

STATE OF LIBYA MINISTRY OF EDUCATION
SABHA UNIVERSITY



FACULTY OF Energy And Mining Engineering
Department of Materials and Corrosions Engineering

Project Title:-

*Effect of Partially Replacement or Partially Replaced Sand
with Iron oxide Particles on Compression Strength of
Concrete*

A project submitted to the faculty of energy and mining engineering in partial fulfillment of the requirement for the degree of bachelor of engineering in the department of Material engineering

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الإهداء

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

{قل اعملوا فسيرى الله عملكم ورسوله والمؤمنون}

صدق الله العظيم

إلهي لا يطيب الليل إلا بشكرك ولا يطيب النهار إلا بطاعتك .. ولا تطيب اللحظات إلا بذكرك ..
ولا تطيب الآخرة إلا بعفوك .. ولا تطيب الجنة إلا برويتك

"الله ﷻ"

إلى من بلغ الرسالة وأدى الأمانة .. ونصح الأمة .. إلى نبي الرحمة ونور العالمين

"سيدنا محمد ﷺ"

إلى الأرض التي ترعرعنا عليها واستنشقتنا نسيم الحياة والحرية فيها وعلمتنا معاني التضحية
والفداء

"ليبيبا"

إلى من كلله الله بالهبة والوقار .. إلى من علمني العطاء بدون انتظار .. إلى من أحمل اسمه
بكل افتخار .. أرجو من الله أن يمد في عمرك لترى ثمارا قد حان قطافها بعد طول انتظار
وستبقى كلماتك نجوم أهتدي بها اليوم وفي الغد وإلى الأبد

"والدي العزيز"

إلى ملاكي في الحياة .. إلى معنى الحب وإلى معنى الحنان والتفاني .. إلى بسملة الحياة وسر
الوجود إلى من كان دعائها سر نجاحي وحنانها بلسم جراحي إلى أغلى الحبايب

"أمي الغالية"

إلى سندي وقدوتي وملاذي بعد الله إلى من أثروني على أنفسهم إلى من علموني علم الحياة إلى
من أظهروا لي ما هو أجمل من الحياة

"أخوتي"

الآن تفتح الأشرعة وترفع المرساة لتنتقل السفينة في عرض بحر واسع مظلم هو بحر الحياة
وفي الظلمة لا يضيء إلا قنديل الذكريات ذكريات الأخوة البعيدة إلى الذين أحببتهم وأحبوني

"أصدقائي"

كلمة الشكر

الحمد والشكر لله عز وجل الذي أنعم علينا بنعمه التي لا تعد ولا تحصى ومنها نعمة العلم ونصلي ونسلم على خاتم الأنبياء والمرسلين ونبينا محمد الذي صدق في قوله الكريم

{لا يشكر الله من لا يشكر الناس}

في مثل هذه اللحظات يتوقف اليراع ليفكر قبل أن يخط الحروف ليجمعها في كلمات .. تتبعثر الأحرف وعبثا أن يجاول تجميعها في سطور سطورا كثيرة تمر في الخيال ولا يبقى لنا في نهاية المطاف إلا قليلا من الذكريات وصور تجمعا برفاق كانوا إلى جنبنا ...

فواجب عليا شكرهم ووداعهم وأنا أخطو خطوتي الأولى في غمارة الحياة وأخص بجزيل الشكر والعرفان إلى كل من اشعل شمعة في دروب عملي وإلى من وقف على المنابر وأعطى من حصيلة فكره لينير دربي إلى الأساتذة في كلية هندسة الطاقة والتعدين .

وأتوجه بالشكر الجزيل إلى الأستاذ المحترم :- محمد الكيلاني المدني

الذي تفضل بالإشراف على هذا البحث فجزاه الله عني كل خير فله مني كل التقدير والاحترام

وذلك لإشرافه على هذه الدراسة وحرصه على أن يظهر البحث بالصورة اللائقة كما أشكره على المعلومات القيمة والإرشادات البناءة التي أمدني بها أثناء فترة عملي بهذا البحث أمل من الله تعالى أن أكون قد وفقت في انجازه وتقديمه على أكمل وجه

كما أتقدم بالشكر والعرفان إلى والداي وأخوتي والذين تكتمل بهم سعادتني وفرحتي ويتمنون لي النجاح والتوفيق دائما ..

أما الشكر الذي من النوع الخاص أتوجه بالشكر أيضا إلى كل من لم يقف إلى جانبي ، ومن وقف في طريقي وعرقل مسيرة بحثي ، فلولا وجودهم لما أحسست بمتعة البحث ، ولا حلاوة المنافسة الايجابية ، ولولاهم لما وصلت إلى ما وصلت إليه فلهم مني كل الشكر ...

ABSTRACT

Concrete is a heterogeneous material obtained by mixing cement paste (binder) with aggregates (filler), The later constitutes more than 80% of the concrete. Concrete is a macro-material strongly influenced by addition nano-properties such as iron oxide. One of the most important properties of hardened concrete is its compressive strength, which can be quantitatively measured.

We have studied effects of different concentrations of hematite (5 to 25 gram weight) at 5 gram intervals) on compression strength of concrete. This work aims to evaluate the use of iron oxide (Hematite) in Portland cement concrete, as a replacement for local sand. Cement mortars with mix proportioning 1:3 were prepared.

The water/cement ratio used was about 0.52 for all mix proportions.

The compressive strength was measured after 14 days of completion of curing time.

Results showed that the compressive strength of the concrete using iron oxide nanoparticles were not equivalent to that of the conventional concrete. Maximum decreasing in compressive strength was about 40%. According to the results of compression strength for conventional and incorporated specimen, the addition of iron oxide to concrete will decreases the compressive strength of concrete due to formation of porosity.

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CHAPTER 1

1. LITERATURE REVIEW

1.1 IRON OXIDE

1.1.1 ORIGN OF IRON OXIDE MINERAL

Iron ores of sedimentary origin account for nearly 80% of the world's reserves; the remaining 20% is of magnetic origin such as magnetite. The most important oxide minerals are the following [1]:

1.1.1.1 Hematite (Fe_2O_3): Occurs in nature in the following forms:

- Specular hematite: black to steel grey crystals with metallic luster;
- Micaceous hematite: Occurs in thick flakes resembling mica; they may be so thin as to be translucent and they are then deep red;
- Common red hematite: This is the ($\alpha\text{-Fe}_2\text{O}_3$), is dark red in massive, granular or earthy (red other) form;
- Magnetic: This is the ($\gamma\text{-Fe}_2\text{O}_3$), which occur in the ural as mineral

maghemite. They are shown in figure 1.1

1.1.1.2 Magnatite (Fe_3O_4): It is a brittle with a dark grey to black poeque color, with metallic luster, strongly magnetic [1].

1.1.2 PROPERTIES OF HEMATITE IRON OXIDE

Iron oxides are chemical compounds composed of iron and oxygen. Iron III oxide or ferric oxide is the inorganic compound with the formula (Fe_2O_3). It is one of the three main oxides of iron, the other two being iron(II) oxide (FeO), which is rare, and iron(II,III) oxide (Fe_3O_4), which also occurs naturally as the mineral magnetite. As the mineral known as hematite, (Fe_2O_3) is the main source of the iron for the steel industry. (Fe_2O_3) is paramagnetic, reddish brown, and readily attacked by acids. Rust is often called iron(III) oxide, and to some extent, this label is useful, because rust shares several properties and has a similar composition.

To a chemist, rust is considered an well-defined material, described as hydrated ferric oxide [2]. Table 1.1. shows the properties of Hematite Iron Oxides.

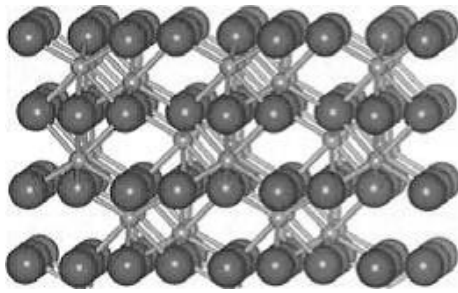


Figure 1.1. The Hematite Iron oxides Crystal Structure [3]

Table 1.1. Properties of Hematite Iron Oxides [3]

| Hematite Oxide | Formula | Cation | Crystallographic System | Colour | Density g.cm^{-3} |
|----------------|--------------------------------|------------------|-------------------------|---------------|----------------------------|
| Hematite | $\alpha\text{-Fe}_2\text{O}_3$ | Fe^{3+} | Hexagonal | Red | 5.26 |
| Maghemite | $\gamma\text{-Fe}_2\text{O}_3$ | Fe^{3+} | Cubic / Tetragonal | Reddish brown | 4.87 |

