

ACCELERATOR AGENTS IN CONCRETE

Dr Ayham Al Rahawi, Aliaa Ali Al-Kyomi

Chemical Engineering Department, Nizwa University

Abstract. Concrete is the world's most widely used man-made material, and there is a huge database of empirical knowledge on how to mix, place, and cure concrete for specific applications. This knowledge has been extensively codified into standards that ensure that concrete has the required strength, durability, and other properties needed to fit a specific application. However, possessing some knowledge of the chemical processes that underlie the workability of concrete, the time to set, the ultimate strength, the tendency to shrink on drying, the tendency to deteriorate under adverse environmental conditions and other phenomena can be a great advantage.

Cement can be described as material with adhesive properties, which make it capable of binding mineral fragments into a compact whole. For constructional purposes the meaning of the term cement is restricted to the binding materials used with stones, sand, bricks and building blocks. The cements of interest in the making of concrete have the property of setting and hydraulic cement. Hydraulic cements consist mainly of silicates and aluminates of lime, and can be classified broadly as natural cement, Portland cement and aluminous cement. In general many additives were used to give additional strength and flexibility.

In this project the effect of the additive to cement and concrete were tested. Aluminum sulfate and activated carbon were used and tested to accelerate the Drying and Hardening of cement. Different percentages of aluminum sulfate and activated carbon were tested. The data were analyzed to examine the effect of this addition and observe the time that takes to be Hardening.

Experimental results showed that the addition of aluminum sulfate will improve the concrete hardness by shortening the setting time (time for hardness) of cement and improve the early strength; however, after 28 days results showed that the hardness decreases as a result of reducing the fluidity due to the presence of sulfate.

Also, activated carbon has benefits in concrete; it is better workability and ultimate strength.

INTRODUCTION

Cement can be described as material with adhesive properties, which make it capable of binding mineral fragments into a compact whole. For constructional purposes the meaning of the term cement is restricted to the binding materials used with stones, sand, bricks and building

blocks. The cements of interest in the making of concrete have the property of setting and hydraulic cement. Hydraulic cements consist mainly of silicates and aluminates of lime, and can be classified broadly as natural cement, Portland cement and aluminous cement. In general many additives were used to give additional strength and flexibility.

Structural cement belongs to the class of cements which harden by reacting with water and give a water-resistant product. Portland cement, high-alumina cement and slag cement are typical of this class of hydraulic cements, but not gypsum, which in spite of the fact that it hardens by reacting with water, cannot resist water over longer periods because it is soluble in it. Hardened lime is, however, water-resistant, but because its hardening depends on the absorption of carbon dioxide and not of water, lime is also excluded from the class of hydraulic cements.^[1]

The principal raw materials used in the manufacture of hydraulic cements are lime, silica, alumina and ferric oxide. It is with these that we shall deal first.^[2]

Four essential elements are needed to make cement. They are Calcium, Silicon, Aluminum and Iron. Calcium (which is the main ingredient) can be obtained from limestone, whereas silicon can be obtained from sand and/or clay. Aluminum and iron can be extracted from bauxite and iron ore, and only small amounts are needed. Cement is usually gray. White cement can also be found but it is usually more expensive than gray cement.

Cement mixed with water, sand and gravel, forms concrete. Cement mixed with water and sand, forms cement plaster. Cement mixed with water, lime and sand, forms mortar.

Cement powder is very, very fine. One kilo (2.2 lbs) contains over 300 billion grains, although we haven't actually counted them to see if that is completely accurate! The powder is so fine it will pass through a sieve capable of holding water.^[2]

Composition of concrete

concrete is a composite material which consists essentially of a binding medium within which are embedded particles or fragments of a relatively inert mineral filler in Portland cement concrete the binder or matrix either in the plastic or in the hardened state is a combination of Portland cement and water; it is commonly called the "cement paste". The filler material called "aggregate" is generally graded in size from a fine sand to pebbles or fragments of stone which in some concretes may be several inches in diameter.

In practical concrete mixtures the overall proportions of these principal components the binder and the aggregate are controlled by the requirements that (1) when freshly mixed the mass be workable or placeable (2) when the mass has hardened it possess strength and durability adequate to the purpose for which it is intended and (3) cost of the final product be a minimum consistent with acceptable quality .

