formation of “inner product” calcium silicate hydrate (C-S-H) with a low density microstructure. Results from the examination of C₃S hydrating in a solution containing CaCl₂ show that this accelerator increases the rate of formation of inner product C-S-H. Furthermore, this C-S-H is less dense than in a control sample. The accelerative power of CaCl₂ may come, at least in part, from its ability to flocculate hydrophilic colloids, such as C-S-H, facilitating diffusion of ions and water through the initial C-S-H layer due to an increased mean pore diameter, and thus allowing a higher rate of hydration during the early diffusion-controlled period.

Sahmaran et al (2007) experimented on the sulphate resistance of blended cements containing various amounts of natural pozzolan and/or Class-F fly ash. The performance of
blended cements was monitored by exposing the prepared mortar specimens to a 5% Na$_2$SO$_4$ solution for 78 weeks. It was found by them that blended cements prepared with mineral admixtures (both fly ash and natural pozzolan) improved the resistance of mortars to sulphate attack due to reduction in C$_3$A content. Moreover, the pozzolanic reactions of blended cements also reduced the CH content which was necessary for the formation of Gypsum.

Dale P. Bentz (2007) presented a prototype virtual test method that includes prediction of the conductivity of the cementitious binder pore solution and the total charge passed during an ASTM C1202 RCPT. The technical background used and the numerous assumptions employed in creating the prototype virtual test were outlined in detail. In addition, the computer implementation of the virtual test, as a set of HTML/Java-Script web documents, is presented. Validation against existing data sets is presented, with a generally reasonable agreement noted between the experimental and the virtual test results. The author has emphasized that a virtual standard is quite similar to a conventional standard but is based on a virtual measurement as opposed to a physical one. The author stated that the software has been developed in such a manner that it is downloadable to each user’s individual PC, where they are free to modify it and investigate variations/extensions as they see fit.

Natalya Shanahan and Abla Zayed (2007) studied four cements to address the effect of tricalcium silicate content of cement on external sulfate attack in sodium sulfate solution. The selected cements had similar fineness and Bogue-calculated tricalcium aluminate content but variable tricalcium silicates. Durability was assessed using linear expansion and compressive strength. Phases associated with deterioration were examined using scanning electron microscopy and X-ray diffraction. Mineralogical phase content of the as-received cements was studied by X-ray diffraction using two methods: internal standard and Rietveld analysis. The results indicated that phase content of cements determined by X-ray mineralogical analysis correlated better with the mortar performance in sulfate environment than Bogue content.
Chindaprasirt et al (2008) presented a study of the resistance to chloride penetration of blended Portland cement mortar containing ground palm oil fuel ash (POA), ground rice husk ash (RHA) and fine fly ash (FA). Ordinary Portland cement (OPC) was partially replaced with pozzolan at the dosages of 20% and 40% by weight of cementitious materials. The water to cement ratio is kept constant at 0.5 and the flow of mortar is maintained at 110 ± 5% with the aid of superplasticizer (SP). Compressive strength, rapid chloride penetration test (RCPT), rapid migration test (RMT) and chloride penetration depth after 30 days of immersion in 3% NaCl solution of mortars were determined. Test results revealed that the resistance to chloride penetration of mortar improves substantially with partial replacement of OPC with POA, RHA and FA. The resistance was higher with an increase in the replacement level. RHA was found to be the most effective pozzolan followed by POA and FA. The use of FA reduced the amount of SP required to maintain the mortar flow, while the incorporations of POA and RHA require more SP. The use of a blend of equal weight portion of POA and FA, or RHA and FA produced mixes with good strength and resistance to chloride penetration. They also required less amount of SP in comparison to that of normal OPC mortar. The incorporations of POA, RHA and FA significantly improved the resistance to chloride penetration of mortar by increasing nucleation sites for precipitation of hydration products, reducing Ca(OH)$_2$ and improving the permeability of mortar. RHA was the most effective, followed by POA and FA. Test results also indicated that the use of blended pozzolans of equal portion of POA and FA, and RHA and FA also effectively improved the mortar in terms of strength and resistance to chloride penetration. The improvement was due to dispersing effect of fly ash and synergic effect of the blend of fine pozzolans.