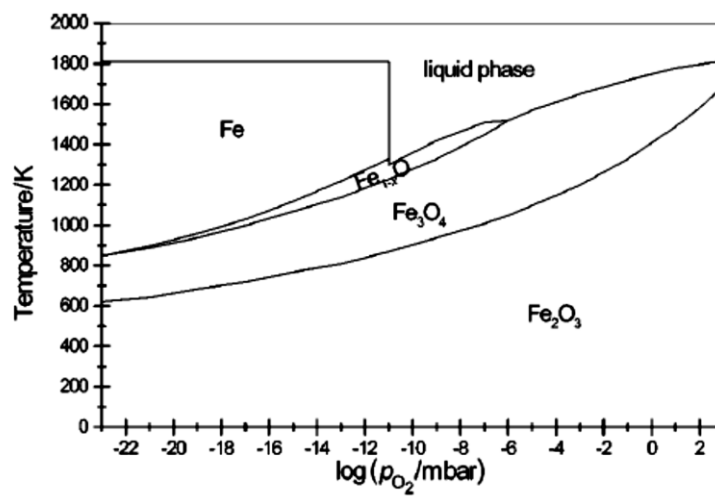


Figure 1.2. Phase Diagram for the Fe-O₂ System [3]

1.1.3 NANOPARTICLES

1.1.3.1 General

In nanotechnology, a particle is defined as a small object that behaves as a whole unit in terms of its transport and properties. Particles are further classified according to size: in terms of diameter, fine particles cover a range between 100 and 2500 nanometers. On the other hand, ultrafine particles are sized between 1 and 100 nanometers. Similar to ultrafine particles, nanoparticles are sized between 1 and 100 nanometers. Nanoparticles may or may not exhibit size-related properties that differ significantly from those observed in fine particles or bulk materials [4]. Although the size of most molecules would fit into the above outline, individual molecules are usually not referred to as nanoparticles. Nanoclusters have at least one dimension between 1 and 10 nanometers and a narrow size distribution. Nanopowders are agglomerates of ultrafine particles, nanoparticles, or nanoclusters. Nanometer-sized single crystals, or single-domain ultrafine particles, are often referred to as nanocrystals [4].

1.1.3.2 Iron Oxide Nanoparticles

Iron oxides are not only engineered materials, but are also present in various forms in natural systems, both in bulk as well as in nano-form [5]. Nano-scale iron oxides can be formed under mineral weathering process and biotic processes or nanobiomineralization. Naturally occurring nano-scaled iron oxides are widely distributed throughout the atmosphere, ocean, water and most living organisms [6].

Although copper, cobalt and nickel are highly magnetic materials but they have very limited applications due to their toxicity and susceptibility to oxidation. Unlike these, iron oxide nanoparticles have attracted extensive interest due to their superparamagnetic properties and their potential applications in many fields. These are two main forms of iron oxide nanoparticles. They are magnetic (Fe_2O_3) or its oxidized form maghemite (Fe_2O_3). They are shown in figure 1.3. .

1.1.3.3 Application of Iron Oxide Nanoparticles

With their large surface area and adjustable surface charge, nano-FeOX can be used to absorb cations such as Cd, Co, Zn etc. and anions such as PO_4^{3-} [6].

Engineered nano-FeOX has unique properties, which can be applied in various industrial fields. Nano-FeOX can be fully dispersed in a matrix due to the small size and do not scatter light anymore. Therefore, they can be used to manufacture transparent FeOX coatings with high Ultra-vanlit absorption and increased durability [7]. Moreover, when the particle size is below a few nanometers, nano-FeOX become superparamagnetic, which facilitates phase separation processes after metal binding and selective adsorption [8]. Iron oxide nanoparticles have many other applications in construction industry, but of particular interest is as a colouring and as a anti-corrosion agent in construction materials and coatings. Iron oxide nanoparticles have very good UV blocking capabilities making nanoparticles ideal for glass applications ranging from glass coatings to cunlglasses. Also allow for better dispersion in paints and coatings, especially in high gloss and automotive applications [9].

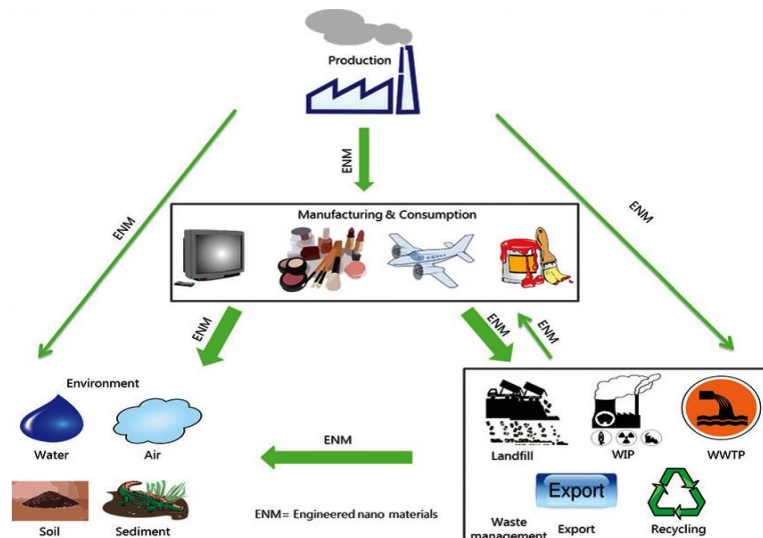


Figure 1.3. Framework of the material flow model. The framework contains four parts: production; manufacturing & consumption; waste management; & environment [10]

1.1.4 CEMENT

1.1.4.1 Introduction

Cement is a binder, a substance used in construction that sets and hardens and can bind other materials together. The most important types of cement are used as a component in the production of mortar in masonry, and concrete. Cement is extremely important construction materials. It is used in the production of the many structures that make up the modern world that including buildings, bridges, harbors,

runways, roads and etc. The constant demand for all of these structures, increasingly from developing world, means that cement is the second most consumed commodity in the world after water [11].

Cement in general, adhesive substances of all kinds but, in a narrow sense, the building materials used in building and civil engineering construction. Cements of this kind are finely ground powders that, when mixed with water, set to hard mass. Setting and hardening result from hydration, which is a chemical combination of the cement compounds with water that yields submicroscopic crystals or a gel-like material with a high surface area. Because of their hydration properties, constructional cements, which will under water, are often called hydraulic cements. The most important of these is (Portland) even set and hardens cement [12].

1.1.4.2 Portland Cement

1.4.2.1 General information

Portland cement is essentially a calcium silicate cement, which is produced by firing to partial fusion, at a temperature of approximately 1500°C, a well-homogenized and finely ground mixture of limestone or chalk (calcium carbonate) and an appropriate quantity of clay or shale. The composition is commonly fine tuned by the addition of sand and/or iron oxide [13]. Table (1.2). shows the Typical composition of portland cement.

Table 1.2. Typical Chemical Composition of Portland Cement [13]

| Main constituents | SiO ₂ | Al ₂ O ₃ | Fe ₂ O ₃ | CaO |
|-------------------|------------------|--------------------------------|--------------------------------|------|
| % | 21.1 | 5.6 | 3.0 | 65.3 |

It is the two calcium silicate minerals, C₃S and C₂S, which are largely responsible for the strength development and the long-term structural and durability properties of Portland cement. However, the reaction between CaO (lime from limestone) and SiO₂ (silica from sand) is very difficult to achieve, even at high firing temperatures. Chemical combination is greatly facilitated if small quantities of alumina and iron oxide are present (typically 5.6% Al₂O₃ and 3.0% Fe₂O₃), as these help to form a molten flux through which the lime and silica are able to partially dissolve, and then react to yield C₃S and C₂S [13].

Table 1.3. Ranges of Principal Minerals in European Clinkers [13]

| Shorthand nomenclature | Chemical Formula | Mineral Name | Typical Level (mass %) |
|------------------------|---|--------------|------------------------|
| C ₃ S | 3CaO·SiO ₂ | Alite | 57 |
| C ₂ S | 2CaO·SiO ₂ | Belite | 16 |
| C ₃ A | 3CaO·Al ₂ O ₃ | Aluminate | 9 |
| C ₄ AF | 4CaO·Al ₂ O ₃ ·Fe ₂ O ₃ | Ferrite | 10 |

Alite is the most important constituent of all normal Portland cement clinkers, of which it constitutes 50-70%. It is tricalcium silicate (3CaO·SiO₂) modified in composition and crystal structure by ionic substitutions. It reacts relatively quickly with water, and in normal Portland cements is the most important of the constituent phases for strength development; at ages up to 28 days.

Belite constitutes 15-30% of normal Portland cement clinkers. It is dicalcium silicate (2CaO·SiO₂) modified by ionic substitutions and normally present wholly or largely as the β polymorph. It reacts slowly with water, thus contributing little to the strength during the first 28 days, but substantially to the further increase in strength that occurs at later ages. By one year, the strengths obtainable from pure alite and pure belite are about the same under comparable conditions [14].

Aluminate constitutes 5-10% of most normal Portland cement clinkers. It is tricalcium aluminate (3CaO·Al₂O₃), substantially modified in composition and sometimes also in structure by ionic substitutions. It reacts rapidly with water, and can cause undesirably rapid setting unless a set-controlling agent, usually gypsum, is added [14].

