

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction:

This chapter contains a definition of admixture, historical review, types of admixtures, ready mixed concrete, and effect of retempering on concrete properties.

2.2 Definition of admixture:

An admixture is defined in ACI 116R [14] and ASTM C125 [15] as “a material other than water, aggregates, hydraulic cement, and fiber reinforcement used as an ingredient of concrete or mortar, and added to the batching during its mixing”. Chemical admixtures are primarily water-soluble substances used to enhance the properties of concrete in the plastic and hardened state.

2.3 Historical development of admixture:

Since ancient times organic materials have been used as admixtures for concrete to achieve plasticity, such materials added to time – pozzolan admixtures are said to include milk, blood and lard [16].

In 1936 Kennedy [17] investigated the initial work on set controlling and water reducing compounds and compositions. In 1938 Tucker G.R [18] investigated some products that were produced by condensing formaldehyde with naphthalene sulfonic acid and neutralizing. These compounds provide significant reduction of water requirement. K. Winter [19] in United States in 1939 investigated the use of water soluble salts of hydroxylated carboxylic acids in concrete to achieve reduction of water requirement, improved strength and set retardation.

In 1943, the corps of engineers in united states, department of the army initiated an investigation on a composition based on calcium lignosulfonates, this compound provides significant reduction of water requirement [20].

Products based on lignosulphonates were used in 51 million cubic meters of concrete during the period 1952-56. In 1968, 50 million cubic meters of concrete containing an air entraining admixtures and a water-reducing, or both were being placed annually in Japan [21]. Since 1958, Hattori [22] has done an extensive basic study on formaldehyde condensates of beta naphthalene sulphonates. Based on this knowledge, it was discovered in 1962 that its high condensate was effect for dispersing cement practices in water in comparison with other existing surfactants [23].

The high condensate produced very high flow ability in fresh concrete, with a low tendency for set retardation and reduction of air entrainment. By the early 1960s, most of the favorable properties of the high condensate as superplasticizers for concrete were understood [24].

In 1964, the product was first introduced into market by Kaosoap company in powder and 42 wt% active solution forms. During the past 25 years since its debut in the Japanese market, about 25 million cubic meters of concrete admixed with beta-NSFHC has produced mainly in factory prefabricated products and to a lesser extent, in site placed structures [24]. By the introduction of formaldehyde high condensate of beta-naphthalene sulfonate (beta-NSFHC), concrete products of 100 N/mm^2 (1000 kg/cm^2) compressive strength at the 28 days became available in Japan. In 1965, centrifugally formed and autoclave cured concrete piles with 70 N/mm^2 strength were first commercialized [25]. In 1971, hattori and his co-workers developed a technique of controlling slump loss during the mixing of concrete by the inter mitten addition of beta-NFHC [26]. Kasami, Ikeda Yamane [27] showed that since 1975 several kind of superplasticizers have been commercialized in Japan. In 1975 more than 500000 cubic meters of the superplasticized concrete containing different types of superplasticizers for delayed addition have been used in general construction in Japan.

Superplasticizers [28] are linear polymers containing sulfonic acid groups attached to the polymer backbone at regular intervals (Verbeck 1968) [29]. Most of the commercial formulations belong to one of four families:

1. Sulfonated melamine-formaldehyde condensates (SMF)
2. Sulfonated naphthalene-formaldehyde condensates (SNF)
3. Modified lignosulfonates (MLS)
4. Polycarboxylate derivatives.

The sulfonic acid groups are responsible for neutralizing the surface charges on the cement particles and causing dispersion, thus releasing the water tied up in the cement particle agglomerations and thereafter reducing the viscosity of the paste and concrete (Mindess and Young 1981) [30].

ASTM C 494 was modified to include high-range water-reducing admixtures in the edition published in July 1980. The admixtures were designated Type F water-reducing, high range admixtures and Type G water-reducing, high-range, and retarding admixtures (Mielenz 1984) [31].

Superplasticizers affect the concrete properties. The main purpose of using superplasticizers is to produce flowing concrete with very high slump in the range of 7-9 inches (175-225 mm) to be used in heavily reinforced structures and in placements where adequate consolidation by vibration cannot be readily achieved. The other major application is the production of high-strength concrete at w/c's ranging from 0.3 to 0.4 (Ramachandran and Malhotra 1984) [32].

The ability of superplasticizers to increase the slump of concrete depends on such factors as the Type, dosage, and time of addition of superplasticizer; w/c; and the nature or amount of cement. It has been found that for most types of cement, superplasticizer improves the workability of concrete. For example, incorporation of 1.5% SMF to a concrete containing Type I, II and V cements increases the initial slump of 3 inches (76 mm) to 8.7, 8.5, and 9 inches (222, 216, and 229 mm), respectively.

The capability of superplasticizers to reduce water requirements by 12-25% without affecting the workability leads to production of high-strength concrete and lower permeability. Compressive strengths greater than 14, 000 psi (96.5 MPa) at 28 days have been attained (Admixtures and ground slag 1990) [32]. Use of superplasticizers in air-entrained concrete can produce coarser-than-normal air-void systems. The maximum recommended spacing factor for air-entrained concrete to resist freezing and thawing is 0.008 inch (0.2 mm). In superplasticized concrete, spacing factors in many cases exceed this limit (Malhotra 1989; Philleo 1986) [33]. Even though the spacing factor is relatively high, the durability factors are above 90 after 300 freeze-thaw cycles for the same cases (Malhotra 1989) [33]. A study conducted by Siebel (1987) [] indicated that high workability concrete containing superplasticizer can be made with a high freeze-thaw resistance, but air content must be increased relative to concrete without superplasticizer. This study also showed that the type of superplasticizer has nearly no influence on the air-void system.

One problem associated with using a high range water reducer in concrete is slump loss. In a study of the behavior of fresh concrete containing conventional water reducers and high range water reducer, Whiting and Dzedzic (1989) [34] found that slump loss with time is very rapid in spite of the fact that second-generation high range water reducer are claimed not to suffer as much from the slump loss phenomenon as the first-generation conventional water reducers do. However, slump loss of flowing concrete was found to be less severe, especially for newly developed admixtures based on copolymeric formulations.

The slump loss problem can be overcome by adding the admixture to the concrete just before the concrete is placed. However, there are disadvantages to such a procedure. The dosage control, for example, might not be adequate, and it requires ancillary equipment such as truck-mounted admixture tanks and dispensers. Adding admixtures at the batch plant, beside dosage control improvement, reduces wear of truck mixers and reduces the tendency to add water onsite (Wallace 1985) [35].

New admixtures now being marketed can be added at the batch plant and can hold the slump above 8 inches (204 mm) for more than 2 hours.

The third generation of superplasticizers based on polycarboxylic have been used all over the world since 1993 to produce flowable and self-compacted concrete as previously mentioned in section 1.2, see references from [6] to [13].

2.4 Types of admixtures:

2.4.1 ACI classification:

ACI 212.3R-04 [36] classifies the chemical admixtures for concrete as:

1. Air-entraining admixtures
2. Accelerating admixtures
3. Water reducing and set-controlling admixtures:

It includes 7 types:

- Type A—Water-reducing admixtures
- Type B—Retarding admixtures
- Type C—Accelerating admixtures
- Type D—Water-reducing and retarding admixtures
- Type E—Water-reducing and accelerating admixtures
- Type F—Water-reducing, high-range admixtures
- Type G—Water-reducing, high-range, and retarding admixtures

4. Admixtures for flowing concrete
5. Miscellaneous admixtures

It includes 13 types:

- Gas-forming admixtures
- Grouting admixtures
- Extended set-control admixtures

- Bonding admixtures
- Pumping aids
- Pigments
- Flocculating admixtures
- Fungicidal, germicidal, and insecticidal admixtures
- Permeability-reducing admixtures
- Chemical admixtures to reduce alkali-aggregate reaction expansion
- Corrosion-inhibiting admixtures
 - Anti-washout admixtures
 - Freeze-resistant admixtures

2.4.2 ASTM C494 [4] classification of chemical admixtures:

ASTM C494 [4] specification covers materials for use as chemical admixtures to be added to hydraulic-cement concrete mixtures in the field for the purpose or purposes indicated for the seven types as follows:

1. Type A—Water-reducing admixtures
2. Type B—Retarding admixtures
3. Type C—Accelerating admixtures
4. Type D—Water-reducing and retarding admixtures
5. Type E—Water-reducing and accelerating admixtures
6. Type F—Water-reducing, high range admixtures, and
7. Type G—Water-reducing, high range, and retarding admixtures.

Physical requirements:

Table (2-1) contains the physical requirements of chemical admixture:

Table (2-1) Physical requirements [4]:

	Type A, Water Reducing	Type B, Retarding	Type C, Acceler- ating	Type D, Water Reducing and Retarding	Type E, Water Reducing and Accelerating	Type F, Water Reducing, High Range	Type G, Water Reducing, High Range and Retarding
Water content, max, % of control	95	...	...	95	95	88	88
Time of setting, allowable deviation from control, h:min:							
Initial: at least	...	1:00 later	1:00 earlier	1:00 later	1:00 earlier	...	1:00 later
not more than	1:00 earlier nor 1:30 later	3:30 later	3:30 earlier	3:30 later	3:30 earlier	1:00 earlier nor 1:30 later	3:30 later
Final: at least	...	...	1:00 earlier	...	1:00 earlier	...	...
not more than	1:00 earlier nor 1:30 later	3:30 later	...	3:30 later	...	1:00 earlier nor 1:30 later	3:30 later
Compressive strength, min, % of control: ^B							
1 day	...	...	...	...	...	140	125
3 days	110	90	125	110	125	125	125
7 days	110	90	100	110	110	115	115
28 days	110	90	100	110	110	110	110
6 months	100	90	90	100	100	100	100
1 year	100	90	90	100	100	100	100
Flexural strength, min, % control: ^B							
3 days	100	90	110	100	110	110	110
7 days	100	90	100	100	100	100	100
28 days	100	90	90	100	100	100	100
Length change, max shrinkage (alternative requirements): ^C							
Percent of control	135	135	135	135	135	135	135
Increase over control	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Relative durability factor, min ^D	80	80	80	80	80	80	80

2.5 Water reducing admixtures:

2.5.1 Applications:

Water – reducing admixtures are used to reduce the quantity of mixing water required to produce concrete of a certain slump, reduce water – cement ratio, reduce cement content, or increase slump. Typical water reducers reduce the water content by approximately 5% to 10%. Adding a water – reducing admixture to concrete without reducing the water content can produce a mixture with a higher slump. The rate of slump loss in most cases increases, see Figure (2-1) [34].

