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Design of High Compressive Strength Concrete Mix without Additives

تصميم الخلطة الخرسانية عالية المقاومة دون استخدام المضافات

A thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Structural Engineering)

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الآية

قال تعالي:

﴿ إِنَّ فِي خَلْقِ السَّمَاوَاتِ وَالْأَرْضِ وَاخْتِلَافِ اللَّيْلِ وَالنَّهَارِ وَالْفُلْكِ الَّتِي تَجْرِي فِي الْبَحْرِ بِمَا يَنْفَعُ النَّاسَ وَمَا أَنْزَلَ اللَّهُ مِنَ السَّمَاءِ مِنْ مَاءٍ فَأَحْيَا بِهِ الْأَرْضَ بَعْدَ مَوْتِهَا وَبَثَّ فِيهَا مِنْ كُلِّ دَابَّةٍ وَتَصْرِيفِ الرِّيَاحِ وَالسَّحَابِ الْمُسَخَّرِ بَيْنَ السَّمَاءِ وَالْأَرْضِ لَآيَاتٍ لِقَوْمٍ يَعْقِلُونَ ﴾

صدق الله العظيم

سورة البقرة الآية (164)

Dedication

I dedicate this research and give special thanks to my beloved Mom and Dad

Both of you have been greater support of me in life.

Acknowledgement

Would like to express my gratitude to my supervisor D. Nuha .M. Akasha for the useful comments, remarks and engagement through the learning process of this master thesis. Furthermore I would like to thank Eng. Salah eldeen . A. Yousif General Manager of Material Tests Engineering for introducing me to the topic as well for the support on the way. Special thanks to Eng. Omer Nasir for support me and standing by me at all I do appreciate what he did and thanks a lot ,Also I would like to thanks my loved ones, who have supported me throughout entire process,. I will be grateful forever for your love…….

Abstract

In this study selected materials, with high specification using special production techniques, the properties ,the mix design procedure and mix proportion of the high strength concrete (HSC) were discussed. Different proportions of Ordinary Portland cement (410, 430 & 450) kg/m^3 with different crushed Basalt and uncrushed Granite coarse aggregate amount (1120 &1050) kg/m^3 and fine aggregate of fine modulus of 3.65 were used. Eight concrete mixes were prepared: two as control mix for crashed Basalt and uncrushed Granite, three with crashed Basalt and three with uncrushed Granite coarse aggregate with mix proportions (1:1.66:2.73), (1:1.42:2.44) and (1:1.22:2.33), (cement: fine aggregate : coarse aggregate) respectively. Specimens of trail mixes were tested. The concrete (Mix3) consist of Granite (1:1.22:2.33) with w/c of 0.46 was found to give the highest value of strength in the 28 and 56 days in comparison with other two mixes. It gave compressive strength 56 and 64 N/mm^2 in 28 and 56days respectively.

المستخلص

في هذا البحث تم مناقشة المواد المختارة و وتقنيات الإنتاج والخواص وخطوات تصميم الخلطة ونسب الخلط للخرسانة عالية المقاومة. في هذا البحث تم استخدام الأسمنت البورتلاندي العادي بنسب مختلفة هي (410 , 430 و 450)كجم/م^3 مع نسب مختلفة من الركام الكبير من البازلت المكسور و الجرانيت الغير مكسور هي (1050 و1120) كجم/م^3 مع رمل ذو معامل نعومة 3.65. تم إجراء اختبارات معملية مختلفة للمواد للتاكد من جودتها ومنها تم تصميم خلطات خرسانية بنسب مختلفة لتحقيق أعلى مقاومة للخرسانة بأستخدام المواد فقط، بدون مواد مضافة. والنسب هي(1:1.66:2.73)، (1:1.42:2.44),(1:1.22:2.33)، (اسمنت:ركام ناعم:ركام خشن) للبازلت والجرانيت. وفقا للنتائج المتحصل عليها وجد ان نسبة الجرانيت (MIX3 (1:1.22:2.33)بنسبة w/c 0.46 تعطي أعلى مقاومة للخرسانة في 28 يوم و 56يوم بين الخلطات الأخرى وهي 56 و64 نيوتن/مم^2.

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INTRODUCTION

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INTRODUCTION

1.1 General

Concrete is one of the most common material and widely used in construction work. Concrete production is estimated to increase from about 10 billion tons in 1995, to nearly 16 billions tons in 2010 [E.Gjorv and Koji Sakai, 2004]. But such increase brings serious implications to the environmental [2,4and7].Today the emerging awareness to reduce the impact it had, through a sustained effort to make concrete. One effort is make concrete with higher quality and durable [Aichin dan Mindes,2011; Schmidt, M Habil. 2008].

Concrete that has these properties is High Performance Concrete [Sobolev, K.G. and Soboleva, S.V.1998)]. In the Strategic Highway Research Program (SHRP] , HPC was initially defined by three requirements : maximum water-cementations material ratio of 0.35,minimum durability factor of 80%, as determined by ASTM C 666 method and 21 MPa within 4 hours after placement, 34 MPa within 24 hours and 69 MPa within 28 days. [Caijun Shi dan YL Mo, 2008]. In 1998 ACI published HPC as concrete which meets special performance and uniformity requirements that cannot always be achieved by using only the conventional materials and mixing, placing and curing practices the performance requirements may involve enhancements of placement and compaction without segregation, long-term mechanical properties, early-age strength, toughness, volume stability or service life in severe environment. [Magee and Olek],(2000) Collected and analysed approximately 260 HPC mixtures from more than 200 publications.