Ferrite makes up 5-15% of normal Portland cement clinkers. It is tetracalcium aluminoferrite (4CaO·Al₂O₃·Fe₂O₃), substantially modified in composition by variation in Al/Fe ratio and ionic substitutions. The rate at which it reacts with water appears to be somewhat variable, perhaps due to differences in composition or other characteristics, but in general is high initially and low or very low at later ages [14].

1.1.4.2.2 Portland Cement Hydration

The hydration of Portland cement involves the reaction of the anhydrous calcium silicate and aluminate phases with water to form hydrated phases. These solid hydrates occupy more space than the anhydrous particles and the result is a rigid interlocking mass whose porosity is a function of the ratio of water to cement (w/c) in the original mix. Provided the mix has sufficient plasticity to be fully compacted, the lower the w/c, the higher will be the compressive strength of the hydrated cement paste/mortar/concrete and the higher the resistance to penetration by potentially deleterious substances from the environment. Cement hydration is complex and it is appropriate to consider the reactions of silicate phases (C_3S and C_2S) and aluminate phases (C_3A and C_4AF) separately [15].

1.1.4.2.3 Portland Cement Physical Properties

Portland cement are commonly characterized by their physical properties for quality control purpose. Their physical properties can be used to classify as:

Setting Time: Initial set of cement paste must not occur too early; final set must not occur too late. The setting times indicate that the paste is or is not undergoing normal hydration reactions. Setting time is also affected by cement fineness, water-cement ratio, admixtures and Gypsum. Setting times of concrete do not correlate directly with setting times of pastes because of water loss to air or substrate and because of temperature differences in the field as contrasted with the controlled temperature in the testing lab [16].

Fineness: Fineness of cement affects heat released and the rate of hydration. Greater cement fineness increases the rate at which cement hydrates and thus accelerates strength development [16].

Soundness: Soundness refers to the ability of a hardened cement paste to retain its volume after setting without delayed expansion. This expansion is caused by excessive amounts of free calcium oxide (CaO) or magnesium oxide (MgO) [16].

Strength: Strength of cement paste is typically defined in three ways; compressive and tensile. These strengths can be affected by a number of items including: water cement ratio, cement-fine aggregate ratio, type and grading of fine aggregate, curing conditions, size and shape of specimen, loading condition and age. For a rapid

development of strength a high fineness is necessary. When the cement particles are coarse, hydration starts on the surface of the particles. So the coarser particles may not be completely hydrated. This causes low strength and low durability [16]. They are shown in figure 1.4.

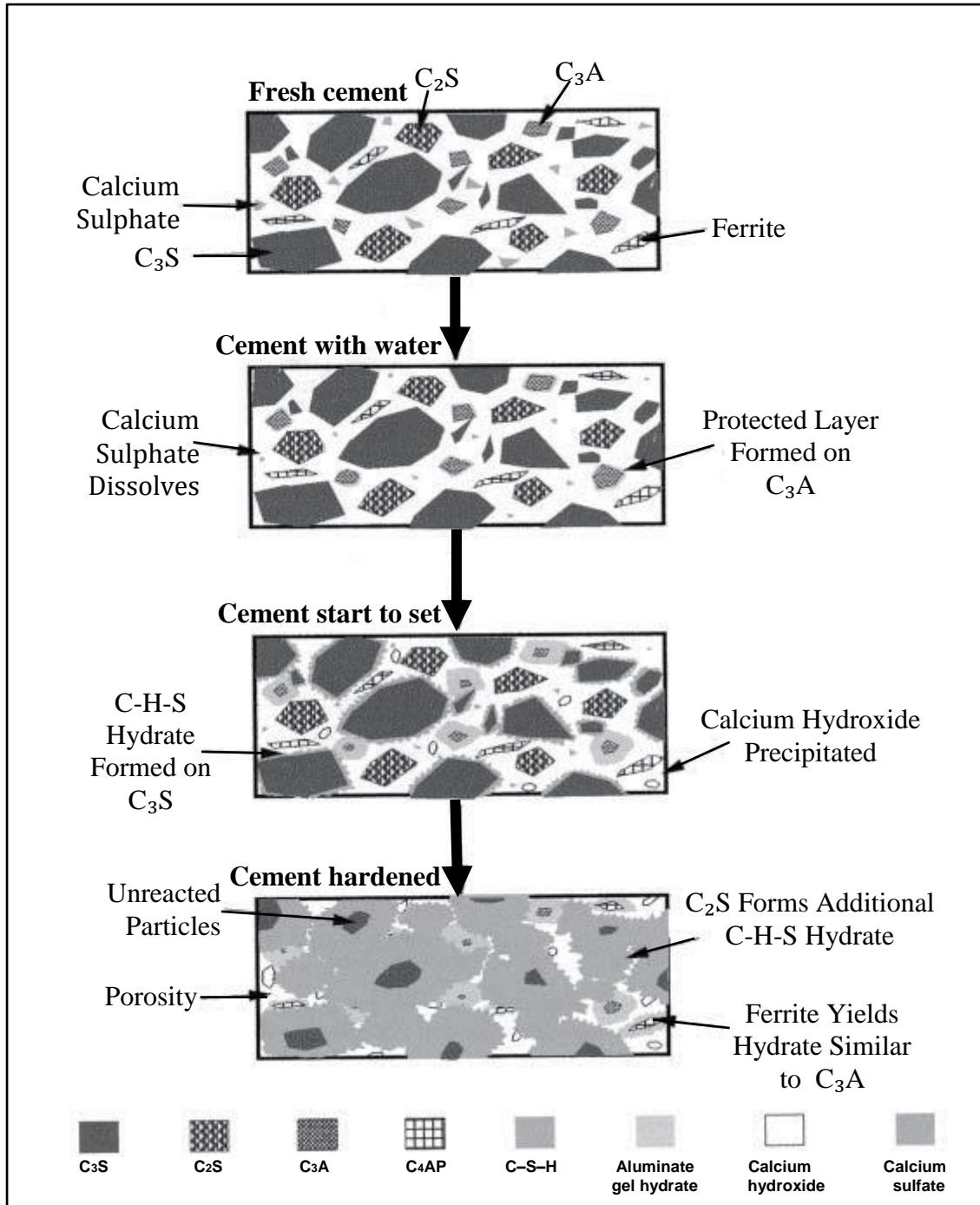


Figure 1.4. Simplified Illustration of Hydration of Cement Paste [17]

1.1.5 CONCRETE

1.1.5.1. General

Concrete is a heterogeneous material obtained by mixing cement paste (binder) with aggregates (filler), the latter constituting more than 80% of the concrete, [18]. The binder (cement and water) glues the filler (fine or coarse aggregate, or both) together to form a synthetic conglomerate. Sometimes material other than water, aggregates and hydraulic cement is added to concrete batch before or during mixing, to provide a more economical solution and enhanced concrete properties. Such a material is known as admixture. It is difficult to imagine the modern society without concrete. It finds wide application in buildings, roads, bridges and dams, among others [19].

Concrete may be considered as being composed of four basic separate ingredients: cement, coarse aggregates, fine aggregates, and water. Another way of looking at concrete is as a graded mixture of fine and coarse aggregates held together by wetted cement. Still another way of viewing concrete is that the coarse aggregates are held together by a mortar that is composed of cement, fine aggregates, and water. The requirements of concrete are complex, but the ultimate aim is to produce the most economical combinations of concrete materials that will satisfy the performance requirements and specifications. A properly designed concrete mixture should possess the following physical properties [20]:

1. When still in the plastic state, it must be adequately workable;
2. It must fulfill the required strength parameters;
3. Durability to be able to withstand imposed forces and elements such as traffic abrasion for a concrete pavement;
4. Other properties that may vary in importance with the location of the concrete in a structure are permeability and appearance.

1.1.5.2. Concrete Strength

The most two important properties of hardened concrete are its compressive strength and durability. The former can be quantitatively measured while the latter cannot. In concrete design and quality control, strength is the property generally specified. This is because, compared to most other properties, testing strength is

relatively easy. Furthermore, other properties of concrete, such as elastic modulus, water tightness or impermeability, and resistance to weathering agents including aggressive waters, are directly related to strength and can therefore be deduced from the strength data [19].

1.1.5.2.1 Compressive Strength of Concrete:

- Strength always increases with age and curing;
- Strength is the stress required to cause fracture of the material.

Theoretical considerations:

There exists a fundamental inverse relationship between porosity and strength: [20]

$$S = S_0 e^{-K} \quad (1)$$

where, S is compressive strength at porosity, S_0 is intrinsic Strength at zero porosity, K is constant and P is porosity. They are shown in figure 1.5.