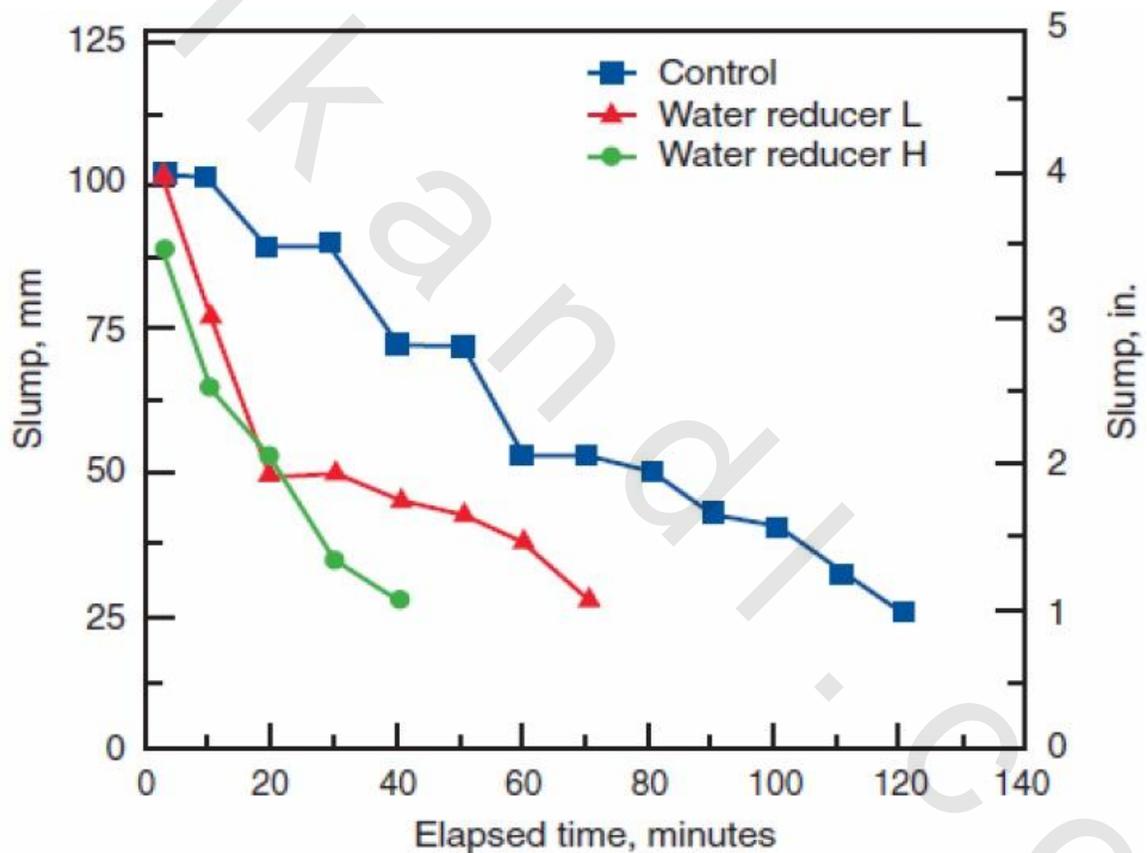


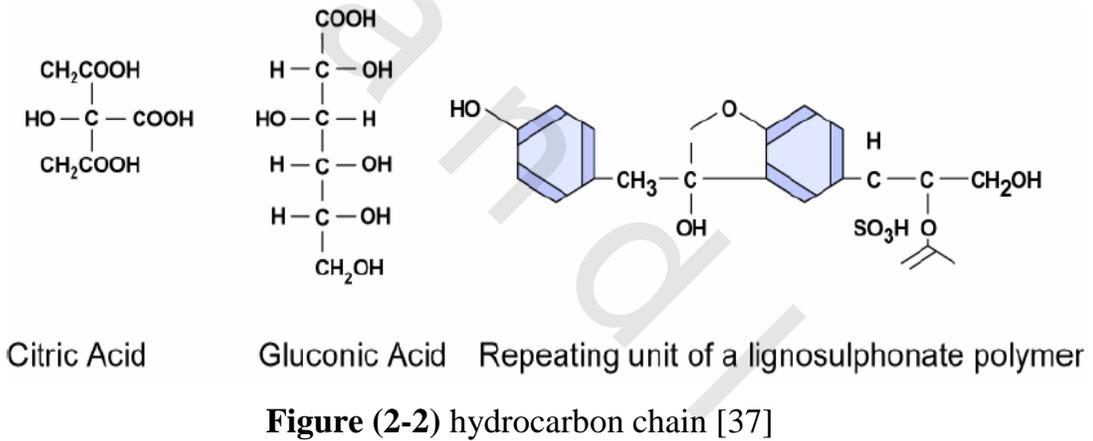
Figure (2-1) Slump loss at 23°C in concretes containing conventional water reducers (ASTM C 494 [4] and AASHTO M 194 Type D - quoted by [34]) compared with a control mixture

An increase in strength is generally obtained with water reducing admixtures as the water – cement ratio is reduced. For concrete of equal cement content, air content, and slump, the 28 day strength of concrete containing a water reducer can be 10% to 25% greater than concrete without admixtures [37].

2.5.2 Chemical base:

These materials can be produced using the following chemical bases: Salts and derivatives of ligno sulfonic acids, hydroxylated carboxylic acids, and carbohydrates see Figure (2-2).

The anionic polar group is joined to hydrocarbon chain which itself is polar or hydrophilic.



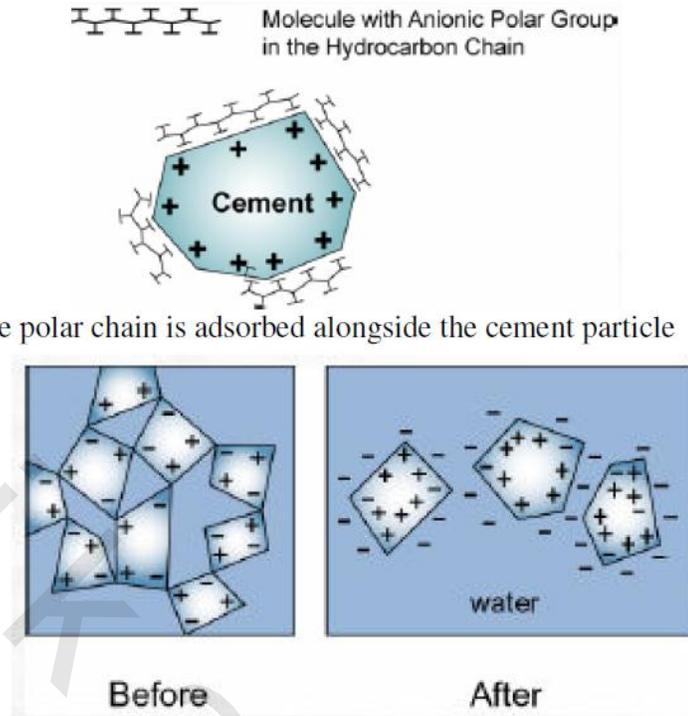


Figure (2-3) Mechanism of water reducing

2.5.3 Mechanism:

Water-reducing admixture are surface-active chemicals. It can separate the cement particles by increasing the static charge on the particle surfaces and thus releasing the water entrapped by cement particle clusters (see Figure 2-3). More water is then water-reducing admixture is surface-active chemicals. It can separate the cement available to ‘lubricate’ the mix.

2.6 High range water reducing admixtures:

2.6.1 General:

In the 1970s, the main superplasticizers were water-soluble synthetic polymers such as sulfonated melamin formaldehyde condensates, sulfonated naphthalene formaldehyde condensates, additives based on a single repeating unit (naphthalene or melamine sulfonated [38]).

The new additives studied e.g. polycarboxylates polymers [39] are based on two or more structural groups that provide greater diversity in possible molecular structures e.g. changing the number of carboxyl groups per unit of polyether, polymer adsorption on the surface of cement particles can be changed significantly [40].

The molecular weight of the polyether molecules can be properly adjusted to form polymers with different characteristics to reduce the mixing water or to produce a retarding effect on initial cement hydration. Table 2 presents the chemical structures of various types of superplasticizer. A well-known class of water reducing additives, which is a synthetic precursor of concrete superplasticizers used today, is the lignosulfonates group.

Lignosulfonates are produced by lignin degradation a bisulfate extraction process of cellulose in paper industry. Lignosulfonate molecule consists of aromatic rings containing functional groups in 3 positions, with alkoxy groups (OCH_3), ether groups ($-\text{O}-$) or polar upland substitutes or ionic groups ($\text{OH}-$, $\text{COO}-$, SO_3^-). Lignosulfonate is a polymer with hydrophobic and ionisable groups and/or polar functional groups.

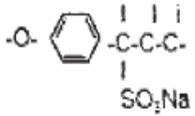
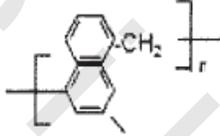
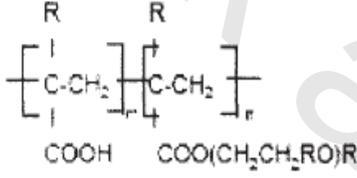
2.6.2 Chemical base:

These admixture are produced using the following chemical base:

- Sulfonated melamine formaldehyde condensates
- Sulfonated naphthalene formaldehyde condensates
- Modified lignosulfonates
- Polycarboxylates
- Poly acrylates and polyethylene
- based co-polymers

Table (2-2), and Figure (2-4) show the chemical base of superplasticizers types:

Table (2-2) chemical base of superplasticizers types [38]

Chemical formula	Type	Year
	Modified lignin sulfonated	1930
	Sulfonated naphthalene	1970
	Polycarboxylic copolymers	2000

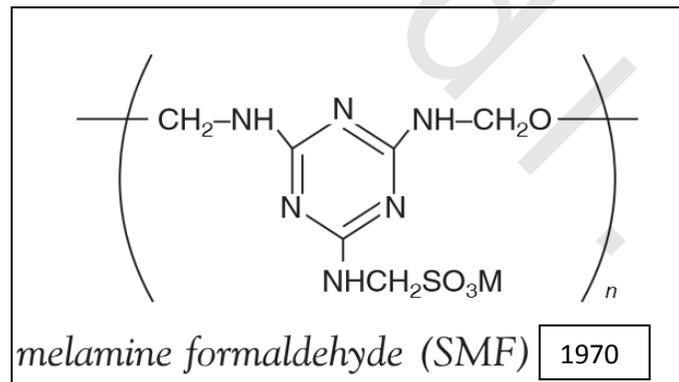


Figure (2-4) The chemical base of melamine [41].

2.6.3 Mechanism:

Most highly water reducing additives work in a similar way to normal water reducing additives. They dissociate in water SO_3 groups being obtained. Some are adsorbed by positive charge of cement particles, others form negative charges around the grains, reducing the inter-particle attraction by electrostatic mechanism, producing a more uniform dispersion of cement grains, see Figure (2-5). This reduces the amount of water needed to achieve proper consistency for cement grout.

The strong adsorption of NSF and lignosulfonate additives on the surfaces of the anhydrous or partially hydrated particles of the system can explain the influence of the admixtures upon the kinetics of the hydration process: retardation or acceleration [42, 43].

The introduction of polycarboxylate types superplasticizers, a highly efficient water reduction class, has revolutionized the advanced concrete and mortar market.

These polycarboxylates provide significant improvements in the dispersion by electrostatic flow similar to the steric hydration of cement particles, while conventional water reducers work only by electrostatic rejection. Recently discovered products such as ethers polycarboxylates are designed to work through steric stabilization resulting from hydrophilic polyether chains which are grafted onto the main chain (primary structure) of polycrylic acid [38], see Figure (2-6).

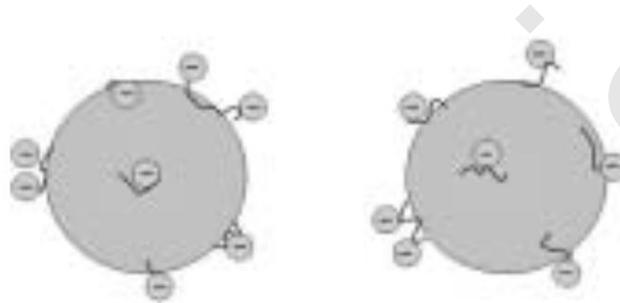


Figure (2-5) Electrostatic dispersion of cement particles [41]

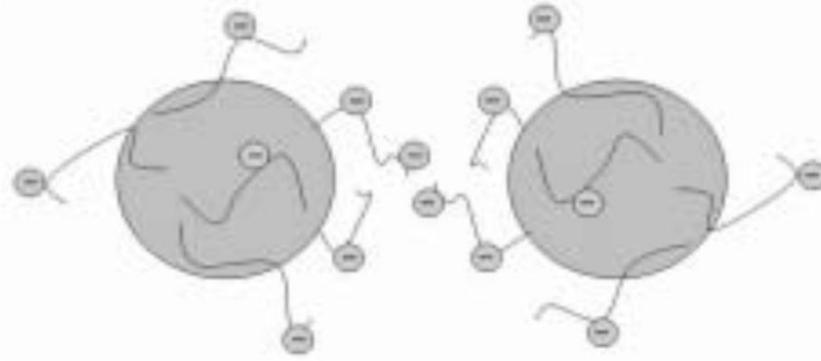


Figure (2-6) Separation of cement particles facilitated by steric hindrance [41]

2.7 Retarding admixture:

2.7.1 General

Retarding admixtures are used to delay the rate of setting of concrete. Retarding admixtures are useful in extending the setting time of concrete, but they are often also used in attempts to decrease slump loss and extend workability, especially prior placement at elevated temperatures.