Michelle Nokken et al (2008) carried out a study to investigate the magnitude of variables such as mixture design, inclusion of chemical and mineral admixtures, the temperature during testing and the age or maturity at test time on measured conductivity. Conductivity was measured using the same equipment as the ASTM C1202 method with changes in the magnitude and duration of the applied voltage as well as the solutions used in the test cell chamber. Conductivity was measured every three hours starting at one day after
casting until seven days and weekly until 28 days. Conductivity was found to decrease with hydration as expected. It was determined that mixture design and temperature have significant effects on measured conductivity while chemical admixtures have less influence with the exception of corrosion inhibitors. The developed test method presents potential as a tool for prequalification and quality control that can be directly related to maturity and durability. It was determined that concrete mixture design has a significant influence on measured conductivity in regards to both water to cement ratio and the inclusion of mineral admixtures. For chemical admixtures, their influence was rather minimal with the exception of calcium nitrite corrosion inhibitors. The curing and testing temperature can present overlapping effects on conductivity.

Rahhal and Talero (2009) analysed the influence of three siliceous mineral admixtures or mineral additions, on hydration reactions of two Portland cements with very different mineral composition, but focussing it on the heat hydration parameter, mainly. The main techniques used in the study were conduction calorimetry and Frattini test and the ancillary analytic tests included the determination of setting times and the chemically combined water amount as well as X-ray diffraction analysis of the plain PC and their blended cement pastes. The results show how size, morphology and crystalline or vitreous state of the siliceous mineral additions affect its pozzolanicity and hydraulicity and, concomitantly, the hydration reactions in Portland cements with widely varying mineralogical characteristics. On the other hand, the findings also differentiate the effects of direct, non-direct and indirect stimulation of the hydration reactions by these siliceous mineral admixtures.

Rikard Ylmén et al (2009) used Diffuse Reflectance Infrared DR-FTIR spectroscopy to monitor chemical transformations in pastes of Portland limestone cement. To obtain a sufficient time resolution a freeze-dry procedure was used to instantaneously ceasing the hydration process. Rapid re-crystallization of sulphates is observed during the first 15 s, and appears to be complete after ~30 min. After ~60 min, spectroscopic signatures of polymerizing silica start to emerge. A hump at 970–1100 cm\(^{-1}\) in conjunction with increasing
intensity in the water bending mode region at 1500–1700 cm$^{-1}$ is indicative of the formation of Calcium Silicate Hydrate, C-S-H. Simultaneously with the development of the C-S-H signatures, a dip feature develops at 800–970 cm$^{-1}$, reflecting the dissolution of Alite, C$_3$S.

Setting times, 180 (initial) and 240 (final) minutes, are determined by the Vicat technique. Combining DR-FTIR, SEM and Vicat measurements it is concluded that the setting is caused by inter-particle coalescence of C-S-H.

Pacheco-Torgal and Said Jalali (2009) reported results of a wider investigation which aimed to understand the best option for the concrete pipe industry as far as sulphuric acid resistant is concerned, polymer addition or polymer impregnation. Results have shown that the use of polymer addition it is not economically attractive when compared to polymer impregnation. The increase of costs per meter of pipe is too high. The use of polymer impregnation enhances the chemical resistance of concrete considerably. Furthermore, it was economically viable, especially for smaller diameters. Results also have shown that using sulphate resistant cements improve the chemical resistance without cost increase.

Kyle Riding et al (2010) studied enhancement of the 1 day strength of cementitious systems by a combination of calcium chloride (CaCl$_2$) and diethanol-isopropanolamine (DEIPA), particularly in blended cement systems. The additives were found to increase the early age mortar strength by enhancing the cement hydration, with the DEIPA enhancing primarily the aluminate hydration. DEIPA also affected the morphology of portlandite which was formed as thin plates. In parallel, the calcium-to-silica ratio of the C–S–H was found to increase with the use of DEIPA, possibly because of the inclusion of microcrystalline portlandite. After 48 h DEIPA was found to directly enhance the rate of reaction of fly ash.