The aggregate occupies roughly three-quarters of the space within a given mass . for convenience particles smaller than about 3/16 in .in diameter are designated as fine aggregate or sand . natural coarse aggregates may consist of gravel or crushed stone . other materials employed as aggregates include slag ,cinders, and artificial lightweight aggregates made of burned clay or shale .

The space not occupied by aggregate ,roughly one quarter of the entire volume of an average concrete , is filled with cement paste and air voids . after concrete has been placed , even though it has been compacted with considerable thoroughness , some entrapped air remains within the mass. In a freshly made and compacted concrete of suitable proportions ,the volume of unavoidable entrapped air is comparatively small, usually not over 1 or 2 percent . for particular purposes , however , there has developed in recent years the practice of incorporating in the mixture special.^[4]

ACCELERATING ADMIXTURES

An accelerating admixture is used to accelerate the rate of hydration (setting) and strength development of concrete at an early age. The strength development of concrete can also be accelerated by other methods: (1) using Type III or Type HE high-early-strength cement, (2) lowering the water-cement ratio by adding 60 to 120 kg/m³ (100 to 200 lb/yd³) of additional cement to the concrete, (3) using a water reducer, or (4) curing at higher temperatures.

When used, calcium chloride should be added to the concrete mixture in solution form as part of the mixing water. If added to the concrete in dry flake form, all of the dry particles may not be completely dissolved during mixing. Undissolved lumps in the mix can cause popouts or dark spots in hardened concrete.

The amount of calcium chloride added to concrete should be no more than is necessary to produce the desired results and in no case exceed 2% by mass of cementing material. When calculating the chloride content of commercially available calcium chloride, it can be assumed that:

1. Regular flake contains a minimum of 77% CaCl₂
2. Concentrated flake, pellet, or granular forms contain a minimum of 94% CaCl₂

An overdose can result in placement problems and can be detrimental to concrete. It may cause: rapid stiffening, a large increase in drying shrinkage, corrosion of reinforcement, and loss of strength at later ages.

TYPES OF PORTLAND CEMENT

Portland cement is a closely controlled chemical combination of calcium, silicon, aluminum, iron and small amounts of other compounds, to which gypsum is added in the final grinding process to regulate the setting time of the concrete. Some of the raw materials used to manufacture cement are limestone, shells, and chalk or marl, combined with shale, clay, slate or blast furnace slag, silica sand, and iron ore. Lime and silica make up approximately 85 percent of the mass.

Table1: General features of the main types of portland cement

	Classification	Characteristics	Applications
Type I	General purpose	Fairly high C_3S content for good early strength development	General construction (most buildings, bridges, pavements, precast units, etc)
Type II	Moderate sulfate resistance	Low C_3A content (<8%)	Structures exposed to soil or water containing sulfate ions
Type III	High early strength	Ground more finely, may have slightly more C_3S	Rapid construction, cold weather concreting
Type IV	Low heat of hydration (slow reacting)	Low content of C_3S (<50%) and C_3A	Massive structures such as dams. Now rare.
Type V	High sulfate resistance	Very low C_3A content (<5%)	Structures exposed to high levels of sulfate ions
White	White color	No C_4AF , low MgO	Decorative (otherwise has properties similar to Type I)

Composition of Portland Cement (OPC)

There are four minerals present in a Portland cement grain: tricalcium silicate (Ca_3SiO_5), dicalcium silicate (Ca_2SiO_4), tricalcium aluminate ($\text{Ca}_3\text{Al}_2\text{O}_5$) and calcium aluminoferrite ($\text{Ca}_4\text{Al}_n\text{Fe}_{2-n}\text{O}_7$). The formula of each of these minerals can be broken down into the basic calcium, silicon, aluminum and iron oxides.

The composition of cement is varied depending on the application. A typical example of cement contains 50–70% (Ca_3SiO_5), 15–30% (Ca_2SiO_4), 5–10% ($\text{Ca}_3\text{Al}_2\text{O}_5$), 5–15% ($\text{Ca}_4\text{Al}_n\text{Fe}_{2-n}\text{O}_7$), and 3–8% other additives or minerals (such as oxides of calcium and magnesium).

It is the hydration of the calcium silicate, aluminate, and aluminoferrite minerals that causes the hardening, of cement.