The result that the range for water content (150-170 kg/m^3), high binder content (350-500 kg/m^3), fine aggregate and coarse aggregate are (700 – 800) kg/m^3 and (1000-1100 kg/m^3. Mix proportions for HPC are influenced by many factors, including specified performance properties, locally available materials, local experience, personal and cost [Caijun,Shidanyl Mo, 2008; El-Reedy, 2009]. Research on High Performance Concrete mix proportions have been carried out in several countries, but unfortunately the result of research only applies to mixtures using local ingredients are the same. Therefore it is necessary to do research on development of High Performance mix proportions using local materials, where until now general, used concrete with $f'c$ = 35 MPa to $f'c$= 45 MPa. In this study the proportion of the mixture which was developed for $f'c$ =60 MPa, and $f'c$= 80 MPa using local materials that have generally been used ready mix producers. Basic development of High Performance Concrete on aspects of concrete compressive strength and durability.

High strength concrete is a type of high performance concrete. The primary difference between high strength concrete and normal-strength concrete relates to the compressive strength that refers to the maximum resistance of a concrete sample to be applied pressure. Although there is no precise point of separation between high strength concrete and normal strength of concrete.

The American concrete institute ACI defines high strength concrete as concrete with a compressive strength greater than 41MPa (6000psi). high strength concrete is a superior product with increased modulus of elasticity, lower creep and drying, Shrinkage excellent freeze thaw resistance, low permeability and increased chemical resistance high strength concrete is specified where reduced weight is important or where architectural considerations call for small support element by carrying load more efficiently than normal strength concrete. high strength concrete HSC also reduces the total amount of materials placed and lower the overall cost of the structure, Although a 97 MPa (14000psi) concrete costs approximately three time as much as a 21 MPa (3000 Psi) concrete, its compressive strength is nearly five times greater, thus it is economical. Much research in recent years has been devoted to establishing the fundamental and engineering properties of high-strength concrete HSC, as well as the engineering characteristic of structural member made with material it is well known that the inhomogeneous structure of concrete can be described as three-phase system consisting of hardened. Cement paste, aggregate and the interfaced between aggregate and cement paste, the smaller nominal maximum size has a larger surface compared with the larger nominal maximum size and results therefore a high bonding strength at the interface zone around the aggregate particles when concrete is under loading. In consequence bond failure is avoided and the fracture surfaces pass through the aggregate as well as through the hardened cement paste both under compressive and under tensile loading. The aggregate take a better part in transfer of sternness under loading.

The interface one beams stranger, more homogeneous and dense , as a result of silica addition the concrete shows a more brittle behaviour and Tran granular type of fracture, the cracks then usually pass through the aggregate. In this research work the locally available constituents of concrete were selected for the purpose to obtained high strength concrete HSC [2,4].

1.2 Problem Statement

Production of HSC may or may not require special materials, but it definitely requires materials of highest quality and their optimum proportions [Carrasquillo, 1985]. The production of HSC that consistently meets requirements for workability and strength development places more stringent requirements on material selection than that for lower strength concrete [ACI 363R, 1992]. However, many trial batches are often required to generate the data that enables the researchers and professionals to identify optimum mix proportions for HSC. Practical examples of mix proportions of HSC used in structures already built can also be the useful information in achieving HSC.

In this research numbers of trial mixes have been considered, following the reviewed information, in order to achieve concretes with compressive strengths from 30 MPa to as high as 60 MPa. The information obtained from literature as well as the results of experimental work described here in will be beneficial to researchers and engineers dealing with HSC.

1.3 Objectivities

This research deals with HSC without additive to achieve the target of this research the following specific objectives are proposed:-

1. To have an adequate Knowledge about HSC special materials and HSC special production techniques, properties of HSC and its mix design procedures and proportions.
2. Use of quality materials, smaller water/cement ratio, larger ratio of coarse aggregate (CA) to fine aggregate (FA), smaller size of coarse aggregate, with their optimum dosages are found necessary to produce HSC
3. To achieve optimum Mix proportion by using availability material without use any kind of additive gives strength above 60 N/mm^2 in 56days.

1.4 Methodology

The proposed methodology of the thesis is as follow:-

1. Collecting adequate information about the basic characteristics of normal strength concrete (NSC) materials and properties.
2. Collecting adequate information about HSC special material and their special production technique, properties of HSC and its mix design procedures and proportions.
3. Using special material after tested quality control between different types of availability material to select the best one.
4. Use different mix proportion to achieve the optimum and make comparative between them.
5. Testing the concrete to find maximum compressive strength from proportion mix.
6. Writing the conclusion and recommendation.

1.5 Hypothesises

What is High Strength Concrete means?

Why do we need to produce high strength concrete?