The fallacy of this approach is shown in Figure (2-7), where the addition of a retarder resulted in an increased rate of slump loss compared to the control mixtures [44]. In general, some reduction in strength at early ages (one to three days) accompanies the use of retarding admixtures.

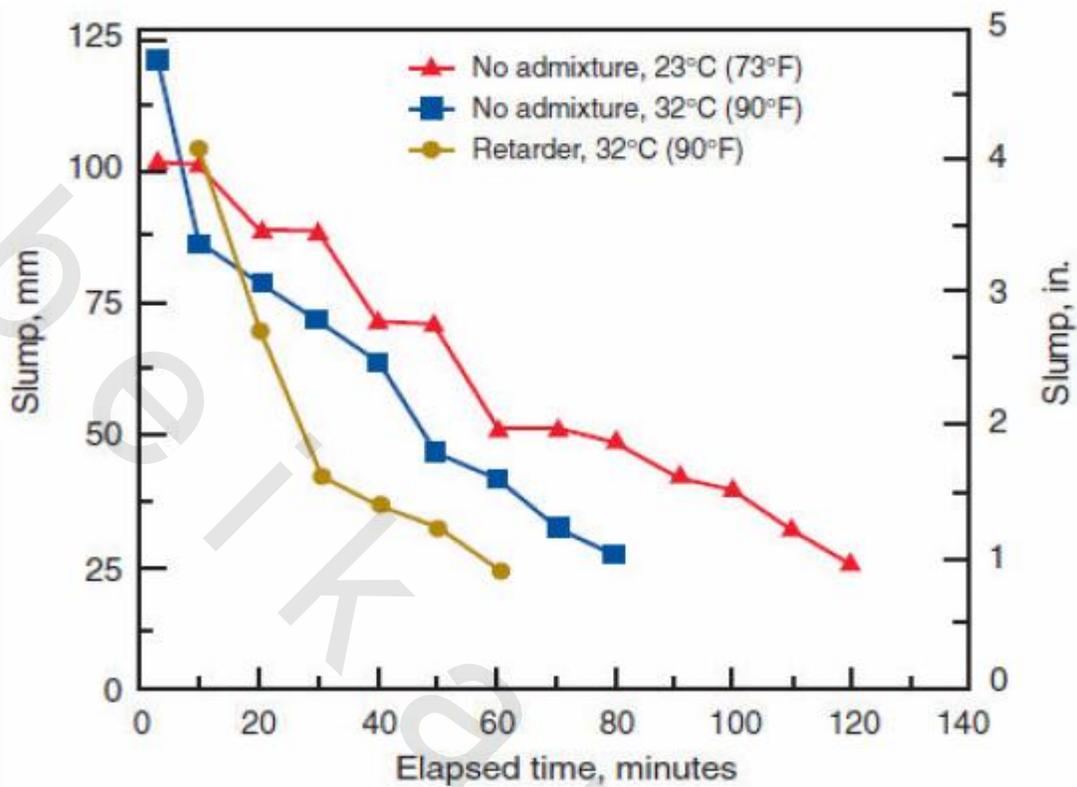


Figure (2-7) Slump loss at various temperatures for conventional concretes prepared with and without set-retarding admixture quoted by [45]

2.7.2 Chemical base:

These admixture are produced using the following chemical base:

- Lignosulfonates
- hydroxylated carboxylic acids
- carbohydrates

2.7.3 Mechanism:

The setting and hardening phenomena of Portland cement paste are derived from the progressive crystallization of the hydration products.

As discussed before, setting, or the start of significant crystallization of hydration products occurs at the end of the induction period, when the concentration of ions (calcium, aluminates and silicates, etc) has reached a critical state. Since the solubility of ions is sensitive to the presence of other ions in solution, it is possible to change the dissolution rate of ions from the cement, by introducing other ions.

This is the principle behind retarding and accelerating admixtures. Retarding admixtures are chemicals that can slow down the dissolution of ions from the cement, thus extending the induction period and delaying initial set [1].

2.8 Accelerators:

An accelerating admixture is used to accelerate the rate of hydration (setting) and strength development of concrete at an early age. Accelerators are designated as Type C admixture under ASTM C494.

Calcium chloride (CaCl_2) is the chemical most commonly used in accelerating admixtures, especially for non – reinforced concrete. It should conform to the requirements of ASTM D98 and should be sampled and tested in accordance with ASTM D345. But besides accelerating strength gain, calcium chloride causes an increase in drying shrinkage, potential reinforcement corrosion.

Several non-chloride accelerators are available for use in concrete where chlorides are not recommended such as salts formic acid and triethanolamine [37].

2.9 Mineral Admixtures:

2.9.1 General:

Table (2–3) shows the specifications and classes of supplementary cementitious materials.

Table (2-3) Specifications and classes of supplementary cementitious materials.

- | |
|--|
| <ol style="list-style-type: none">1) Ground granulated iron blast – furnace slags – ASTM C989<ul style="list-style-type: none">- grade 80
slags with a low activity index- grade 100
slags with a moderate activity index- grade 120
slags with a high activity index2) fly ash and natural pozzolans – ASTM C618<ul style="list-style-type: none">- Class N
Raw or calcined natural pozzolans including :
Diatomaceous earths
Opaline cherts and shales
Tuffs and volcanic ashes or pumicites calcined clays , including
metakaolin and shales- Class F
fly ash with pozzolanic properties- Class C
fly ash with pozzolanic and cementitious properties3) Silica fume – ASTM C1240 |
|--|

Fly ash, ground granulated blast – furnace slag, silica fume, and natural pozzolans such as calcined shale, calcined clay or metakaolin, are materials that, when used in conjunction with Portland or blended cement, contribute to the properties of the hardened concrete through hydraulic or pozzolanic activity or both.

A pozzolan is a siliceous or aluminosiliceous material that in finely divided form and in the presence of moisture, chemically reacts with the calcium hydroxide released by hydration of Portland cement to form calcium silicate hydrate.



The pozzolanic reaction is slow, so the rate of the strength development and the heat of hydration associated with this reaction are low [46]. It may be noted that the pozzolanic reactions can be accelerated by temperature [46].

2.9.2 Fly Ash:

Fly ash, the most widely used supplementary cementitious material in concrete, is a by-product of the combustion of pulverized coal in thermal power plants.

The dust-collection system removes the fly ash, as a fine particulate residue, from the combustion gases before they are discharged into the atmosphere [46]. Figure (2-8) shows micrograph of fly ash particles [46].

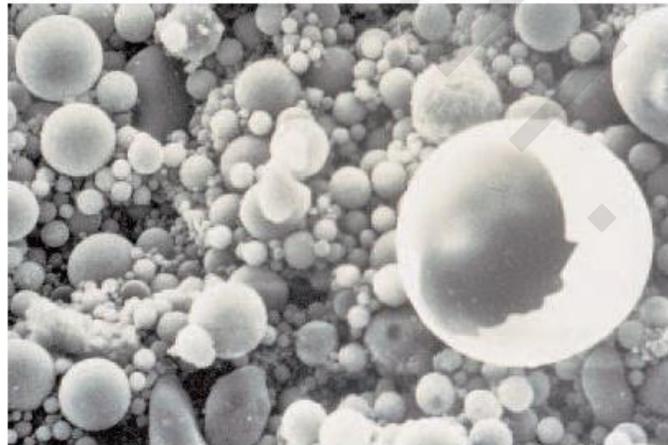


Figure (2-8) Scanning electron microscope (SEM) micrograph of fly ash particles at 1000X.

Although most fly ash spheres are solid, some particles, called cenospheres, are hollow (as shown in the micrograph).



Figure (2-9) Fly ash, a powder resembling cement, has been used in concrete since the 1930s.

Fly ash is a finely divided powder resembling Portland cement (Figure 2 – 9). The particle sizes in fly ash vary from less than 1 mm (micrometer) to more than 100 mm with the typical particle size measuring less than 20 mm. Only 10% to 30 % of the particles by mass are larger than 45 μm [37].

The surface area is typically 300 to 500 m^2/kg , although some fly ashes can have surface areas as low as 200 m^2/kg and as high as 700 m^2/kg . The bulk density can vary from 540 to 860 Kg/m^3 whereas with close packed storage or vibration, the range can be 1120 to 1500 Kg/m^3 . The specific gravity of fly ash generally ranges between 1.9 and 2.8 and the color is generally gray or tans [37].

ASTM C618 class F and class C fly ashes are commonly used as pozzolanic admixture for general purpose concrete. Class F materials are generally low – calcium (less than 10 % CaO) fly ashes with carbon contents usually less than 5% but some may be as high as 10 %. Class C materials are often high calcium (10 % to 30 % CaO) fly ashes with carbon contents less than 2 %.

Some fly ashes meet both class F and class C classifications. Class F fly ash is often used at dosages of 15 % to 25 % by mass of cementitious material. Class C fly ash is used at dosages of 15% to 40% by mass of cementitious material.

2.9.3 Slag:

Ground granulated blast – furnace slag is made from iron blast – furnace slag.



Figure (2-10) Ground granulated blast-furnace slag.

The molten slag at a temperature of about 1500 C (2730 F) is rapidly chilled by quenching in water to form a glassy sand like granulated material. The specific gravity for ground granulated blast – furnace slag is in the range of 2.85 to 2.95.

The bulk density varies from 1050 to 1357 Kg/m³ [37]. The rough and angular – shaped ground slag presented in Figure (2-10), and Figure (2-11) hydrates and sets in a manner similar to Portland cement due to the presence of water and an activator, NaOH or CaOH.

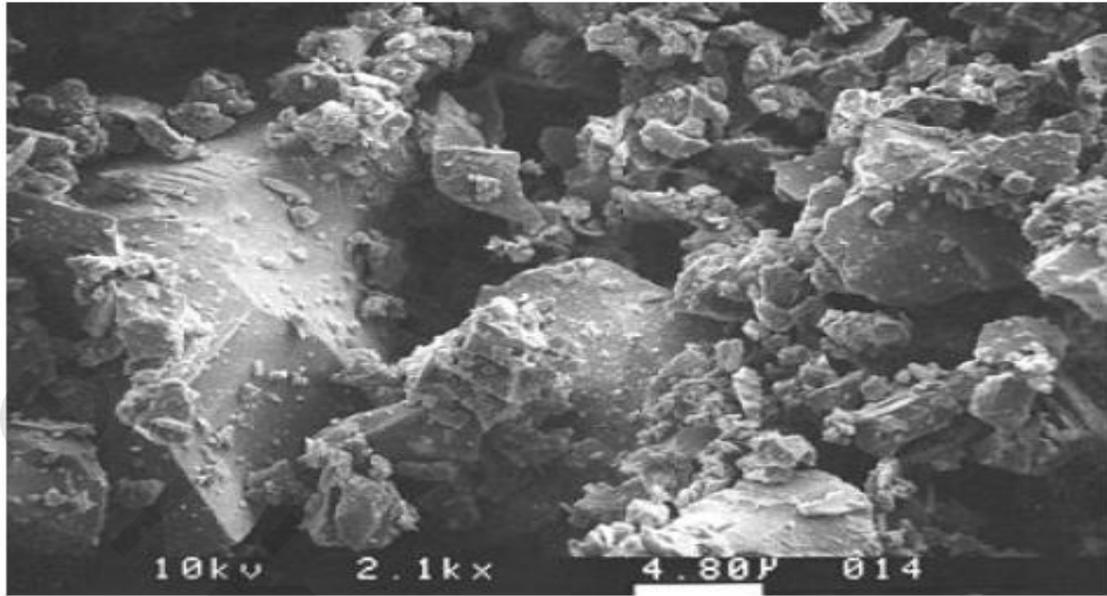


Figure (2-11) Scanning electron microscope micrograph of slag particles

Granulated blast furnace slag was first developed in Germany in 1853 [47]. Ground slag has been used as a cementitious material in concrete since the beginning of the 1900s [48].

2.9.4 Silica fume:

Silica fume is a by-product material that is used as a pozzolanic material (Figure 2 – 12).