Physical and Mechanical Properties:

Blain CM2/GR	3,25
Autoclave Expansion	0,02
Initial Setting Time (VICAT)	105 minutes
Final Setting Time (VICAT)	135 minutes
Compressive strength	03 days – 230 kg/cm ²
	07 days – 305 kg/cm ²
	28 days – 420 kg/cm ²

Factors influencing compressive strength of concrete

There are a number of factors which can be identified; some of the major ones are:

1- The quality of cement paste :

The quality of cement paste: In well-cured concretes the quality of cement paste depends on the water/cement ratio, (w/c). If one assumes that some cement never hydrates, then, on a weight basis, the water equivalent of approximately 0.25 w/c ratio is required for the hydration of Portland cement. Usually more water is used in order to achieve the desired workability characteristics in concrete. The extra water contributes to enhanced volume of voids, which act as local stress concentrations that reduce the strength of the cement paste.

2- The characteristics of aggregate:

The characteristics of aggregate: The stiffness, shape, texture, maximum size, and grading of both coarse and fine aggregate are known to exercise significant influence on compressive strength of concrete.

3- The ratio of cement to aggregate.

The ratio of cement to aggregate: In a concrete mix, as the volume of cement is decreased, and correspondingly as the volume of aggregate is increased, more water is generally needed to attain a fixed workability. According to above, therefore, the decreasing cement/aggregate ratio would cause deterioration in the quality of cement paste and, hence, result in lowered compressive strength. Too much cement can lead to shrinkage problems.

Procedure

Prepare the mortar using mixing motor. Then after mixing, place half of the mortar in the mold through a hopper as quickly as possible and compact it by jolting machine 60 times. Put the other half and jolt it 60 times as before. Cut off the top of the mold by drawing straight edge with a sawing motion and level it with few touches of trowel. Store the specimens in a moist curing chamber and cover the exposed top of the cubes to avoid or reduce evaporation. After 24 hrs remove the cubes from the mold and immediately submerge all the specimens in water tank.

Carry the compressive strength tests after 2, 7 and 28 days using the compressive strength machine as follows: wipe the bearing platens of the machine and remove any loose grit or other material from the surface of the cubes which are to be in contact with bearing platens. Finally, calculate the compressive strength of each specimen by dividing the maximum load by cross sectional area.

Determination of setting time

1.Determination of final setting time

Invert the filled mould used before on its base-plate so that the tests for final set are made on the face of the specimen as the final setting time of the cement. This time the ring attachment to facilitate accurate observation of small penetration. the intervals of time between penetration tests may be increased to 30 mm.

Record to the nearest 15 mm the time measured from zero at which the needle first penetrates only 0.5 mm into the specimen as the final setting time of the cement. This time is that at which the ring attachment first fails to mark the specimen and may be accurately established by reducing the time interval between tests near the end-point and observing that successive test results do not fluctuate excessively.

The automatic setting time machines are commercially available and may be used provided that they can be shown to give the same test results as the specified apparatus and procedure. When using automatic setting time machines are commercially available and may be used provided that they can be shown to give the same test results as the specified apparatus and procedure. When using automatic machines there is no need to turn the mould over.

2.Initial Setting Time

Test the setting time using the molded paste with Vicat apparatus, by place the mold under the movable rod of Vicat apparatus with the needle. Lower gently into contact with the surface of the cement paste at least 10mm from the edge of the mold, then quickly release it and allow to sink into the surface of the cement paste. Repeat the process until the needle, when brought into contact with the undisturbed part of the surface at least 4+1 mm from the bottom or 36 mm from the top. Record the elapsed time between this conditions is reached and the time of adding water to the cement.

3. Final Setting Time

After getting the initial setting time, replace the needle with final setting time then lower it gently into contact with the surface, then quickly release it and allow to sink. Repeat this process until only the needle makes an impression on an undisturbed part of the surface of the cement paste. But the attachment fails to do so. or the penetration is 0.5mm. Recoerd the elapsed time between when this condition is reached and the time of adding water to the cement.



4. Soundness and expansion test:

Put the preparation paste in the le Chatelier mold on one glass plate . cover the mold with other glass plate .Immerse the whole immediately in water at temperature of 20° C and leave it for 24hr. Remove the mold from water and measure the distance separating the indicator points to the nearest 0.5 mm.

Put the mold in water bath and bring to boiling in 25-30 min.and keep boiling for 2 hr. Remove the mold from water and allow to cool and measure the distance separating the indicator point to nearest 0.5mm.the difference between the two measurement represents the expansion of the cement (max specs =10 mm).