Mohammad Iqbal Khan (2010) has investigated various combinations of pulverised fuel ash and silica fume as partial cement replacements for composite systems. To establish the resistance of these concrete types to chloride ion penetration ASTM C1202 chloride permeability test was used. Prediction models were developed, based on the experimentally
obtained results, which enabled the establishment of isoresponse contours showing the interaction between the various parameters investigated. He found that SF inclusion, by up to 10% replacement level, significantly reduced the chloride permeability in binary systems. The incorporation of PFA in these systems resulted in further reductions in permeability. The replacement with more than 12% SF resulted in no further reductions in permeability and at early age a detrimental effect was observed. In general, the incorporation of PFA resulted in slight reductions in chloride permeability in comparison with those observed with SF.

Girardi et al (2010) have studied the behavior of different concrete mixtures in relation to a cyclic exposure to sulfuric acid and sodium sulfate solutions, recording the expansion and mass loss of the test specimens for about 5 years. Three different cements – i.e. Portland limestone, blast furnace slag and pozzolanic cement – were used, the latter two both with and without silica fume (SF), to prepare the concretes for the study. Scanning Electron Microscopy (SEM) and energy-dispersive X-ray analysis (EDX) were used to correlate the samples’ microstructure and deformation. The lowest expansion was obtained by mixtures containing silica fume, although they were more susceptible to corrosion in acid. After a dormant period when no expansion occurred, the Portland limestone cement and blast furnace slag cement exhibited a large expansion that began suddenly and increased at an almost constant rate. This expansion correlated with the presence of cracks filled with calcium sulfate crystals in the core of the concrete samples. For comparison, the expansion of concretes specimens left in a sodium sulfate solution was also measured. The dormant period in the two-step expansion process seen in the Portland limestone and blast furnace concretes was shorter in the cyclic testing in sulfate and sulfuric acid, which can be considered as a model of accelerated deterioration, than in the latter.

Parande et al (2011) studied the strength of the concrete in various environments using different techniques such as compressive strength, flexural test, rapid chloride
permeability, weight loss measurements, linear polarization and open circuit potential. Two
types of cement namely Ordinary Portland Cement (OPC) and Portland Pozzolana Cement
(PPC) with one mix ratio were used for complete study. Concrete specimens exposed in three
environments namely: normal water (NW Potable water), domestic sewage water (DSW) and
textile wastewater (TWW). From the results, it is observed that PPC exposed in different
media shows better performance than OPC in both mechanical and electrochemical studies.
The said study found Compressive strength tested with normal water exposure the control
PPC showed superior to OPC at 150 days. Specimen cured in DSW, PPC concrete had the
maximum value when compared to OPC concrete at all ages of curing. The increase in
compressive strength in PPC is due to the pozzolanic reaction between pozzolan and calcium
hydroxide there after the lime and C₂S in the cement begin to hydrate. The Strength of OPC
has been reduced in TWW and it is due to the presence of more CaO in OPC than PPC which
leads to leaching and deterioration of its strength. Gravimetric weight loss measurements
showed that the corrosion rate in PPC was lesser than OPC in NW and DSW except TWW. It
clearly shows that the organic substances present in the wastewater and the chemicals present
in the PPC cement joined together to give a protective layer over the steel surface. In RCPT
studies, the total electrical charge (coulombs) passed was more in OPC and less in PPC
specimen. The presence of anion and cation Na⁺, K⁺, Ca²⁺, OH⁻ and Cl⁻ are responsible for
diffusion. The RCPT result reflects the interconnected pore’s network of concrete in which
ions migrate. The use of pore’s concrete would not lead to lower the permeability of concrete.
If the interfacial between aggregate/cement is intact lesser pores are formed that's lead
minimal migrate of ions. From the FT-IR spectra observation OPC and PPC exposed in DSW
showed to the presence of hydrogen sulphide and other compounds in DSW that destroys the
upper surface of the concrete that leads to the deterioration of its strength in sewage when
compared to NW curing.