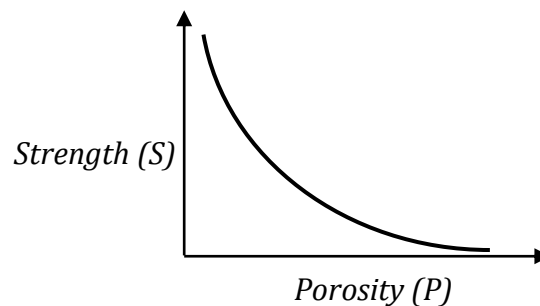


Figure 1.5. Relation between Compressive Strength and Porosity [20]

1.1.5.2.2 Factors Affecting the Compressive Strength of Concrete (f_c)

i) **Water / Cement Ratio:**

water/ cement ratio of concrete is the single most important factor that influences the strength of concrete. The strength of concrete increases when less water is used to make concrete. The hydration reaction consumes a specific amount of water. Concrete is usually mixed with more water than needed for hydration. The extra water is needed to give concrete sufficient workability. Flowing concrete is desired to achieve proper filling and composition of the moulds. The water not consumed in the hydration reaction will remain in the microstructure pore space. These pores make the concrete weaker due to the lack of strength forming calcium silicate hydrate bonds. Porosity is thus determined by the water to cement ratio. Low water to cement ratio leads to high strength but low workability. High water to cement ratio leads to low strength, but high workability [18].

Water / Cement Ratio: “Abram’s Law” [20]
$$f_c = \frac{K_1}{K_2^{(w/c)}} \quad (2)$$

where, K_1 and K_2 are empirical constants, w is water content and c is cement content.

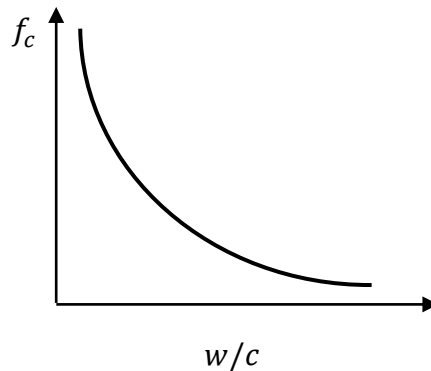


Figure 1.6. Relation between Compressive Strength and Water Cement Ratio [20]

$w/c < 0.3$, disproportionately high increase in f_c can be achieved for very small reduction in w/c . This phenomena is mainly attributed to a significant improvement to the strength of the transition zone (TZ). The reason for that is a size of the calcium hydroxide crystals become smaller with decreasing w/c ratio [20].

ii) *Air Entrainment*

- Air voids are formed due to inadequate compaction;
- They have an effect in increasing porosity and decreasing of the strength;
- At a given w/c ratio, high-strength concretes (containing high cement content) suffer considerable strength loss with increasing amounts of entrained air, whereas low strength concretes tend to suffer a little strength loss or may actually gain some strength as a result of air entraining;
- Entrainment of air increases workability without increasing w/c ratio [20].

iii) *Cement Type*

- Type III cement hydrates more rapidly than Type I, therefore at early ages,
- Type III cement will have lower porosity and have higher strength matrix;
- Degree of hydration at 90 days and above is usually similar;
- Therefore: the influence of cement composition on porosity of matrix and strength of concrete is limited to early ages [20].

iv) *Maximum Size Aggregate*

- Economy mandates that it should used maximum size of aggregate possible;
- Concrete containing larger aggregate particles require less mixing water;

- Larger aggregates tend to have more microcracks. They are shown in figure 1.7.

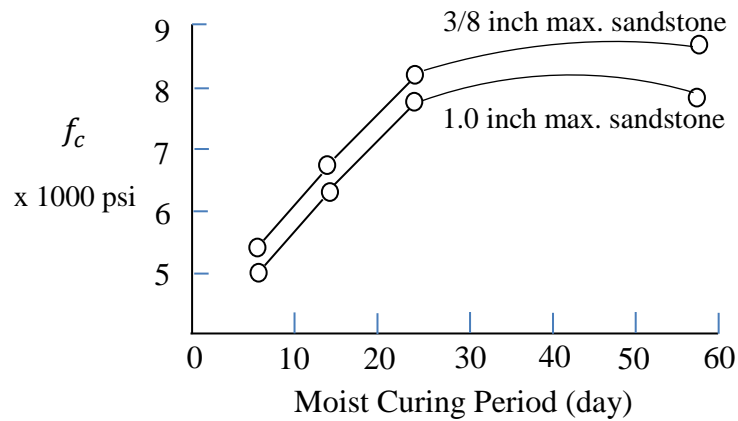


Figure 1.7. Influence of the Aggregate Size on Compressive Strength of Concrete [20]

v) *Mixing Water*

Drinking water is most appropriate for use in concrete.

Oily, acidic, silty, and sea water should not be used in concrete mix.

If drinking water is not available, compare samples made with available water to samples made with distilled water. If strength is not hurt more than 10%, it can be used in the concrete mix [20].

1.1.5.2.3 *Effect of Curing on the Strength of Concrete*

After setting, concrete increases in strength with age. Suitable curing of the concrete whilst it is maturing can further increase the strength at a particular age. Curing can be affected by the application of heat and/or the preservation of moisture within the concrete. Curing by preventing the water used in mixing from escaping is usually done in one of the following ways [21]:

- flooding or submerging the concrete in water;
- treating (for instance by painting) the surface of the concrete so that it cannot dry
- covering the concrete with damp sand or hessian fabrics, which are kept damp by watering periodically, or with thin polythene sheet.

1.1.5.2.4 Effect of Clayey Particles and Organic Matter on Strength of Concrete

For good quality concrete, dust or clayey matter should not be present in excessive quantities on the surfaces of the aggregate particles; otherwise the bond between the aggregate particles and the cement paste may be reduced [22]. In fact, according to British Standards [23], coarse aggregates should not contain clay, silt or fine dust in amounts more than 1% by weight while natural sands should not contain materials, which are likely to decompose or change in volume when exposed to the weather, or materials that will adversely affect the reinforcement. Such undesirable materials include coal, pyrite and lumps of clay, which may soften and form weak pockets [19].

1.1.5.2.5 Relations between Compressive Strength and Porosity

Many empirical relations between compressive strength and one or more of these variables have been proposed. Thus, Feret's law (1892) states that the strength is proportional to:

$$[c/(c + w + a)]^2 \quad (3) \quad [24]$$

where c , w and a are the volumes of cement, water and air respectively.

The porosity of the hardened paste, appropriately defined, is strongly correlated with strength.

The cement pastes of various degrees of hydration and w/c ratio conformed to the relation:

$$\sigma = \sigma_0 X^A \quad (4) \quad [24]$$

where X is a quantity called the gel/space ratio, and equal to the volume of hydration product divided by that of hydration product plus capillary porosity. The value of A was about 30 if non-evaporable water was used as a measure of the degree of hydration, and typical values for σ_0 were 90-130 MPa. This equation breaks down for mature pastes of low w/c ratio, because it implies that the strength does not then depend on the w/c ratio. In reality, strength increases with decreasing w/c ratio, even though some of the cement does not hydrate [24].

1.1.5.2.6 Relations between Strength and Microstructure or Pore Size Distribution

There are several indications that the compressive strength does not depend solely on porosity. In general, procedures that accelerate early reaction and thus increase early strength, such as increase in temperature or addition of certain admixtures, tend

to decrease later strength. It is unlikely that they significantly alter the porosity of the mature paste, but they may affect the microstructure. If one extends consideration to a wider range of materials than normally cured Portland cement pastes, the relation between strength and porosity is markedly dependent on the broad characteristics of the microstructure. *Jambor* concluded that both the volume and the specific binding capacities of hydration products must be considered [25].

Feldman and *Beaudoin* showed that, while the strengths of Portland cement pastes could be fitted to a curve in accordance with equation:

$$\sigma = \sigma_o \exp (C.P) \quad (5) [26]$$

where, C is constant and P is porosity, which has usually been taken to mean total porosity, materials of a broadly similar type but composed largely of denser, crystalline particles were, for a given porosity, stronger at low porosities and weaker at high porosities (figure. 8, curves AB and CD).

Feldman and *Beaudoin* considered that, while porosity was the major factor controlling strength, the morphology and density of the particles were also important. At high porosities, the better bonding properties of ill-crystallized material augmented the strength, but at low porosities the greater intrinsic strength of the dense, crystalline particles was more important [26].

In agreement with *Bozhenov et. al.*, they concluded that the highest strengths for a given porosity could be obtained from an appropriate blend of the two types of particles. Such a blend could be realised in autoclaved cement-silica materials (curve EF). The size and shape distribution of the solid particles in a cement paste is related, though in a complex way, to that of the pores, and other workers have attempted to relate strength to pore size distribution. From studies on autoclaved materials [27].

Mindess concluded that, for a given porosity, the strength increased with the proportion of fine pores [28]. *Jambor* similarly found relations between strength and average pore size. The weaker materials, with relatively coarse pores, were ones containing dense, crystalline phases, and broadly resembled those represented by the high porosity end of curve CD in figure 8 [25].

Odlar and *Rosler* concluded from a study of cement pastes cured for various combinations of w/c , temperature and time that while the main factor influencing strength was porosity, pores with a radius below 10 nm were of negligible [29].

These results suggest that, in attempts to relate strength to porosity, the total porosity should not be used, the capillary or free water porosity or the volume of pores above a certain size being more appropriate.

Parrott and Killoh, in relation to their modelling of properties, similarly considered the volume, size and continuity of the larger pores to be the relevant quantities [30]. They are shown in figure 1.8.