RESULTS

1. The hardness of OPC after two days;

The hardness were measured after two days of adding the aluminum sulfate, the results are summarized in Table (1) . Adding up to 0.025% of aluminum sulfate increased the hardness by 16.9%. The results are illustrated in Figure (1).

Table (1)

percent %	2day (kN/mm2)
-----------	---------------

0	16.5
1%	17.1
1.50%	17.8
1.75%	18.3
2%	18.7
2.50%	19.3

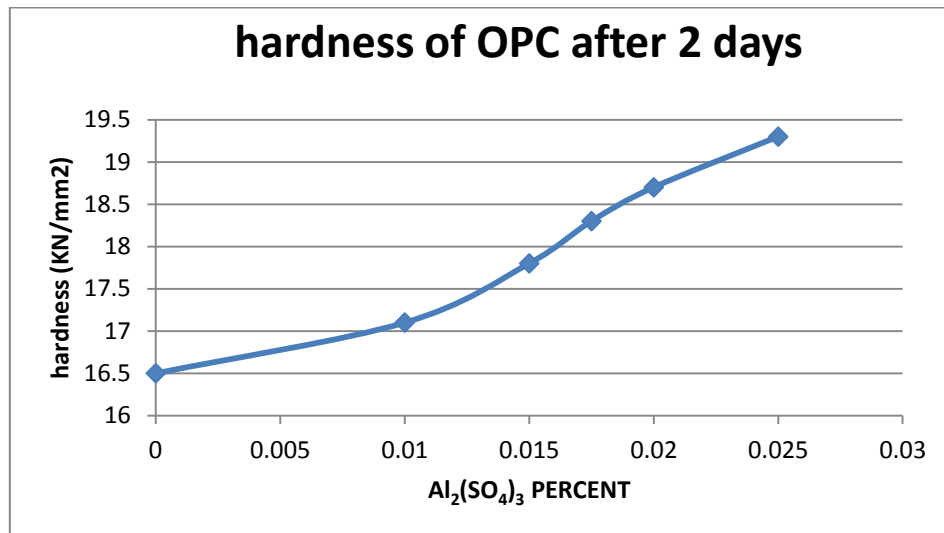


Figure (1)

2. The hardness of OPC after seven days;

After 7 days, the hardness increased by an extra 17.8%. The results are shown in Table (2) and illustrate on Figure (2):

Table (2)

percent %	7day(kN/mm^2)
0	29.8
1%	30.4
1.50%	30.9
1.75%	31.7
2%	32.5
2.50%	34.5

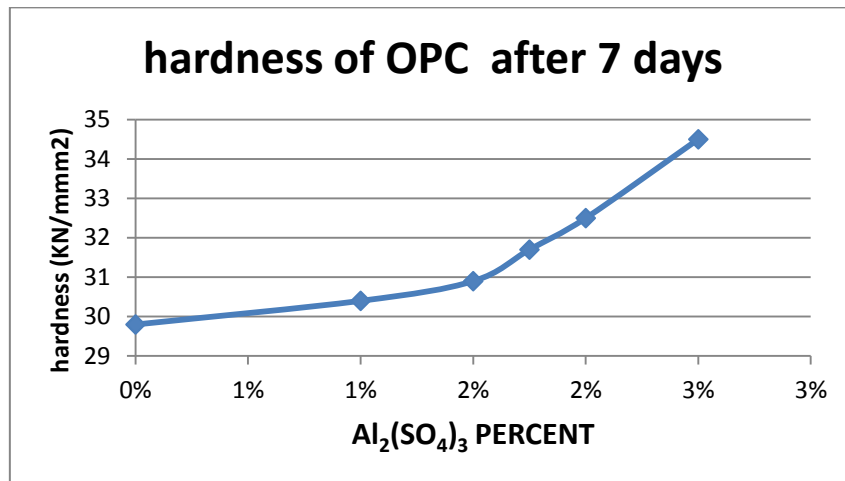


Figure (2)

3. The hardness of OPC after twenty eight days;

After 28 days, a sudden decrease by 8%. The hardness showed to decrease from 44.6 at zero addition of aluminum sulfate to 41.2 after adding 2.5% of aluminum sulfate. The data given in Table (3) and illustrated on Figure (3) :