Figure (2-12) Silica fume powder

This by-product is a result of the reduction of high – purity quartz with coal in an electric arc furnace during the manufacture of silicon or ferrosilicon alloy.

Figure (2–13) shows micrograph of silica – fume particles [37].

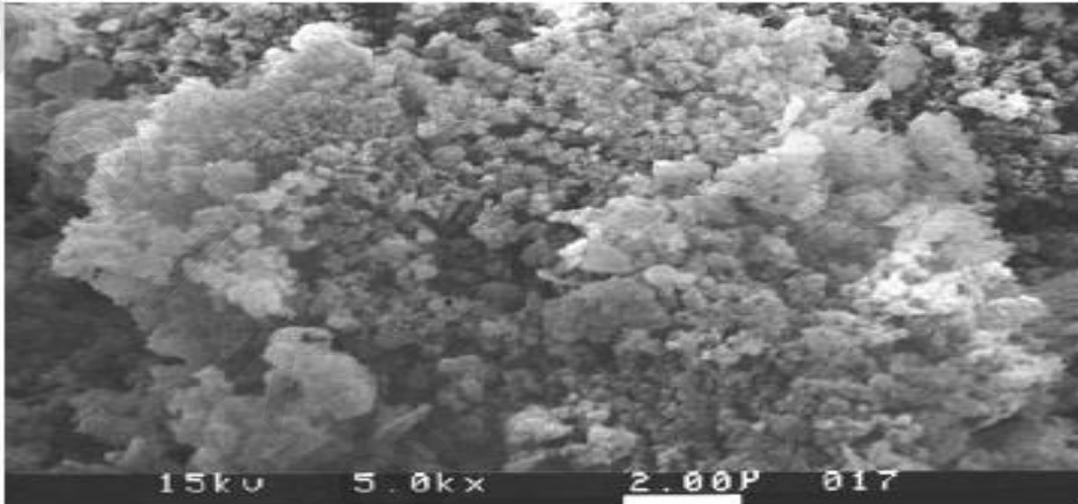


Figure (2-13) scanning electron micrograph of silica fume particles.

Silica fume is extremely fine with particles less than 1 μm in diameter and with an average diameter of about 0.1 μm , about 100 times smaller than average of cement particles. Condensed silica has a surface area of about 20,000 m^2/kg . For comparison, Type I and Type III cements have surface areas of about 300 to 400 m^2/kg and 500 to 600 m^2/kg (Blaine) respectively.

The relative density of silica fume is generally in the range of 2.2 to 2.5 (Portland cement has a relative density of about 3.15). The bulk density of silica fume varies from 130 to 430 Kg/m^3 .

Silica fume is used in amounts between 5 % and 10 % by mass of the total cementitious material [37]. It is used in applications where a high degree of impermeability is needed and in high strength concrete.

2.9.5 Natural Pozzolans:

The term "pozzolan" comes from a volcanic ash mined at pozzoli, a village near Naples, Italy [37]. The North American experience with natural Pozzolans dates back to early 20th. century public works projects, such as dams, where they were used to control temperature rise in mass concrete and provide cementitious material. In addition to controlling heat rise, natural pozzolans were used to improve resistance to sulfate attack and were among the first materials to be found to mitigate alkali – silica reaction.

The most common natural pozzolans used today are processed materials, which can heat treated in a kiln and then ground to a fine powder. They include calcined clay, calcined shale, and metakaolin. Figure (2 –14), Figure (2 –15), and Figure (2 – 16) show the scanning electron microscope of different natural pozzolanic materials.

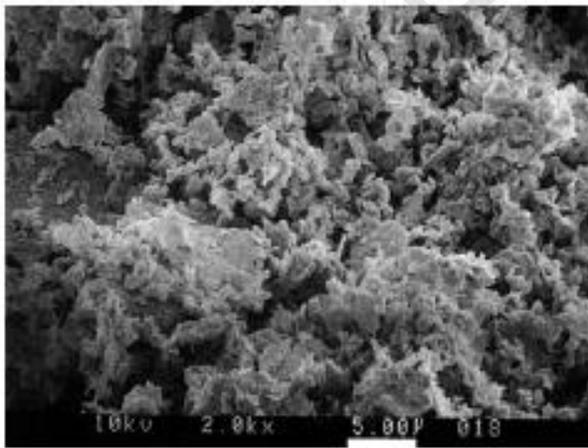


Figure (2-14)

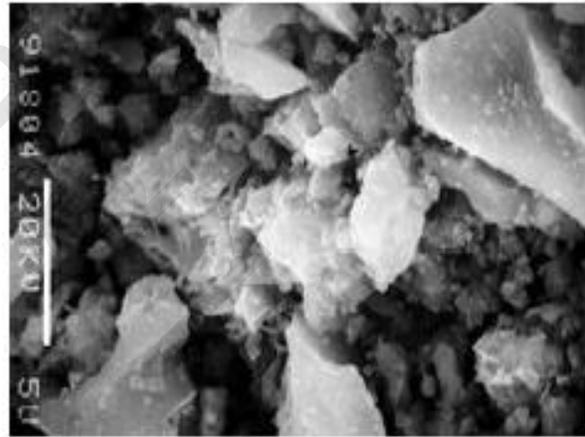


Figure (2-15)

Figure (2-14) and Figure (2-15) Scanning electron microscope micrograph of calcined clay and calcined shale particles, respectively



Figure (2-16) Metakaolin, a calcined clay

Calcined clays are used in general purpose concrete construction much the same as other pozzolans. They can be used as a partial replacement for the cement, typically in the range of 15 to 35 %, and to enhance resistance to sulfate attack, control alkali –silica reactivity, and reduce permeability. Calcined clays have a relative density of between 2.40 and 2.61 with Blaine fineness ranging from 650 to 1350 m²/kg.

Calcined shale may contain on the order of 5 % to 10 % calcium, which results in the material some cementing or hydraulic properties on its own.

Metakaolin, a special calcined clay, is produced by low – temperature calcinations of high purity kaolin clay. The product is ground to an average particle size of about 1 to 2 micrometers. Metakaolin is used in special applications where very low permeability or very high strength is required. In these applications, metakaolin is used more as an additive to the concrete rather than a replacement of cement. Typical additions are around 10 % of the cement mass.

Natural pozzolans are classified by ASTM C 618 as class N pozzolans. ACI 232 provides a review of natural pozzolans. The following table (2-4) illustrates typical chemical analysis and selected properties of pozzolans [37].

Table (2-4) presents chemical analysis and selected properties of typical fly ash, slag, silica fume, calcined clay, calcined shale, and metakaolin.

Table (2-4) chemical analysis and selected properties of typical fly ash, slag, silica fume, calcined clay, calcined shale, and metakaolin

	Class F fly ash	Class C fly ash	Ground slag	Silica fume	Calcined clay	Calcined shale	Metakaolin
SiO ₂ , %	52	35	35	90	58	50	53
Al ₂ O ₃ , %	23	18	12	0.4	29	20	43
Fe ₂ O ₃ , %	11	6	1	0.4	4	8	0.5
CaO, %	5	21	40	1.6	1	8	0.1
SO ₃ , %	0.8	4.1	9	0.4	0.5	0.4	0.1
Na ₂ O, %	1.0	5.8	0.3	0.5	0.2	—	0.05
K ₂ O, %	2.0	0.7	0.4	2.2	2	—	0.4
Total Na eq. alk, %	2.2	6.3	0.6	1.9	1.5	—	0.3
Loss on ignition, %	2.8	0.5	1.0	3.0	1.5	3.0	0.7
Blaine fineness, m ² /kg	420	420	400	20,000	990	730	19,000
Relative density	2.38	2.65	2.94	2.40	2.50	2.63	2.50

2.9.6 Rice Husk Ash:

Rice Husk ash is obtained by burning rice husk and it has highly pozzolanic characteristic. The properties are greatly affected by the burning conditions. The large amount of unburnt carbon due to the incomplete combustion exist and makes the color of rice husk ash black, whereas, the burning is done under enough air supply condition the rice Husk ash become gray and white [46]. The white rice Husk ash has better quality compared to the black rice Husk ash due to the existence of carbon affecting adversely on the reactivity [37].

2.9.7 Effects of pozzolans on freshly mixed concrete:

- **Water Requirements**

Concrete mixtures containing fly ash generally require less water (about 1 % to 10% less at normal dosages) for a given slump than concrete containing only Portland cement. Higher dosages can result in greater water reduction. However, some fly ashes can increase water demand up to 5 % [49].

Fly ash reduces water demand in a manner similar to liquid chemical water reducers [50]. Ground slag usually decreases water demand by 1 % to 10 % depending on dosage. The water demand of concrete containing silica fume increases with increasing amounts of silica fume, unless a water reducer or plasticizer is used. Calcined clays and calcined shales generally have little effect on water demand at normal dosages [37].

- **Workability**

Fly ash, slag, and calcined clay and shale generally improve the workability of concrete at the same slump [37]. Silica fume may contribute to stickiness of a concrete mixture.

- **Bleeding and segregation**

Concretes using fly ash generally exhibit less bleeding and segregation than plain concrete. The reduction in bleed water is primarily due to the reduced water demand in fly ash.

Concretes containing ground slags of comparable fineness to that of the cement tend to show an increased rate and amount of bleeding than plain concretes, but this appears to have no adverse effect on segregation [37].

Slags ground finer than cement reduce bleeding. Silica fume is very effective in reducing both bleeding and segregation. Calcined clays, calcined shales and metakaolin have little effect on bleeding.

- **Heat of hydration**

Fly ash, natural pozzolans, and ground slag have a lower heat of hydration than Portland cement. This reduction in temperature rise is especially beneficial in concrete used for massive structures. Silica fume may or may not reduce the heat of hydration.

- **Setting time**

The use of fly ash and ground granulated blast – furnace slag will generally retard the setting time of concrete. The degree of set retardation depends on factors such as the amount of Portland cement, water requirement, the Type and reactivity of the slag or pozzolan degree, and the temperature of the concrete. Set retardation is an advantage during hot weather, allowing more time to place and finish the concrete. Calcined shale and clay have little effect on setting time.

- **Pumpability**

The use of supplementary cementing materials generally aids the pumpability of concrete.

- **Plastic shrinkage cracking**

Silica fume may exhibit an increase in plastic shrinkage cracking [37]. This is because of its low bleeding characteristics. Other pozzolans and slag generally have little effect on plastic shrinkage cracking. Supplementary cementing materials that significantly increase set time can increase the risk of plastic shrinkage cracking [37].

2.9.8 Effects of pozzolans on hardened concrete strength:

Fly ash, ground granulated blast – furnace slag, calcined clay, metakaolin, calcined shale, and silica fume contribute to the strength gain of concrete. However, the strength of concrete containing these materials can be higher or lower than the strength of concrete using Portland cement as the only cementing material.

The Impact Resistance and Abrasion Resistance of concrete are related to compressive strength and aggregate type. Supplementary cementing materials generally do not affect these properties beyond their influence on strength.

2.10 Ready mixed concrete:

2.10.1 Introduction:

The concrete that produced by a mixture of all the required components at certain ratios controlled by computer, being mixed in a mixer and delivered to the client as fresh concrete is called " Ready mixed concrete (RMC).

RMC is one of the most popular building materials owing to its ability to customize its properties for different applications [51]. RMC has several benefits when compared to concrete prepared by conventional methods in construction sites [52]:

- 1) It is subjected to a better quality control.
- 2) The materials used in the production of RMC are selected and stored properly in the batching plant.
- 3) Ingredient materials for concrete production are weighted and mixed by automated devices.
- 4) The manufacture and transportation of this concrete are performed by skilled personnel.

All of these factors results introduce better quality product of concrete in standard conditions. Concrete as a new material came first to building construction and later to other types of constructions [53].

2.10.2 History of RMC:

Table (2-5) RMC production in Europe and USA [54].

Decade	History
1900-1910	Germany (1903)
1911-1920	Spain (1912) USA (1913) Holland (1918)
1921-1930	Denmark (1926) UK (1930)
1931-1940	Sweden (1932) France (1933)
1941-1950	Iapan (1949)
1951-1960	Finland (1958)
1961-1970	Austria , Ireland (1961) Italy (1962) Greece (1968)

*RMC is used in Egypt in the decade of 1970-1980.