Susan A. Bernal et al (2011) assessed the mechanical and durability performance of
concretes produced using alkali silicate activated ground granulated blast furnace slag as sole
binder. Alkali-activated concretes are formulated with 300, 400 and 500 kg slag per m³ of
fresh concrete, and their performance is compared with reference concretes produced using Portland cement (OPCC). Regardless of the binder content, the alkali-activated slag concretes (AASC) developed higher compressive strength than the comparable reference concretes. Higher binder content leads to increased strength in both AASC and OPCC at 28 days. However, at 90 days, the performance penalty for low binder content is more significant in the OPCC than AASC samples. Permeability, water sorption and carbonation resistance properties were also found to be improved at higher binder contents. The apparent resistance to chloride penetration, as measured by the charge passed in an electrically accelerated test, appeared very high (i.e. low charge passed) in all alkali-activated concrete samples, although the interpretation of the results of this test is not yet certain for concretes, such as these, which contain very high levels of supplementary cementitious materials.

Milica M. Vlahovic et al (2011) tested durability of sulfur concrete with different fillers, as well as Portland cement concrete, in the solutions of HCl, H₂SO₄, and NaCl. Regarding mass changes, in the solutions of HCl and H₂SO₄ sulfur concrete with talc and fly ash exhibited higher durability, while in NaCl samples with alumina and microsilica were better. The type of filler did not affect durability regarding compressive strength. Strength loss was higher in the solution of HCl comparing to H₂SO₄, while negligible in NaCl which is in accordance with apparent porosity increase. It was also found that porosity increase was the highest for the sulfur concrete samples treated in HCl, a bit lower after treatment in H₂SO₄ and the lowest after treatment in NaCl which is connected with the mentioned compressive strength loss.

Xuemei Liu et al (2011) carried out a study to evaluate effect of cumulative light weight aggregate (LWA) content (including lightweight sand) in concrete [water/cement ratio (w/c) = 0.38] on its water absorption, water permeability, and resistance to chloride-ion penetration. Rapid chloride penetrability test (ASTM C 1202), rapid migration test (NT Build 492), and salt ponding test (AASHTO T 259) were conducted to evaluate the concrete resistance to chloride-ion penetration. The results were compared with those of a cement paste and a control normal weight aggregate concrete (NWAC) with the same w/c and a
NWAC (w/c = 0.54) with 28-day compressive strength similar to some of the lightweight aggregate concrete (LWAC). Results indicated that although the total charge passed, migration coefficient, and diffusion coefficient of the LWAC were not significantly different from those of NWAC with the same w/c of 0.38, resistance of the LWAC to chloride penetration decreased with increase in the cumulative LWA content in the concretes. The water penetration depth under pressure and water sorptivity showed, in general, similar trends. The LWAC with only coarse LWA had similar water sorptivity, water permeability coefficient, and resistance to chloride-ion penetration compared to NWAC with similar w/c. The LWAC had lower water sorptivity, water permeability and higher resistance to chloride-ion penetration than the NWAC with similar 28-day strength but higher w/c. Both the NWAC and LWAC had lower sorptivity and higher resistance to chloride-ion penetration than the cement paste with similar w/c.

Cheung et al (2011) had reviewed the impact on hydration of several classes of chemicals with an emphasis on the current understanding of interactions with cement chemistry. These include setting retarders, accelerators, and water reducing dispersants. The ability of the chemicals to alter the aluminate–sulfate balance of cementitious systems is discussed with a focus on the impact on silicate hydration. As a key example of this complex interaction, unusual behavior sometimes observed in systems containing high calcium fly ash is highlighted.

Giner et al (2011) studied the influence of SF additions in quantities ranging from 0% to 15% of cement mass on the dynamic and static mechanical properties of concrete, such as: resonant frequencies, dynamic and static modulus of elasticity, damping ratio, compressive strength and flexural strength. The results proved that the compressive strength of concrete increases proportionally to the SF quantity, whether it is included as an addition or replacement.