Table (3)

percent %	28day(kN/mm^2)
0	44.6
1%	43.7
1.50%	43.1
1.75%	42.6
2.00%	42.2
2.50%	41.2

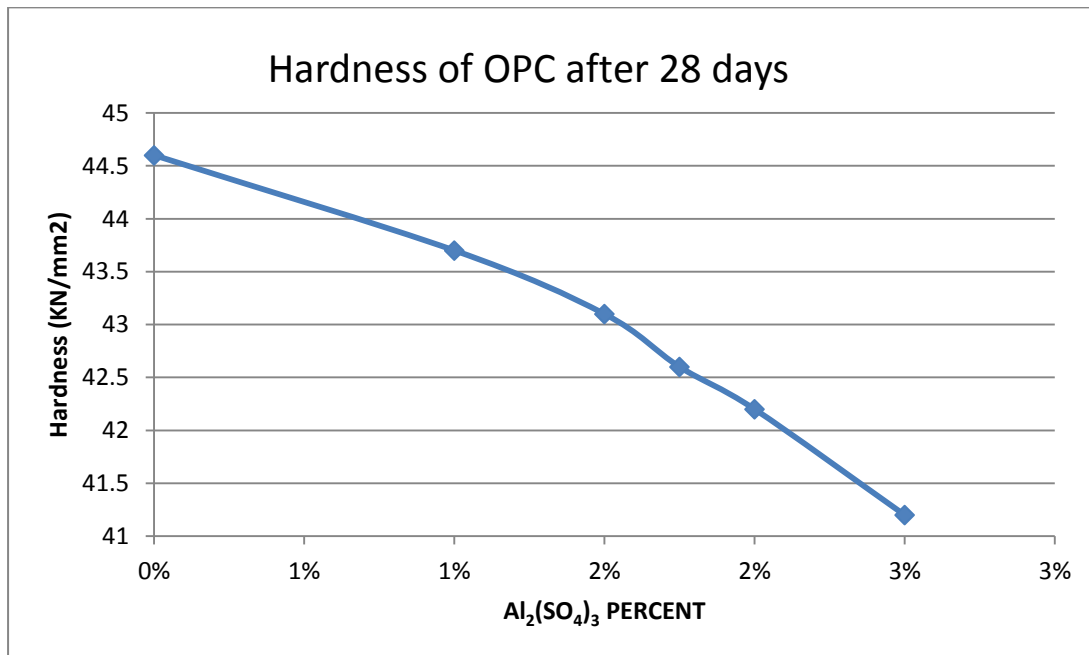


Figure (3)

Compressive strength of concrete with Activated carbon:

The addition of carbon on concrete was tested and the results were tabulated in Table (4). For adding 2% activated carbon, a minor increase in the strength was noticed. An extra addition of activated carbon may improve the strength and this propose for future work.

Table(4)

Percent %	After 7 day (kN/mm^2)
0%	35
0.5%	35.2
1%	34.8
2%	35.62

Result of expansion:

The expansion for all tests was 0.5 mm as the standard which is acceptable and in the range.

Result of setting time:

The setting time data were analyzed and shown in Figure (4). The setting time decrease by 45% for increasing the additive of aluminum sulfate from zero to 2.5%.