2.10.3 Types of concrete plants:

There are two types of ready mixed concrete plants [55]:

- Central plants (sometimes called "wet " plants)

A concrete batch is made up by an operator at the plant before it is loaded into the truck. Central plants offer producers more control over quality and consistency of the concrete mix, but require that a load be dropped in a shorter time.

- Dry plants

The dry components of concrete are weighed and loaded separately into the truck mixer; water is then added and the final mix is made. Concrete plants are located in areas convenient for deliveries of raw materials (cement, sand, gravel, and other aggregates).

Components of concrete plants.

A typical plant consists of storage areas for the raw materials ; feeder ; tanks and conveyors for holding, mixing, and dispensing raw materials ; a control room to weigh, mix, and load materials into trucks (these operations are often computerized) ; a dispatch room to schedule truck pickup and delivery ; a yard area where trucks are washed off and parked when not in use ; a maintenance garage; and offices [55]. Figures (2-17) to (2-23) show the components of concrete plants:



Figure (2-17) Components of concrete plants

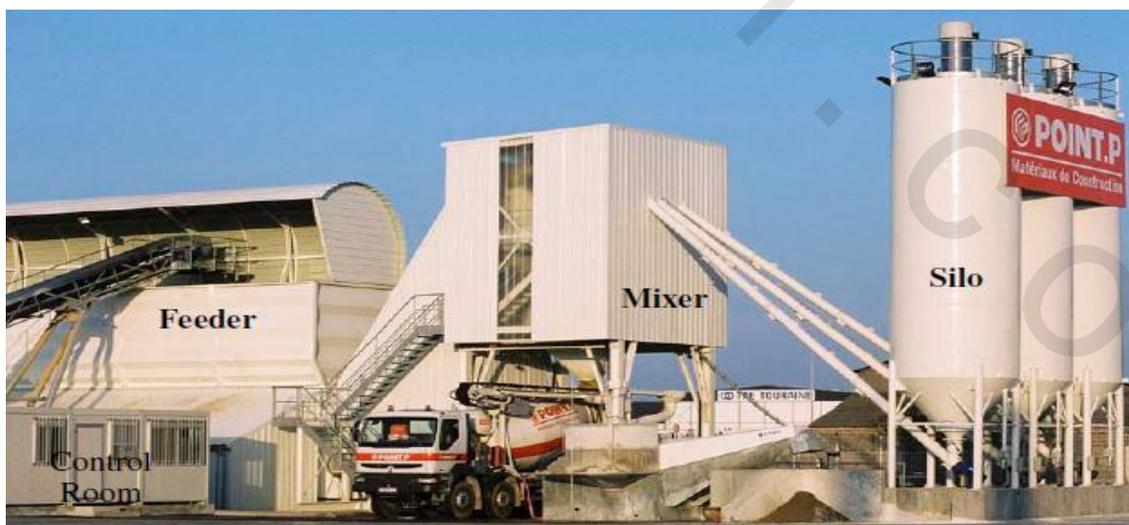
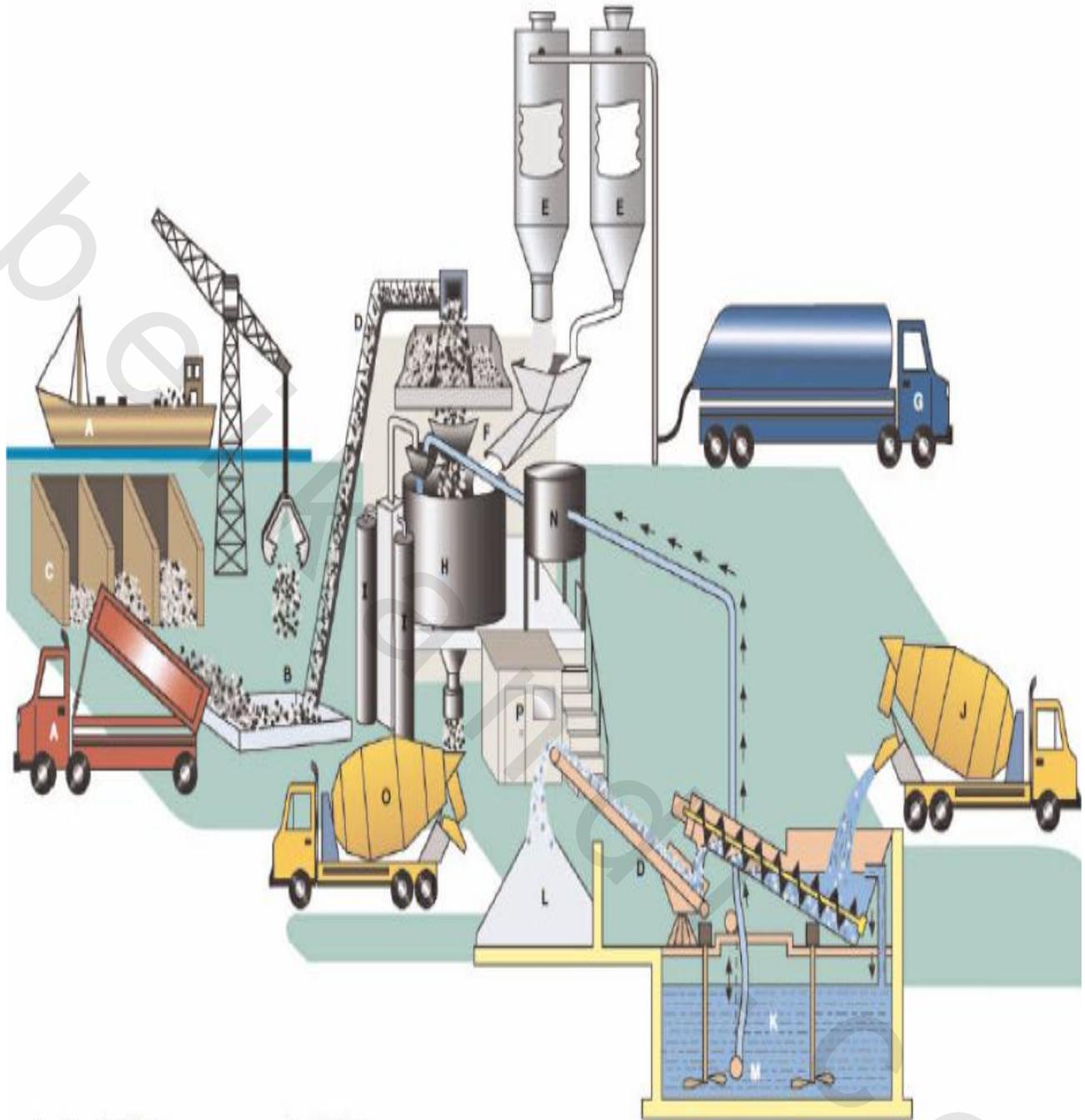


Figure (2-18) Components of concrete plants



- | | |
|---------------------------------|--|
| A Aggregate delivery | I Admixtures |
| B Aggregate receiving hopper | J Ready mix truck with returned concrete |
| C Aggregate storage | K Recycled water |
| D Conveyor belt | L Reclaimed aggregates |
| E Cementitious material storage | M Pump |
| F Weigh hopper | N Water storage |
| G Cement delivery | O Concrete loaded in ready-mix truck |
| H Mixer | P Control Room |

Figure (2-19) Components of concrete plants

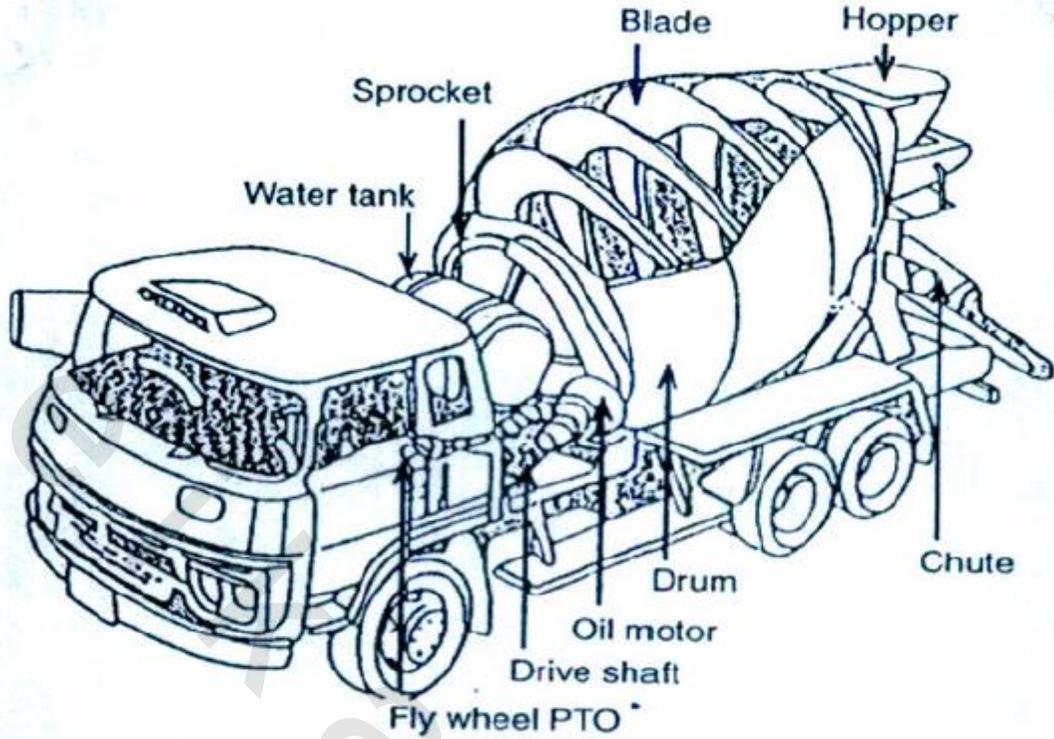


Figure (2-20) Typical construction of a truck agitator drum



Figure (2-21) Ready mixed concrete placed directly in final location using chute discharge from a truck mixer.



Figure (2-22) Components of concrete plants (pump+mixer)



Figure (2-23) The vertical or horizontal movement of a truck mounted pump and boom to cast the concrete in the desired location.

2.10.4 Limitations of delivery time:

It is true that for each mix and particular means of compaction there will be a time after which concrete will be losing workability at too great rate to allow full compaction to be obtained [56].

This limiting time will depend on the mix and on the external conditions, and will be longer for, high-workability mixes, in cold weather and when vibration is employed [56]. However, it is usually impractical to specify different time limits for different mixes and conditions [56].

Some specifications provide a single time limit, covering all mixes and conditions, which is easy to comprehend and is intended to allow the contractor sufficient time subsequently to place and compact the delivered concrete without appreciable change in workability [56]. For Example, the transportation time be no longer than 1 ½ h according to ASTM C94 and ES: 5130 and not longer than 2.0 h according to BS 5328 and IS4926. The reasonableness of this simple approach can be assessed for average ambient conditions from tables (2-6) and (2-7) [56].

Table (2-6) Approximate times of agitation after which the rate of loss in compacting factor exceeds 0.05 per hour, under average conditions [56].

Aggregate cement ratio (by weight)	Agitation time (h)	
	Initial slump 25mm	Initial slump 125mm
3	1	2
4.5	1.5	3
6	2.5	4
9	3.5	5

Table (2-7) Approximate times of agitation at which a strength reduction of 2N/mm^2 occurs below that for concrete of the same slump but compacted shortly after mixing [56].

Aggregate cement ratio (by weight)	Agitation time (h)	
	Initial slump 25mm	Initial slump 125mm
3	1	2
4.5	2	3
6	3	4
9	4	over 5

For example, if a time limit of two hours is specified then, from table (2-6), most concretes delivered at the specified workability within this time would not be losing workability at an excessive rate and, from table (2-7), no excessive strength loss would be expected compared with concrete of the specified slump placed soon after mixing. Kirca and others stated that as a mixing time increases slump decreases [57].