Nattapong Makaratat et al (2011) studied and presented a concrete that utilizes a calcium carbide residue and fly ash mixture as the concrete binder instead of Portland cement. The ground calcium carbide residue (CR) was mixed with classified fly ash (FA) at a ratio of
30:70 (CR:FA) by weight and used as a binder to cast CR-FA concrete specimens. The effects of binder content, water to binder (W/B) ratio, and CaCl\textsubscript{2} dosages on the compressive strength of CR-FA concrete were evaluated. In addition, the modulus of elasticity of CR-FA concrete was measured. The results indicated that the CR-FA mixture could be used as a cementitious material for concrete without using Portland cement. Increasing the binder content and reducing the W/B ratio improved the compressive strength of CR-FA concrete, similar to normal concrete. The addition of 3% CaCl\textsubscript{2} by weight of binder yielded CR-FA concrete that exhibited high workability and accelerated the compressive strength at early ages. In particular, the 450 kg/m\textsuperscript{3} of CR-FA binder content with 3% CaCl\textsubscript{2} at a W/B of 0.35 yielded a compressive strength as high as 24.3 MPa at 90 days, even though this concrete did not contain Portland cement.

Ali Reza Bagheri et al (2012) in their study on the effect of incorporation of silica fume in enhancing strength development rate and durability characteristics of binary concretes containing a low reactivity slag has been investigated. Binary concretes studied included mixes containing slag at cement replacement levels of 15%, 30% and 50% and mixes containing silica fume at cement replacement levels of 2.5%, 5%, 7.5% and 10%. Ternary concretes included combinations of silica fume and slag at various cement replacement levels. The w/b ratio and total cementitious materials content were kept constant for all mixes at 0.38 and 420 kg/m\textsuperscript{3} respectively. Concrete mixes were evaluated for compressive strength, electrical resistance, chloride permeability (ASTM C1202 RCPT test) and chloride migration (AASHTO TP64 RCMT test), at various ages up to 180 days. The results had shown that simultaneous use of silica fume has only a moderate effect in improving the slow rate of strength gain of binary mixes containing low reactivity slag. However it improved their durability considerably. Using appropriate combination of low reactivity slag and silica fume, it is possible to obtain ternary mixes with 28 day strength comparable to the control mix and improve durability particularly in the long term. Ternary mixes also have the added advantage of reduced water demand. Ternary mixes based on silica fume with various amounts of slag showed improvements in durability over control at 28 days.
and at later ages the enhancements were substantial. Unlike the trend observed for the strength, the durability of ternary mixes increased with higher slag contents. Authors stated, if achieving equal 28 day strength to the control mix is not critical, the use of ternary mixes with high contents of low reactivity slags will provide a high durability concrete with added environmental and energy conservation benefits.

Erhan Guneyisi et al (2012) investigated the effectiveness of metakaolin (MK) and silica fume (SF) on the mechanical properties, shrinkage, and permeability related to durability of high performance concretes. Mechanical properties were evaluated by means of compressive and splitting tensile strength. Water sorptivity and gas permeability tests were carried out to find out the permeation characteristics of the concretes due to the incorporation of MK and SF. Shrinkage behavior of the concretes with and without mineral admixtures were dealt through measurements of free shrinkage strains and weight loss of the specimens due to drying. For concrete production, replacement levels of 5% and 15% of MK or SF by the weight of cement were assigned. Water-to-cementitious (w/cm) material ratios of 0.25 and 0.35 were used in production of concrete. The design strength level ranging from 75 to 86 MPa was achieved. Test results revealed that replacement level of MK and SF had significant effects on the mechanical and especially durability characteristics of high performance concretes.

From the literature, it is observed that, a very limited work has been carried out in the arena of individual chemicals presence in mixing water and their effect on blended cement and concrete. In this scenario, the present investigation has focused to study the presence of various chemicals, in mixing water, and their influence on setting times, compressive strength and chloride ion permeability of Blended Cement (BC), Silica Fume Blended Cement (SFBC) and their concretes namely BCC and SFBC and Steel Fibre Reinforced Blended cement Concrete (SFRBCC). In the forthcoming chapter, the scope of current investigation is presented.