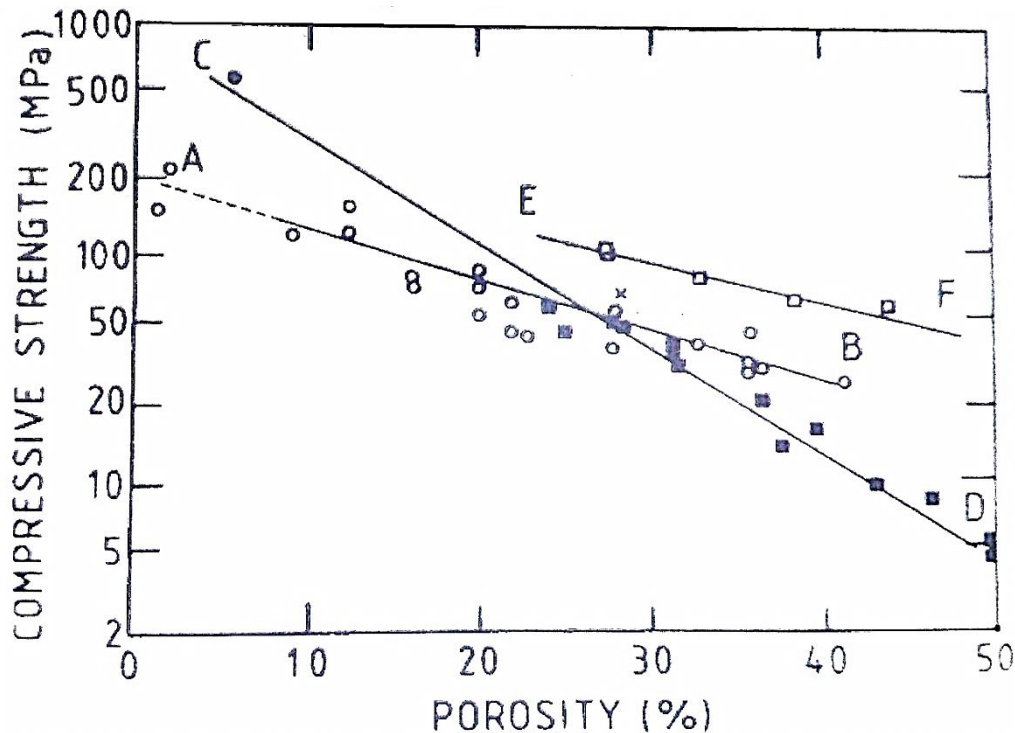


Figure 1.8. Relations between Compressive Strength (log scale) and Porosity [25]

1.1.5.2.7 Mechanism of Compression Failure

Strength cannot be explained by relating it empirically to porosity or pore size distribution; it is necessary to know what holds the material together and what happens when it fails. Cohesion has often been attributed to the interlocking of fibrous or acicular particles. This could be important in the more porous parts of the material, but in the material as a whole, attractive forces between those parts of adjacent layers of C-S-H or other phases that are in contact are probably more important, both within

particles and, in so far as the material is particulate, between them. As in other brittle materials, failure occurs through the initiation and spread of cracks, which originate

in places where the local stress is high. Hardened cement pastes are about ten times as strong in uniaxial compression as in tension. It is probable that the ultimate mechanisms of failure are essentially similar, but that the cracks propagate more readily under tension. The relations between microstructure and strength must thus be sought in the features that give rise to high local stresses and in those that favour or, conversely, that arrest the spread of cracks. This is consistent with the conclusion that porosity is a major factor but not the only one [25].

Beaudoin and *Feldman* discussed some others, in addition to those noted above. The strength, however measured, is less for a saturated paste than for a dry one. In principle, this is readily explained, as the entry of water molecules between particles could weaken the attractive forces between them and thereby favour the initiation or spread of cracks [31].

1.1.6 DURABILITY OF CONCRETE

The durability of concrete is its ability to resist deterioration resulting from external and internal causes. The external causes include the effects of environmental and service conditions, such as weathering, chemical actions and wear. The internal causes are the effects of interaction between, the constituent materials, such as alkali-aggregate reaction, volume changes, absorption and permeability. The main requirements for durability are (Institution of Structural Engineers [32]):

- a. an upper limit to the water / cement ratio;
- b. a lower limit to the cement content;
- c. a lower limit to the concrete cover to reinforcement;
- d. good compaction; and
- e. adequate curing.

The upper limit to the water/cement ratio, the lower limit to the cement content and the lower limit to the concrete cover are all given in BSI 8110 [33]. In addition to lower limit to the cement content, BSI 8110 specifies 550kg/m^3 as the maximum cement content in recognition that high cement content increases the risk of cracking due to drying shrinkage in thin sections or to thermal stresses in thicker sections.

Ensuring full compaction can enhance durability, which contribute to producing a dense, impermeable concrete. Another factor, which enhances concrete durability, includes the use of Portland-pozzolana and low-heat Portland cements. Portland-pozzolana cement reduces heat of setting and thus reduces shrinkage without reducing the 28-day strength of the concrete. This is achieved by substituting fly ash (i.e. pozzolana) for 15-35% by mass of the ordinary Portland cement. Low heat Portland cements generate less heat upon reacting with water compared with other cements and are thus suitable for mass concrete work. In this way flash setting of the cement and voids in the resulting concretes, are avoided. Another important factor that enhances durability of concrete subject to freeze-thaw environment is air entrainment. The mechanism by which air-entrainment enhances durability can be appreciated with the understanding of the air-void system as follows. As unreacted water freezes it expands 9% by volume on phase change. This internal volume expansion causes internal stresses in the matrix. It can generate cracks in the concrete, which may allow water to infiltrate and the process can get progressively worse. It can lead to significant degradation of the concrete. The formation of ice in the pore spaces generates pressure on any remaining unfrozen water. Introducing a large quantity of air bubbles provides a place for this water to move in to relieve the internal pressure. It is more beneficial to generate very small air bubbles well distributed throughout the matrix than a smaller number of larger bubbles. Total air content is only a part of the formula for frost resistance. The nature of the entrained air is equally important. The critical parameter of the air entrained paste is the spacing factor, which is the maximum distance from any point in the paste to the edge of a void. It should not exceed 0.2mm. The smaller the spacing factor the more durable the concrete. The air bubbles themselves should be in the range of 0.05-1.25mm in diameter [34].

1.1.7 CORROSION AFFECTS ON THE DURABILITY OF CONCRETE

Corrosion of reinforcement is well known to be the major cause of durability problems in Portland cement concrete. This is due to impairment of the passive oxide film, which normally protects reinforcing steel in the alkaline environment of the concrete, due to either reduction in this alkalinity through carbonation or the penetration of chloride ions. As with Portland cement, both carbonation and

penetration of chloride ions may lead to the breakdown of the passive layer, and to active corrosion occurring.

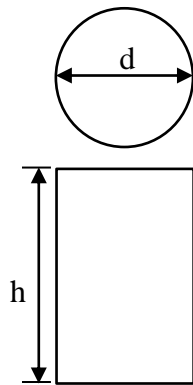
The formation of a dense surface layer at the surface of the concrete is thought to have contributed to its good durability [17].

1.1.8 COMPRESSION TEST

Compressive Strength - is defined as the measured maximum resistance of a concrete or mortar specimen to an axial load, usually expressed in *psi* (pounds per square inch) at an age of 28-days. Compression test is used to obtain mechanical properties and is the basis acceptance and refusal of brittle nonmetallic and other materials that have very low strength in tension like concrete, wood, masonry, etc. In compression test, friction between the machine head and the samples affects the results causing stresses to have a small inclination [35].

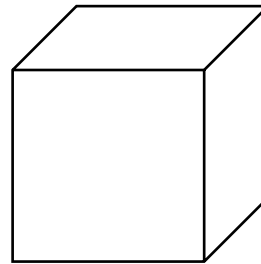
Concrete Compression Test Specimens

Cylinder (American Standards)



Large $d = 150$ mm (6 inch)
 $h = 300$ mm (12 inch)
Small $d = 100$ mm (4 inch)
 $h = 200$ mm (8 inch)

Cube (Egyptian Standards)



Large (150mm x 150mm x 150mm)
(6 inch x 6inch x 6inch)
Large (100mm x 100mm x 100mm)
(4 inch x 4inch x 4inch)

Figure 1.9. Types of Concrete Compression Test Specimens [35]

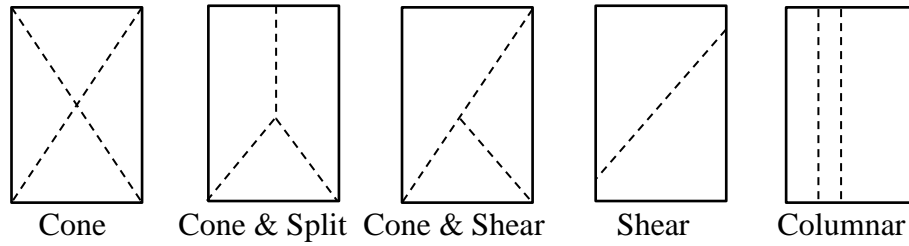


Figure 1.10. Concrete Failure Shapes [35]

1.9 OBJECTIVE OF THE RESEARCH WORK

The objective of the present work is to study the effect of partial replacement of sand with iron oxides. It is proposed to replace fine aggregates with iron oxide and find its effects on the compression strength of the concrete. Six percentage levels of replacement i.e. 5, 10, 15, 20, 25 and 30 percent are considered for partially replacing sand with iron oxide. Plain concrete (PC) grade is initially designed without replacement and subsequently sand is partially replaced with iron oxide.