2.10.5 Retempering of concrete:

Retempering is defined by ACI 116 as the "Addition of water and remixing of concrete or mortar which has lost enough workability to become unplaceable or unsalable".

2.10.5.1 Retempering with water:

When retempering of concrete is done only to restore slump as per ACI 116 definition, it typically causes a loss in compressive strength of 7 – 10 % and it can be much higher depending on the amount of retempering water added [58]. Figure (2-24) illustrates the water needed for retempering of concrete mixture in relation with mixing time [59].

As seen from the graph, the relation between the amount of water used for retempering and the mixing time is rather steep up to 120 min of mixing, and then the increase is slight later on. Retempering with water to restore the initial slump results in an increase in the water to cement ratio and this in turn causes a substantial decrease in the strength of concrete.

Figure (2-25) represents the relationship between the water needed for retempering of concrete and the strength loss in relation with mixing time [58].

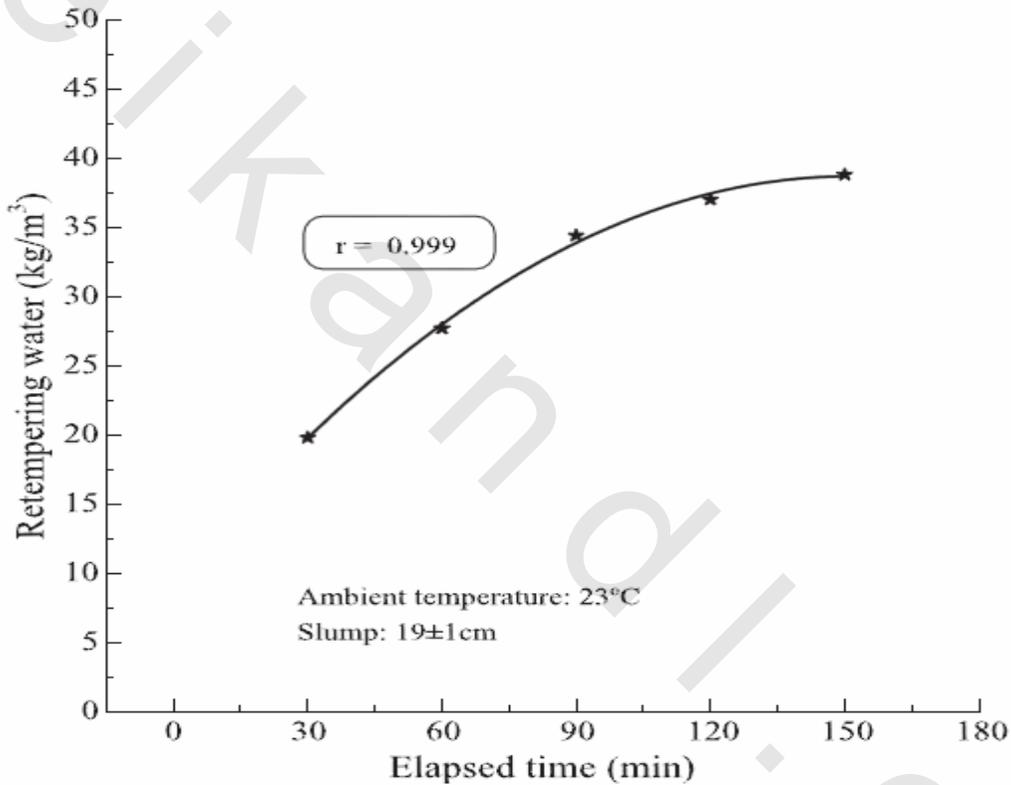


Figure (2-24) Retempering water added to concrete to restore the initial slump [58]

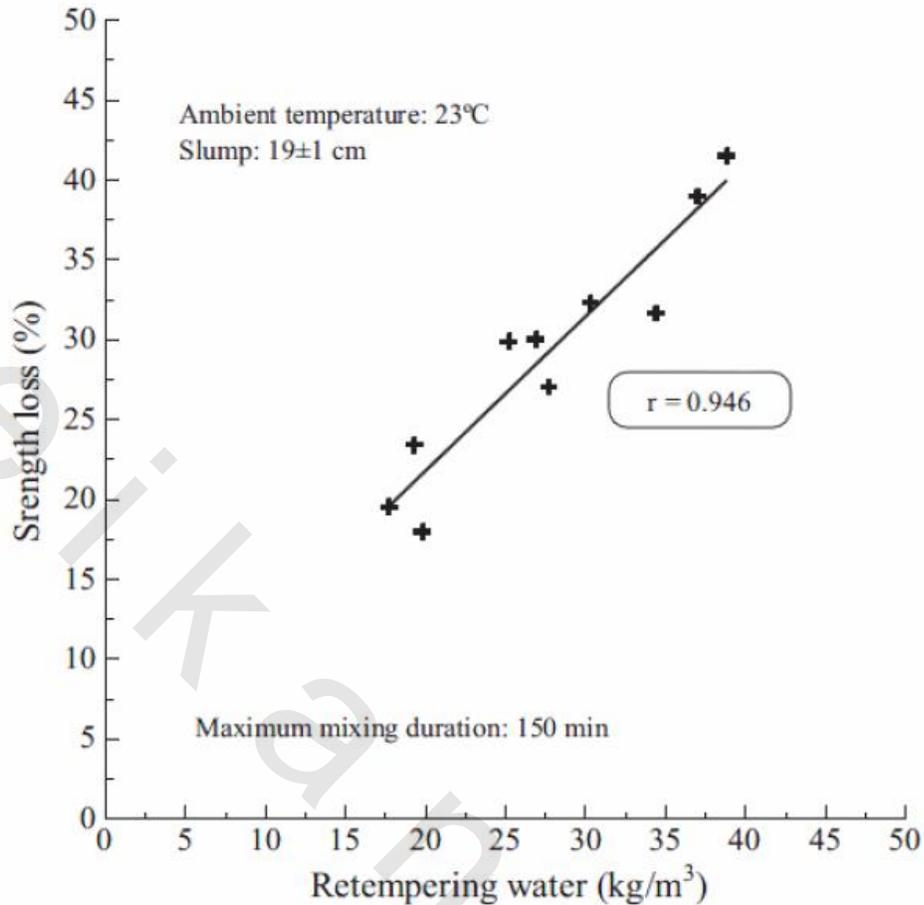


Figure (2-25) Relation between strength loss and retempering water [58]

2.10.5.2 Retempering with admixture:

The relation between the amount of admixture used for retempering to restore the initial slump with respect to mixing time is given in Figure (2-26)

As seen from the graph, the increase in the superplasticizer used for retempering is quite straightforward with mixing time. It is clearly seen that an additional superplasticizer of about 0.7 % by weight of the cement content is needed at the end of a mixing period of 30 min for retempering to restore the initial slump of concrete, and it is only about 1.2 % by weight of the cement at the end of 150 min of mixing [58].

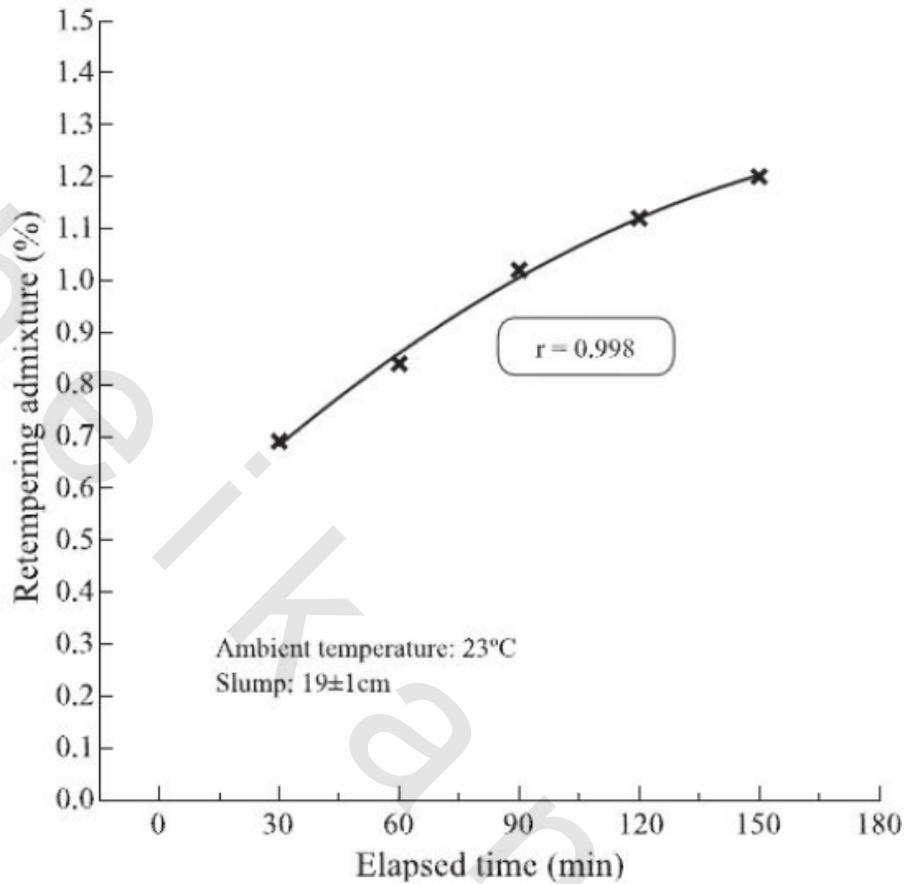


Figure (2-26) Retempering admixture added to concrete to restore the initial slump [58]

Figure (2 -27) represents the effect of retempering with water and with a superplasticizer on the strength of concrete in relation with mixing time [58]. The effect of mixing time on the strength of reference concrete with no retempering is also given in the graph.

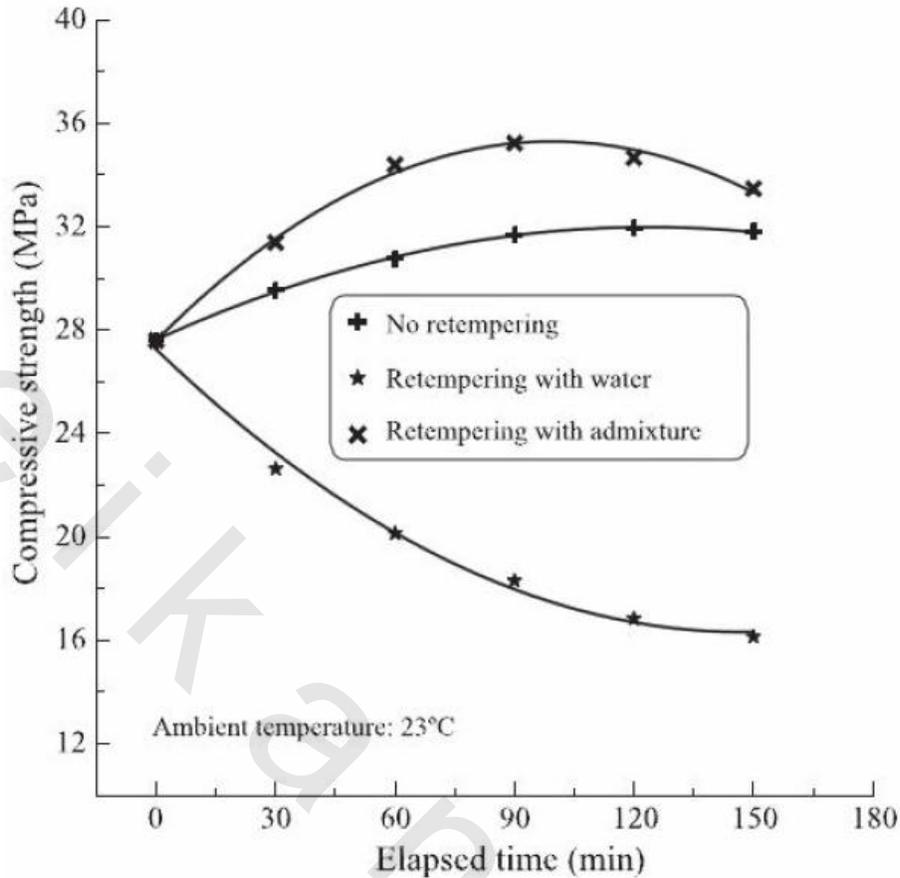


Figure (2-27) Effect of retempering on the compressive strength of concrete subjected to prolonged mixing [58]

A slight increase in the strength of reference concrete is observed due to the observed increase in its unit weight as seen from Figure (2 – 28) [58]. The total increase in the unit weight of reference concrete with no retempering is about 27 kg /m³ which corresponds to a decrease in the air content of concrete slightly over 1 % [58]. This in turn reflects an increase of about 15 % in the strength of concrete at the end of 150 min of mixing.