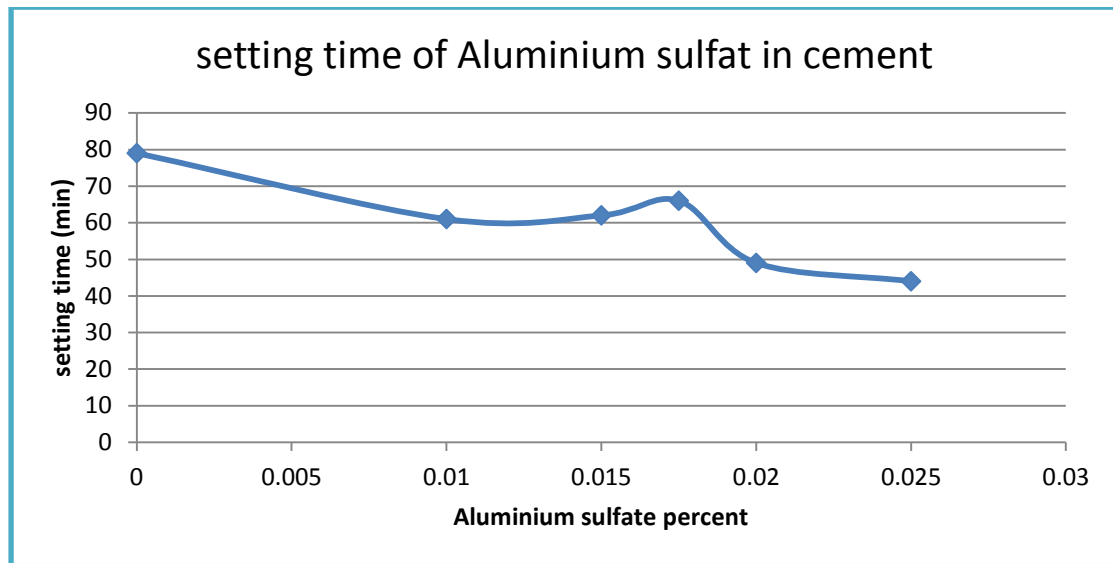
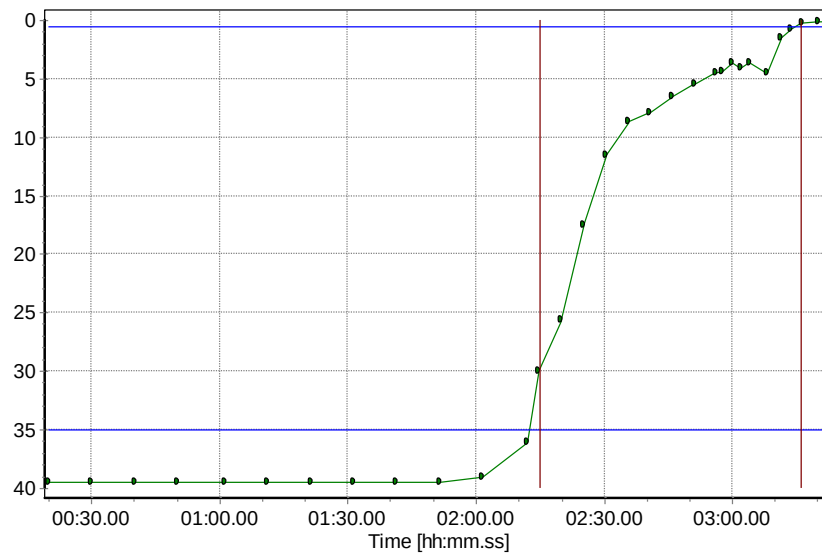


Figure (4)

A sample for setting time test is shown in Figure (5). As seen below:



CONCLUSION

In this project the effect of the additive to cement and concrete were tested. Aluminum sulfate and activated carbon were used and tested to accelerators the Drying and Hardening of cement.

Different percentage of aluminum sulfate and activated carbon were tested. The data were analyzed to exam the effect of this addition and observe the time that takes to be Harding.

Experimental result showed that the addition of aluminum sulfate will improve the concrete hardness by shorten the setting time (time for hardness) of cement and improve the early strength however after 28 days results showed that the hardness decrease as a result of reducing the fluidity due to the presence of sulfate .

Also activated carbon have a benefits in concrete It is better workability and ultimate strength.

REFERENCES

1. Then Science of Concrete, Jeffrey J. Thomas, Department of Civil and Environmental Engineering, Northwestern University, Evanston, IL 60208. USA.2002
2. Cement chemistry and physics for civil Engineers, Wolfgang Czernin., Published by CHEMICAL PUB CO INC (NY), 2014
3. Kosmatka, Steven H., "Discoloration of Concrete—Causes and Remedies," Concrete Technology Today, PL861, Portland Cement Association, http://www.portcement.org/pdf_files/PL861.pdf, 1986.
4. Composition and properties of concrete, George Earl Troxell McGRAW –HILL Civil Engineering Series, 1968.
5. Concrete Pipe Handbook, American Concrete Pipe Association, 1988
6. American Concrete Institute, ACI 233-R, Ground Granulated Blast-Furnace Slag as a Cementations Constituent in Concrete, Farmington Hills, MI, 1995.
7. Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete, ACI Manual of Concrete Practice, American Concrete Institute, Farmington Hill, MI.
8. The Civil Engineering Handbook, Second Edition.."Constituents and
9. Properties of Concrete"" chapter 40"