CHAPTER 2

2. LITERATURE SURVEY

In 2016, *James Alexanders*, et. al. experimental investigation carried out to study the behaviour of concrete by replacing the fine aggregate with locally available red soil. It involves a certain tests to find the quality improvement of concrete when red soil is added to it. The partial replacement of sand with red soil was done according to the specific mix proportion to gain good strength in concrete and to calculate the imperviousness of red soil and also to find the special features of red soil which has the anti pest control in it. Mechanical properties such as compressive strength, split tensile strength, flexural strength and durability properties such as porosity, water permeability tests has been carried out for red soil mixed concrete and plain concrete to differentiate the strength and imperviousness in it . From the chemical properties of red soil, it is found that by replacing the fine aggregate with red soil turns the concrete as anti pest control. This red soil and river sand samples are first taken for preliminary test such as the sieve analysis test. Noticeably the red soil is of uniform size and so it is graded as poorly graded soil but the river sand is not finer as compared to the red soil. The partial replacement of sand in concrete has been done using red soil in a mix proportion of 1:1.5:2.75 which gives the significant improvement in strength and imperviousness. The characteristics of red soil has a great impact on strength, imperviousness and anti pest control. After conducting all these tests, red soil is found suitable for concrete as an admixture of it which can be used in construction of buildings [36].

In 2015, *Anupam Singhal*, et. al. studied the effect of sand replacement by mill scale on the properties of concrete. They aims to evaluate the use of mill scale in Portland cement concrete, as a replacement for natural fine aggregates. Cement mortars with mix proportioning 1:3 were prepared varying the mill scale content of fine aggregate form 0% to 100%, for determination of compressive and tensile strength. The water/cement ratio used was 0.5 for all mix proportions. The compressive strength at different proportions did not give a general trend and two peaks were obtained at 60% replacement and 100% replacement. Maximum tensile strength was observed at 60% replacement of standard sand. A mix design was also

done for M35 grade of concrete by the IS method. Ordinary Portland Cement (OPC) of 43 grade was selected and sand replacement was done with mill scale varying from 0% to 80% with a suitable water cement ratio of 0.40. The compressive strength was measured after 28 days of completion of curing. Maximum strength was obtained for 40% sand replacement. Moreover, concrete with mill scale has demanded greater water content to maintain the workability [37].

In 2014, Mien Van Tran investigated the effect of steel slag on the properties of concrete. In his paper, the steel slag was characterized by chemical, physical and mineralogical analysis, and then the steel slag was used to replace 100% coarse aggregates in high strength concrete which has various compressive strengths as 60, 70 and 80MPa. Results showed that the strength of the concrete using steel slag aggregate was equivalent to that of the conventional concrete, whereas, the durability of the steel slag aggregate concrete was better than that of the conventional concrete in terms of chloride penetration resistance and resistivity. Moreover, dimensional stability of the steel slag cement mortar was detected [38].

In 2010, *Osman GENCEL*, et. al., studied effects of different concentrations of hematite (10 to 50 volume % at 10 % intervals) on physical and mechanical properties of concrete. A unique water-to-cement ratio of 0.42 kg/m³ and 400 kg/m³ cement content was selected. Addition of hematite increases the unit weight (density) so that a smaller thickness of concrete is required to provide radiation shielding. After 30 freeze-thaw cycles the plain concrete loses 21.3 % of its compressive strength while the composite containing 10 % hematite loses only 7.8 % of the strength. Concrete and hematite composites have lower drying shrinkage than plain concrete, thus lowering stresses resulting from the shrinkage [39]. It was expected that addition of hematite – a material with higher density and higher hardness than cement – will increase the compressive strength. The results are presented in figure (9). We see that hematite increases the compressive strength of plain concrete for 10 % hematite and only slightly for 20 % hematite. The reason behind it may be the porosity of hematite. The more hematite we have, the more pores inside of hematite regions will appear. Using plain concrete again as the reference, changes in the compressive strength are as the following table:

Table 2.1 Compositions and Compression Strength of Mixtures of Heavyweight Concrete [39]

| Cement Sample | Plain Cement (PC) | H10 | H20 | H30 | H40 | H50 |
|------------------------------------|-------------------|------|------|-------|-------|-------|
| Cement (g) | 400 | 400 | 400 | 400 | 400 | 400 |
| Water (g) | 168 | 168 | 168 | 168 | 168 | 168 |
| Water/Cement Ratio | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 |
| (%) Change in Compressive Strength | 0.00 | 4.33 | 0.48 | -2.57 | -2.41 | -2.41 |

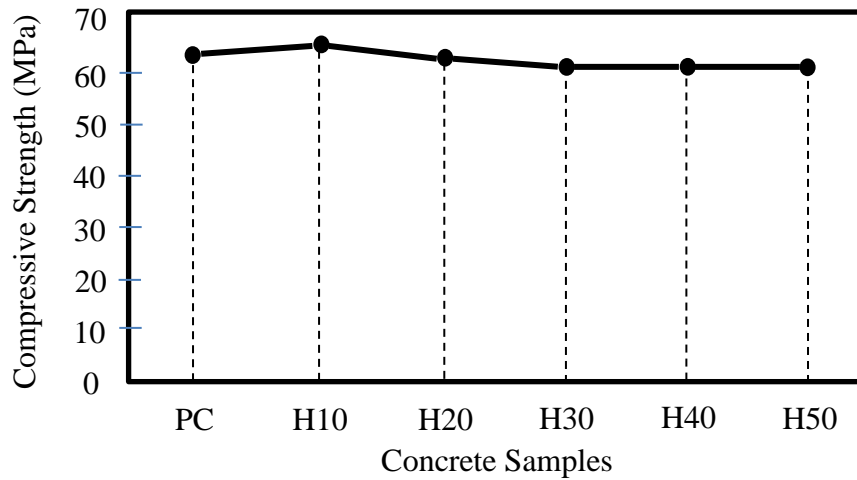


Figure 2.1. Compressive Strength of Mixtures of Heavyweight Concrete [39]

CHAPTER 3

3. MATERIALS AND DESIGN METHODOLOGY

3.1. GENERAL

The present chapter deals with the presentation of results obtained from various tests conducting on material used for concrete. In order to achieve the objectives of the present study, an experimental program was planned to investigate the effect of iron oxide (Hematite) on compressive strength of concrete.

3.2. MATERIALS

3.2.1. Portland Cement

Although all materials that go in concrete mix are essential, cement which is very important because its usually the delicate link in the chain. The function of cement is first of all to bind the sand and other concrete additives and second to fill up the voids in between sand and other additives to form a compact mass. In constitutes about 20 percent of total volume of concrete mix; it is the active portion of binding medium and is only sufficiently controlled ingredient of concrete. Any variation of its quantity affects the compression strength of concrete mix. Portland cement referred to (Ordinary Portland Cement) is the most important type of cement and is a fine powder produced by grinding Portland cement clinker. Cement materials used in the present work experiments were produced in Ziliten cement factory (Libya), it's a Portland cement grade (42.5 N), in accordance to Libyan specifications No. (340/2009). Typical chemical composition of Portland cement is shown in chapter 1 on table (1.2).sample of Portland used in the present work is shown in fig 3.1.



Figure 3.1. Sample of Portland Cement Used in the Present Work

3.2.2. Local Sand

The used sand in the present work is a naturally occurring granular material composed of finely divided rock and mineral particles. The composition of sand varies, depending on the local sources and conditions. The most common is a silica (silicon dioxide) usually in the form of quartz. They are shown in figure 3.2.

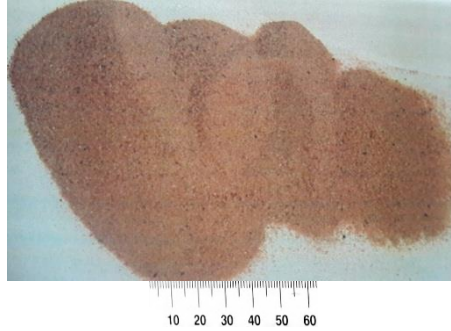


Figure 3.2. Sample of Local Sand Used in the Present Work

3.2.3. Water

Generally, water that suitable for drinking is satisfactory for use in concrete. The pH was 6.07 and the chemical content of water used in this work experiments are showed on table 3.1 .