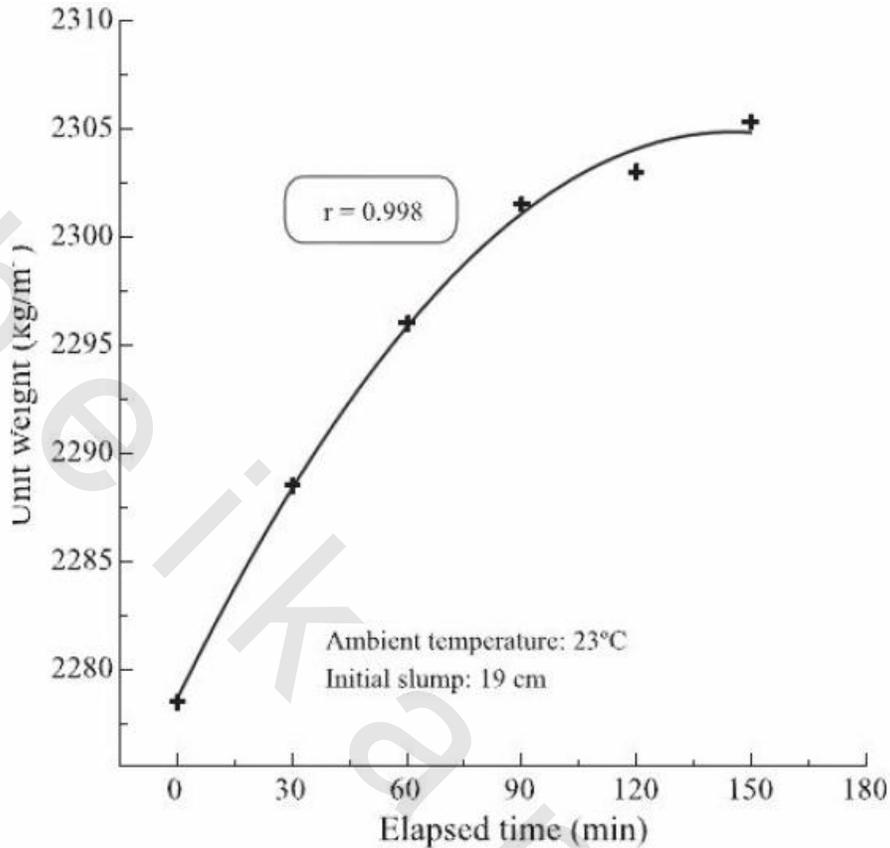


Figure (2-28) Effect of prolonged mixing on the unit weight of concrete [58]

2.10.5.3 Effect of retempering and elapsed time, and temperature on setting time:

Figure (2-29) shows the effect of temperature and Type D admixtures on standard penetration and setting times of concrete [59]. This Figure shows that the use of admixture retards setting. Also as the ambient temperature rises the setting time decreases.

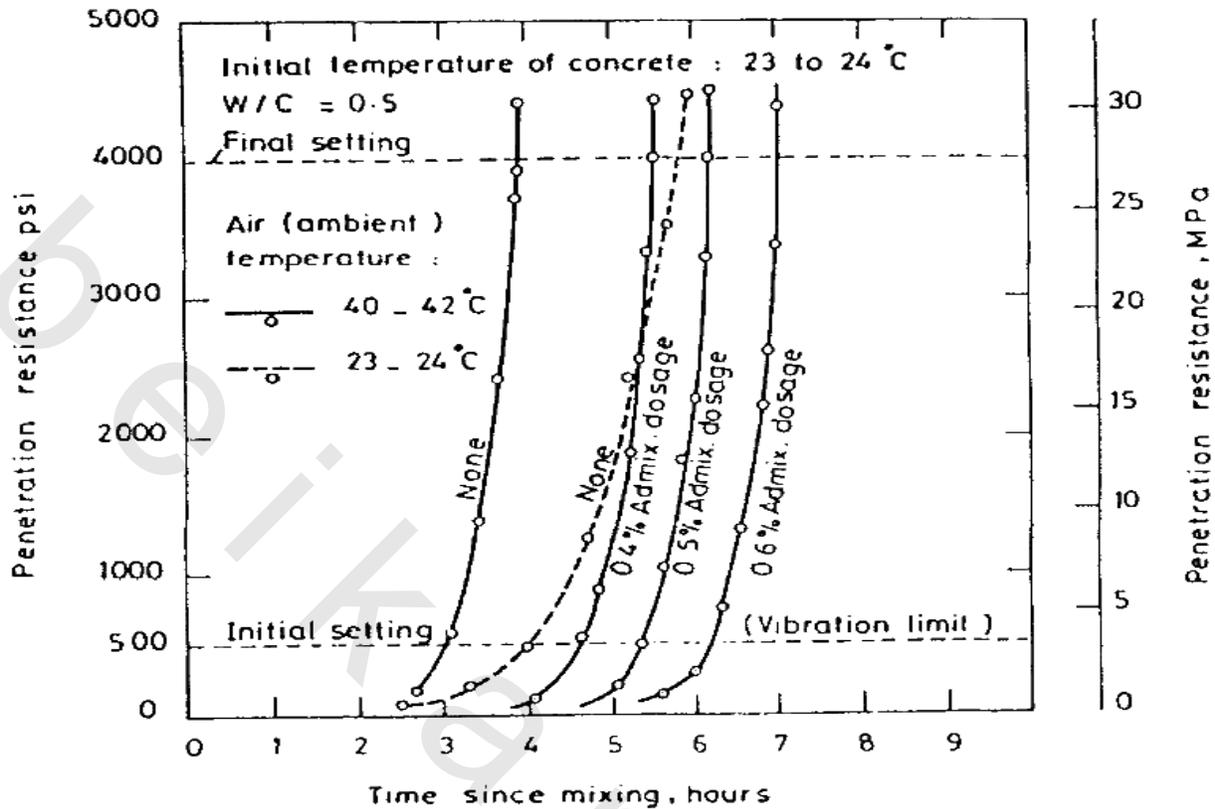


Figure (2-29) Effect of temperature and Type D admixture on standard penetration and setting times of concrete determined in accordance with ASTM C 403[59]

Figure (2-30) shows the effect of mixing time, type of admixture, and type of cement on initial setting [45]. From this figure it was noticed that:

- At a mixing period of 1.5 h (that's recommended to be a maximum mixing time according to ASTM C94 and ES : 5130 [60]), the initial setting time slightly decreases compared to that at a mixing period of 15 min for OPC and SRC concrete using Type F and G admixtures.
- At a mixing time of 2.0 h (that's recommended to be maximum mixing time according to BS 5328 [61] and IS 4926 [62]), the use of Type F chemical admixture with OPC and SRC concrete yields almost the same initial setting time compared with 15 min mixing time.
- At a mixing time of 2.0 h, the use of Type G chemical admixture with OPC and SRC concrete increases the initial setting time in the range of 30 to 40 min.

- At a mixing time of 2.5 h, the use of Type F chemical admixture with OPC and SRC concrete increases the initial setting time by 40 and 29 min respectively.
- At a mixing time of 2.5 h, the use of Type G chemical admixture with OPC and SRC concrete increases the initial setting time by 85 and 75 min respectively.

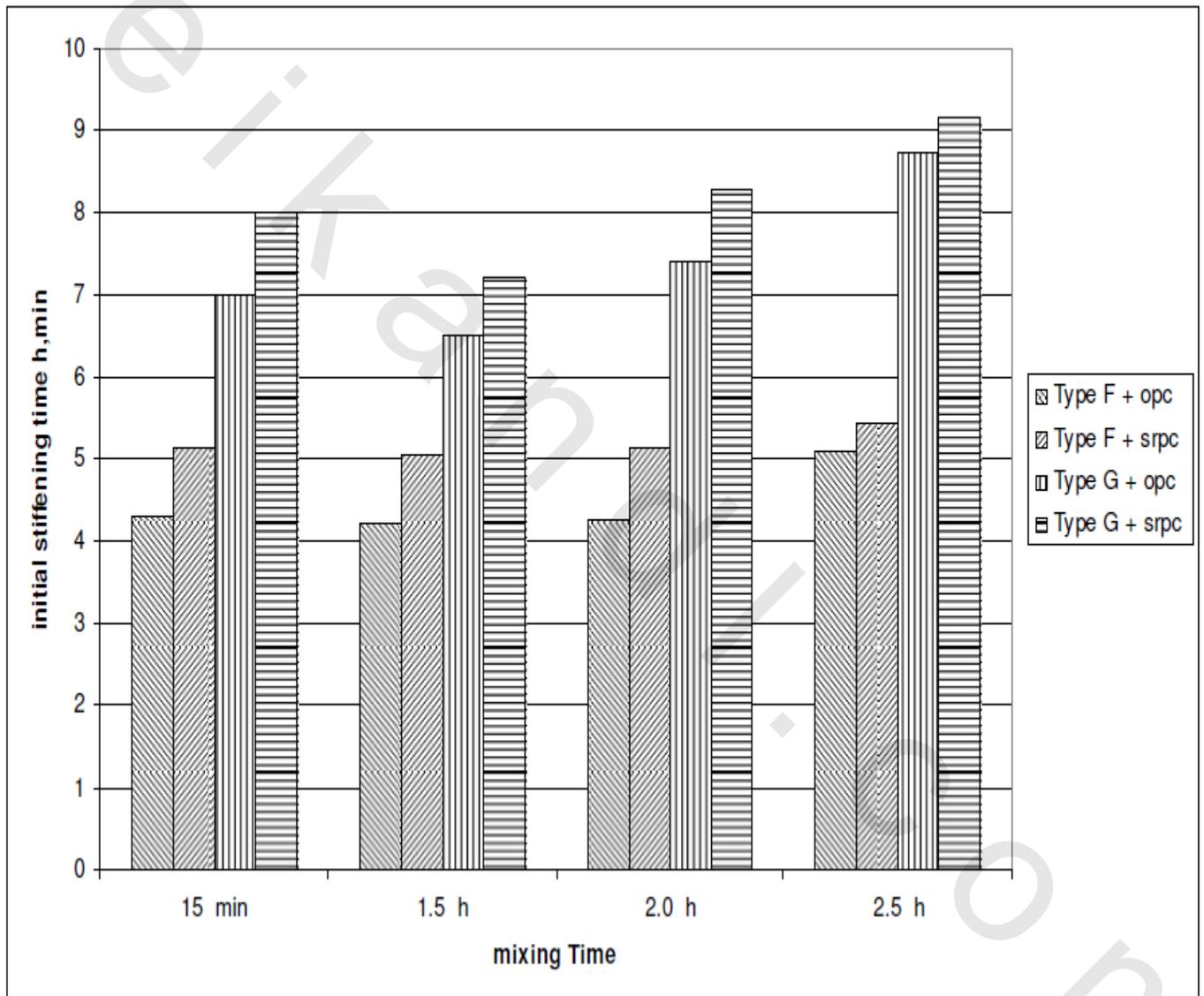


Figure (2-30) Initial setting time for ordinary and sulfate resisting cement at different mixing time [45]

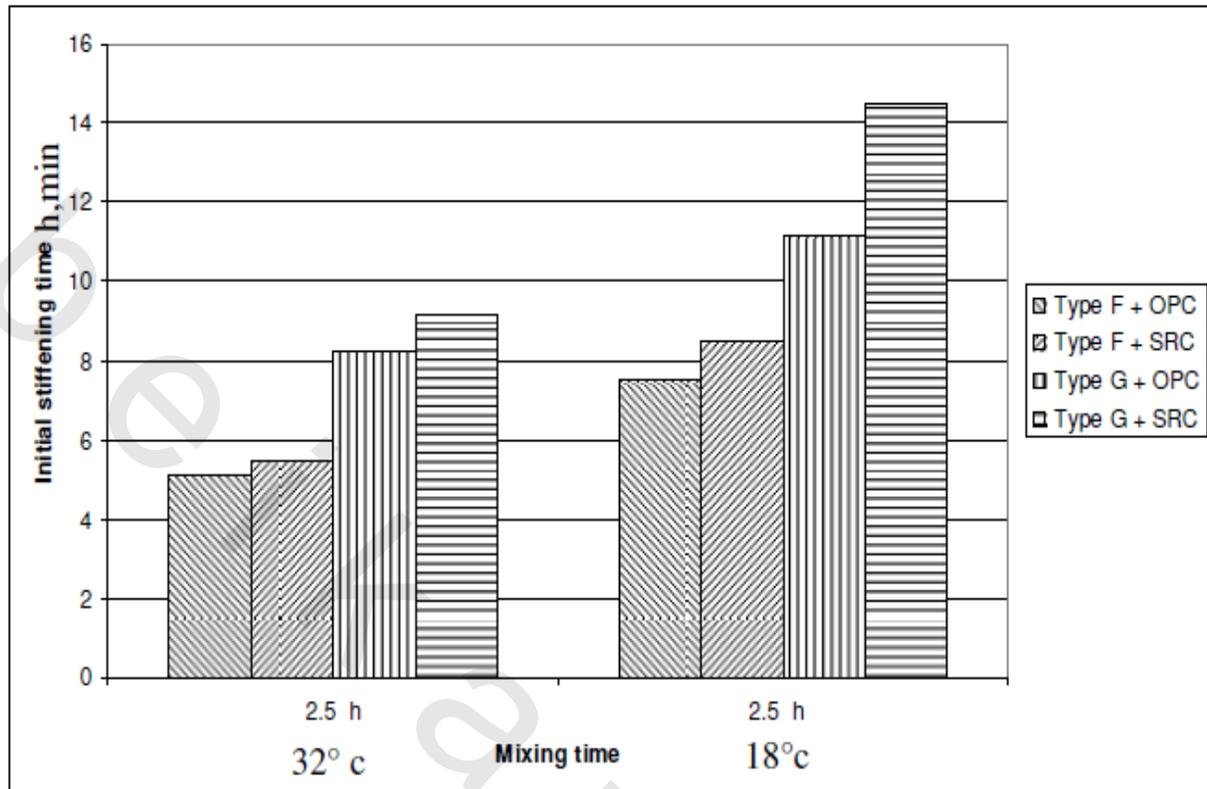


Figure (2-31) Effect of ambient temperature on Initial setting time [45]

It was noticed from Figure (2-31) that the initial setting times for different types of admixtures and cement at 32° c is lower than that at 18 °c [45].

2.10.5.4 Effect of retempering using different methods on compressive strength of concrete:

Kamal and others concluded that in retempering concrete process, the compressive strength of recycled self-compacted concrete is slightly higher than the compressive strength just after mixing [63].

Bashandy studied different methods of retempering and different elapsed time at which the concrete is post mixed. He studied the effect of retempering using water, a mix of cement and water, and a mix of water and superplasticizer [64].

Figure (2–32) shows that retempering using a mix of cement and water enhances 28 days compressive strength [64].

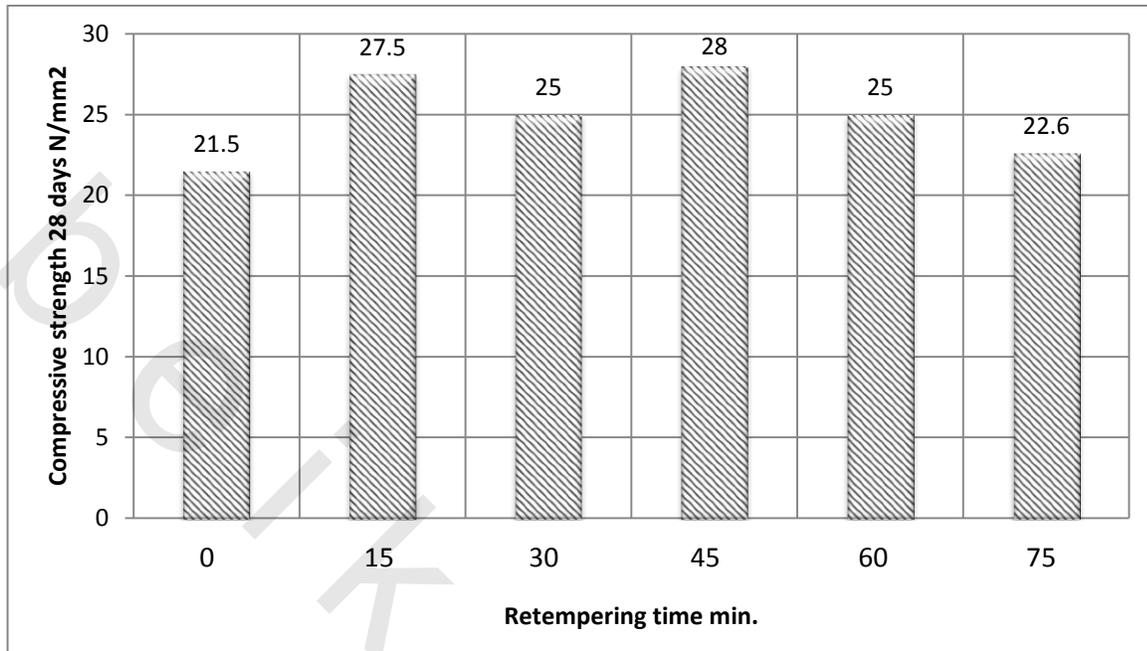


Figure (2-32) Effect of retempering using a mix of cement and water on compressive strength at different retempring time [64]

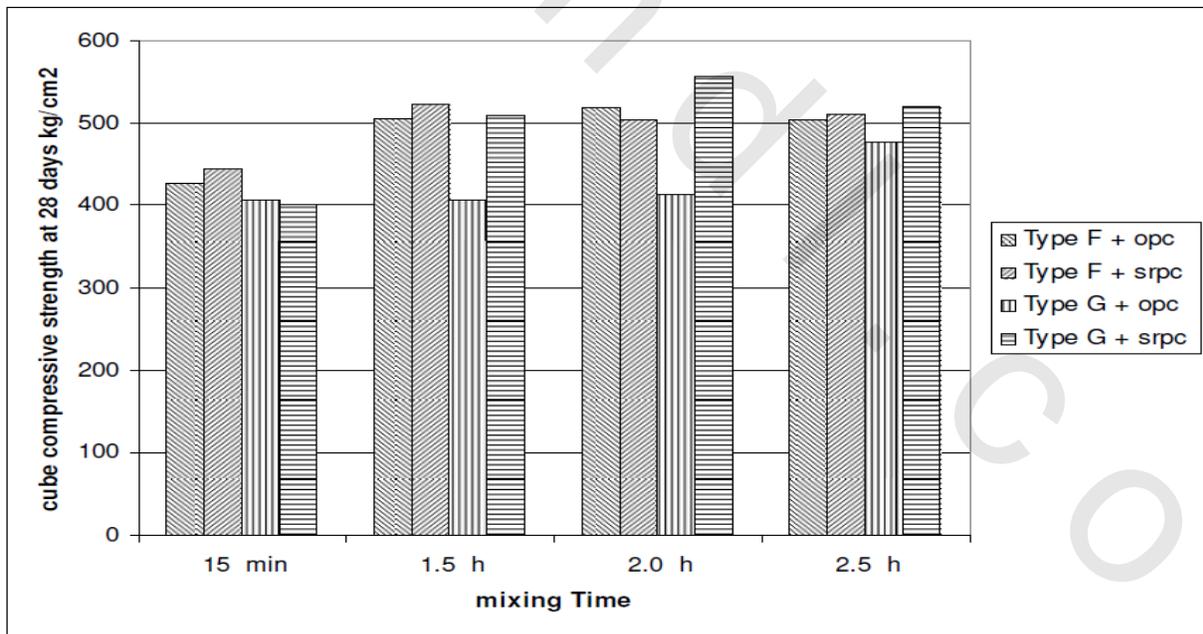


Figure (2-33) Effect of retempering process on compressive strength at 28 days in relation with mixing times [45]

Figure (2-33) shows that, the increase in mixing time generally increases the compressive strength for different types of cement and admixture [45].

2.10.5.5 Effect of retempering on natural absorption:

From Figure (2-34), it was noticed that:

- The natural absorption decreases at the end of 1.5 h of mixing compared with that at a mixing period of 15 min for different types of cement and superplasticizer [45].
- Using Type F admixture in retempering process of OPC concrete at 2.0 h mixing time ensures the least natural absorption. At a mixing time of 2.5 h, the natural absorption starts to increase but it is still lower than that of 15 min mixing time.

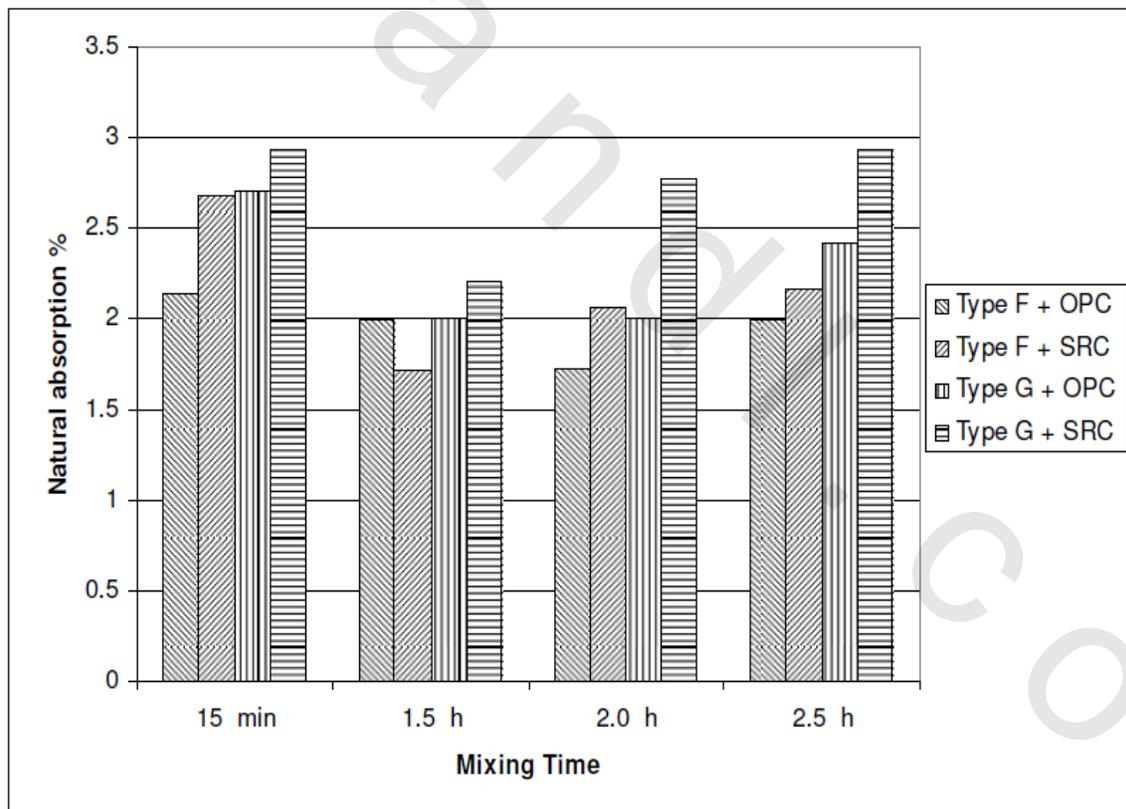


Figure (2-34) Effect of retempering process on natural absorption in relation with mixing times for different types of cement and superplasticizer [45]