Table 3.1. The chemical analysis of water used in the present work

| K | SO ₄ | Cl | Ca | CO ₃ | NO ₃ | NO ₂ |
|--------|-----------------|---------|--------|-----------------|-----------------|-----------------|
| 9.41 % | 3.70 % | 28.40 % | 3.20 % | 39.04 % | 6.16 % | 4.60 % |

3.2.4. Iron Oxide

The used iron oxide namely (Hematite Fe₂O₃) was collected from Wadi Al-Shati iron ore quarry (about 100 km north west Sebha city-Libya) , has a reddish brown color. The collected sample of iron oxide is shown on figure 3.3 .



Figure 3.3. Wadi Al-Shati Iron Oxide Collected Sample

3.3. MATERIALS PREPARATION

The materials used in the present research are listed as following:

- 2.0 kg of Portland cement;
- 6.0 kg of local sand;
- 2.0 L of mineral drinking water;
- About 2.5 kg of Wadi Al-Shati iron oxide.

3.4. CLASSIFICATION AND SCREENING OF IRON OXIDE

The collected sample of iron oxide consists of coarse and fine sizes, The objective is to classify the oxide sizes in order to obtain the minimum possible fine particles to replace the sand used to mix a concrete. For this different screens with different sizes were used. The steps of iron oxide classification is shown on the figure 3.4.

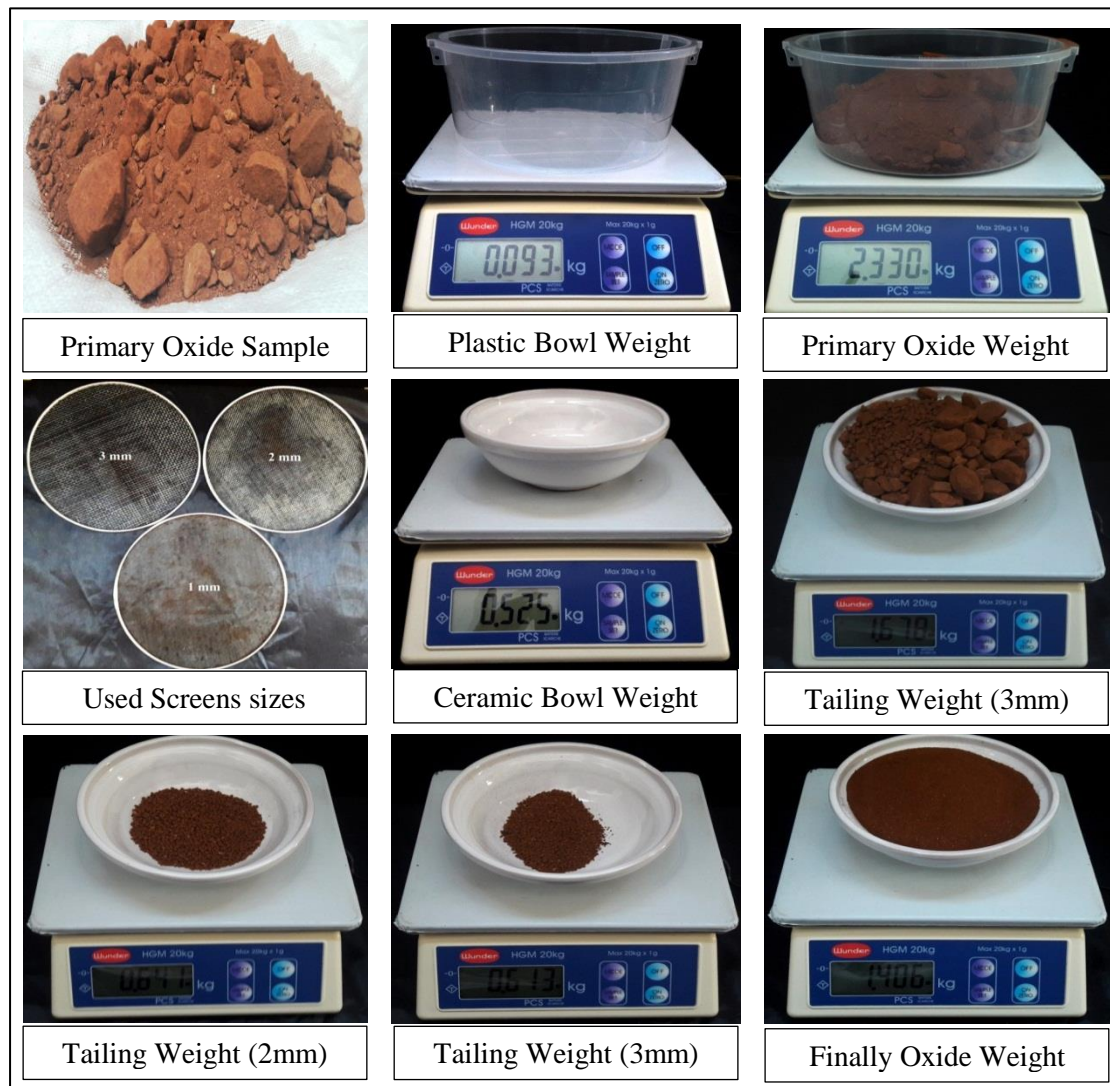


Figure 3.4. Classification and Screening of Iron Oxide

3.5. SPECIMENS PREPARATION

The experimental program including preparation of a six specimens, The first specimen is without sand replacement with iron oxide (reference specimen), and the other five specimens are including gradually replaced of sand with iron oxide (5g, 10g, 15g, 20g, and 25g). The percentage of sand replacement with iron oxide are shown in the table 3.2 .

For each specimen (PC, H10, H20, H30, H40, and H50), a two types were prepared in order to take the average of the obtained results for each specimen.

All specimens were prepared as cylinder shape with dimensions of 30 mm length and 35 mm diameter as shown on figure 3.5 .

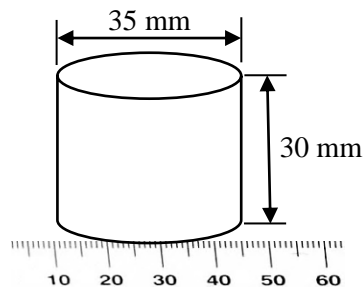


Figure 3.5. Dimensions of Experimental Specimen

Table 3.2. Date of Experimental Work

| Specimen | Portland Cement (pc) (g) | Mineral Water (mL) | Local Sand (g) | Local Sand (%) | Iron Oxide (g) | Iron Oxide (%) |
|--------------|--------------------------------|-----------------------|-------------------|-------------------|-------------------|-------------------|
| Control (PC) | 100 | 50-55 | 300 | 100 | 0 | 0.0 |
| H10 | 100 | 50-55 | 295 | 98.3 | 5 | 1.7 |
| H20 | 100 | 50-55 | 290 | 96.7 | 10 | 3.3 |
| H30 | 100 | 50-55 | 285 | 85.0 | 15 | 5.0 |
| H40 | 100 | 50-55 | 280 | 93.3 | 20 | 6.7 |
| H50 | 100 | 50-55 | 275 | 91.7 | 25 | 8.3 |

CHAPTER 4

4. RESULTS AND DISCUSSION

4.1. GENERAL

The chapter deals with presentation of results obtained from compression strength conducted on concrete specimens cast with and without iron oxide. The main objective of the research program was to understand the compressive strength aspect of concrete obtained using iron oxide as partial replacement of sand. In order to achieve the objectives of the present study, an experimental program was planned to investigate the effect of iron oxide on compressive strength of concrete. The experimental program consists of casting, curing and testing of controlled and iron oxide specimens at different concentrations. The program included the following:

- Design concrete mix (with and without iron oxide);
- Casting and curing specimens;
- Test to determine compressive strength of concrete.

4.2. COMPRESSIVE STRENGTH

4.2.1. General

In most structural application, concrete is employed primarily to resist compressive stresses. When a plain concrete member is subjected to a compression, the failure member takes place, in its vertical plane along the diagonal. The vertical cracks occurs due to lateral tensile strains. A flow in concrete, which is in the form of micro-cracks along the vertical axis of the member will takes place on the application of axial compression load and propagate further due to the lateral tensile strains.

4.2.2. Test cancelled Results

The cylinder specimens of dimension of (30 and 35 mm as length and diameter respectively) were prepared for testing compressive strength concrete. The concrete mixes with varying concentrations (0% , 1.7%, 3.3%, 5.0%, 6.7%, and 8.3%) of iron oxide as partial replacement of sand were cast into cylinders for subsequent testing.

In this study to make a concrete, cement, sand and iron oxide were mix, water then was added and the whole mass was mixed. After 24 hours the specimens were removed

from the moulds and placed in clean fresh water at temperature ($27^{\circ}\text{C} \pm 3$). The specimens so cast were tested after 14 days of curing measured from the time water is added to the dry mix. Each cast-sample was cut into two specimen and three of the four sub-specimens were tested. Before testing a specimen, each specimen was ground in order to obtain a balanced surface to get accurate results . For testing in compression, no cushioning material was placed between the specimen and the plates of the machine. The load was applied axially without shock till specimen was crushed. Results of compressive strength test with varying proportion of iron oxide replacement are given in table 3.3 .

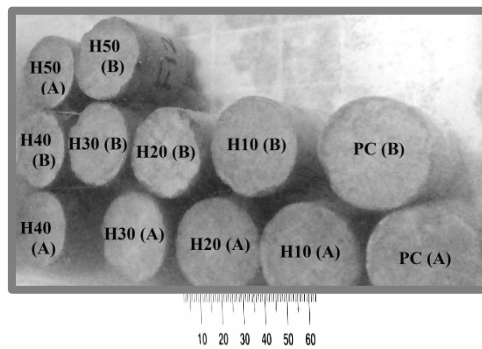


Figure 3.6. Experimental Specimen in Fresh Water

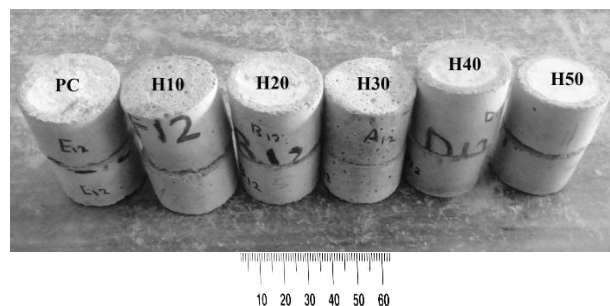


Figure 3.7. Experimental Specimen before Compression Test Carried out

Table 3.3. Compression Test Failure Load Results

| Specimen | Iron Oxide (%) | Failure Load (F_L) (kN) | | Failure Load Average (kN) |
|--------------|----------------|-----------------------------|----|---------------------------|
| Control (PC) | 0.0 | PC (A) | 30 | 26.00 |
| | | PC (B) | 28 | |
| | | PC (C) | 20 | |
| H10 | 1.7 | H10 (A) | 16 | 20.33 |
| | | H10 (B) | 25 | |
| | | H10 (C) | 20 | |
| H20 | 3.3 | H20 (A) | 16 | 15.66 |
| | | H20 (B) | 14 | |
| | | H20 (C) | 17 | |
| H30 | 5.0 | H30 (A) | 12 | 16.00 |
| | | H30 (B) | 18 | |
| | | H30 (C) | 18 | |
| H40 | 6.7 | H40 (A) | 25 | 20.33 |
| | | H40 (B) | 16 | |
| | | H40 (C) | 20 | |
| H50 | 8.3 | H50 (A) | 18 | 18.00 |
| | | H50 (B) | 18 | |
| | | H50 (C) | 20 | |

The compressive strength can be calculated using the formula: [26] $\sigma_c = \frac{F_L}{A}$ (6) where, F_L is the failure load registered on the machine after the concrete specimen had failures, and is the specimen area, and can be calculated as following:

cross-sectional Area of cylinder specimen is equal to $[\pi r^2] = [\pi(0.00175 \text{ m})^2] = 9.621 \times 10^{-6} \text{ m}^2$.

The compressive strength for each specimen was calculated according to the equation (6), the table 3.4 showing the results.



Figure 3.8. Compression Test Machine Used in the Present Work

Table 3.4. Compression Strength Results

| Specimen | Average Failure Load x 10 ³ (N) | Specimen Area x10 ⁻⁴ m ² | Compressive Strength (MPa) | Decreases in Compressive Strength (%) |
|--------------|---|---|-------------------------------|---------------------------------------|
| Control (PC) | 26.00 | 9.621 | 27.02 | 00.00 |
| H10 | 20.33 | 9.621 | 21.13 | - 21.18 |
| H20 | 15.66 | 9.621 | 16.28 | - 39.75 |
| H30 | 16.00 | 9.621 | 16.63 | - 38.45 |
| H40 | 20.33 | 9.621 | 21.13 | - 21.18 |
| H50 | 18.00 | 9.621 | 18.71 | - 30.75 |

4.2.3. Air content in the Concrete

In considering of the issue of air content in concretes, Concrete consists of a graded mix of aggregate particles in a cement paste matrix and the cement paste consists of unhydrated cement, Hydration products and the residue of the water-filled space which gives rise to capillary porosity. Concrete may also contain entrained air, entrapped air and other voids. Intentionally entrained air voids are bubbles typically 0.1 mm in diameter and are distributed evenly throughout the cement paste. Accidentally entrapped air usually forms very much larger voids, often up to several millimeters in diameter. This will typically account for 2 per cent of the volume of the concrete [40]. Differences between air content values determined should not exceed 1 % to be able to accept concrete with uniformity [41].

4.2.4. Compression strength

There is no need to argue that the compressive strength is the most important property of concrete. It was expected that addition of iron oxide – a material with higher hardness than cement – will increase the compressive strength. The results are presented in figure (3.9). It can be seen in the mentioned figure that the addition of iron oxide to the Portland cement has a negative effect. The decreasing in compression strength was not linear as the percentage of iron oxide is gradually increased. In the first specimen H10 (5g – 1.7% iron oxide), the compression strength decreases with percentage about (21%). For the specimens H20 and H30 (10g – 3.3% and 15g – 5.0% respectively), the compression strength decreases with average about (39%). For specimen H40 (20g – 6.7%), the compression strength decreases with about (21%). In the last specimen H50 (25g – 8.3%), the compression strength decreases with about (31%).

The reason behind decreasing in compressive strength (In general about 30%) comparing with the plain concrete may be attributed to the formation of porosity of iron oxide as discussed in section (4.2.3), that is shown on figure 3.10 . The more iron oxide we have, the more pores inside of iron oxide regions will appear [39].

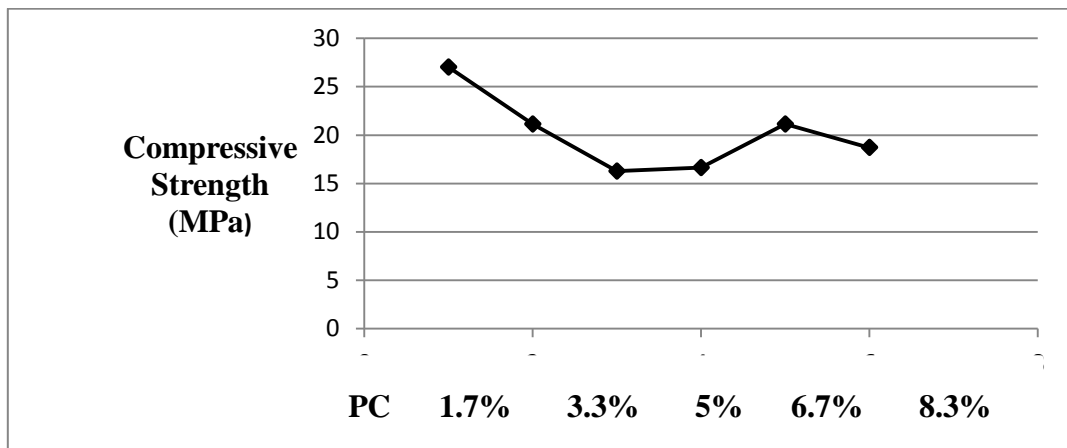


Figure 3.9. Compressive Strength of Hardened Concrete Specimens

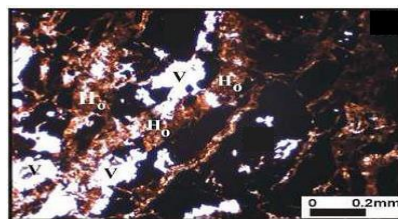


Figure 3.10. Iron Oxide Aggregates have high porosity (A) consequence of voids (V) which have appeared during formation of iron oxide H_0 [39]

CHAPTER 5

5. CONCLUSIONS

This research work is concerned with studying the effect of replacing a mix sand of concrete with different weight of iron oxide namely (hematite) (5g, 10g, 15g, 20g and 25g). It was expected that addition of iron oxide material with higher density higher hardness than Portland cement will increase the compressive strength. Unfortunately, the resulted data of those concrete specimens consists of partially replaced sand with iron oxide showed that there is a decrease in compression strength for all tested specimen comparing with the plain concrete (with no iron oxide addition). The reduction in compression strength of concrete ranges from 21.18% to 39.75% with no linearity. The reason for decline in compression strength for all specimens may attributed to the porosity of iron oxide formation in hardened concrete. It should be considered that because hematite includes high iron ore volume, it tends to undergo undesirable oxidation [39]. The overall conclusion is that the incorporating of iron oxide nanoparticles is not recommended in case of high compression strength is required. As recommended in some literatures, the iron oxide addition to cement base is considered to be useful since hematite has higher density than plain concrete, addition of hematite increases the unit weight – an expected but also desired result. The higher the density, the smaller the thickness of concrete is required to provide radiation shielding [39].

SCOPE FOR THE FUTURE WORK

- In the present study only up to 8.0% replacement of sand with iron oxide (hematite).has been considered. The other percentage i.e. 10%, 15%, 20%, and so on need investigation.
- A partially replacement of concrete sand with iron oxide need to be investigated as a barrier shield of x-ray radiation.

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