How we can to design high strength concrete mixes without additives?

1.6 Research Outlines

Thesis has been outlined as follow:-

Chapter One contains a general introduction, problem statement, objectives, methodology and hypothesises of this research.

Chapter Two contains basic characteristic of HSC materials with special consideration to the factor effecting concrete strength, type of concrete accordance to different factor as general and previous study are discussed.

Chapter Three contains Material making concrete proprieties, sources and manufacturing of cement, qualities and affections of compressive strength of concrete and materials selection and mix design procedures and proportions are discussed.

Chapter Four contains testing material procedure and steps (cement testing, coarse aggregate testing; fine aggregate testing and mix design steps are discussed.

Chapter Five contains Presentation of the results of materials tests and concrete compressive strength tests for different mix proportions and compassion the results between two types of aggregate using in concrete mix design are discussed.

Chapter Six contains research conclusions with recommendations for future researches are presented.

CHAPTER TWO

LITERATURE REVIEW

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LITERATURE REVIEW

2.1 Introduction

Concrete is the most widely used material in the world. It plays an important role in infrastructure and private buildings construction. Understanding the basic behaviours of concrete is essential for civil engineering students to become civil engineering profession. Concrete is a manmade building material that looks like stone. The word “concrete” is derived from the Latin concretus, meaning “to grow together.” Concrete is a composite material composed of coarse granular material (the aggregate or filler) embedded in a hard matrix of material (the cement or binder) that fills the space among the aggregate particles and glues them together. Alternatively, it was said that concrete is a composite material that consists essentially of a binding medium in which are embedded particles or fragments of aggregates. The simplest definition of concrete can be written as: (Concrete = filler + binder) Depending on what kind of binder is used, concrete can be named in different waysals. As a structural material, the compressive strength at an age of 28 days is the main design index for concrete. There are several reasons for choosing compressive strength as the representative index. First, concrete is used in a structure mainly to resist the compression force. Second, the measurement of compressive strength is relatively easier. Finally, it is thought that other properties of concrete can be related to its compressive strength through the microstructure. Pursuing high compressive strength has been an important direction of concrete development. As early as 1918, Duff Adams found that the compressive strength of a concrete was inversely proportional to the water-to-cement ratio. Hence, a high compressive strength could be achieved by reducing the w/c ratio. However, to keep a concrete workable, there is a minimum requirement on the amount of water; hence, the w/c ratio reduction is limited, unless other measures are provided to improve concrete’s workability. For this reason, progress in achieving high compressive strength was very slow before the 1960s. At that time, concrete with a compressive strength of 30 MPa was regarded as high-strength concrete. Since the 1960s, the development of high-strength concrete has made significant progress due to two main factors: the invention of water-reducing admixtures and the incorporation of mineral admixtures, such as silica fume, fly ash, and slag. Water-reducing admixture is a chemical admixture that can help concrete keep good workability under a very low w/c ratio; the latter are finer mineral particles that can react with a hydration product in concrete, calcium hydroxide, to make concrete microstructure denser. Silica fume also has a packing effect to further improve the matrix density. In 1972, the first 52-MPa concrete was produced in Chicago for the

52-story Mid-Continental Plaza. In 1972, a 62-MPa concrete was produced, also in Chicago, for Water Tower Place, a 74-story concrete building, the tallest in the world at that time .In the 1980s, the industry was able to produce a 95-Mpa concrete to supply to the 225 West Whacker Drive building project in Chicago. The highest compressive strength of 130 MPa was realized in a 220-m-high, 58-story building, the Union Plaza constructed in Seattle, Washington (Caldarone, 2009).Concrete produced after the 1980s usually contains a sufficient amount of fly ash, slag, or silica fume as well as many different chemical admixtures, so its hydration mechanism, hydration products, and other microstructure characteristics are very different from the concrete produced without these admixtures. Moreover, the mechanical properties are also different from the conventional concrete; hence, such concretes are referred to as contemporary concretes. There have been two innovative developments in contemporary concrete: self-compacting concrete (SCC) and ultra-high-performance concrete (UHPC). SCC is a type of high-performance concrete. High-performance concrete is a concept developed in the 1980s. It is defined as a concrete that can meet special performance and uniformity requirements, which cannot always be achieved routinely by using only conventional materials and normal mixing, placing, and curing practices. The requirements may involve enhancement of the characteristics of concrete, such as placement and compaction without segregation, long-term mechanical properties, higher early-age strength, better toughness, higher volume stability, or longer service life in severe environments. Self-compacting concrete is a typical example of high-performance concrete that can fill in formwork in a compacted manner without the need of mechanical vibration. SCC was initially developed by Professor [Okamura and his students in Japan in the late 1980s (Ozama et al., 1989]. At that time, concrete construction was blooming everywhere in Japan. Since Japan is in an earthquake zone, concrete structures are usually heavily reinforced, especially at beam–column joints. Hence, due to low flow ability, conventional concrete could hardly flow past the heavy reinforced rebar's, leaving poor-quality cast concrete and leading to poor durability. Sometimes, the reinforcing steel was exposed to air immediately after demolding. To solve the problem, [Professor Okamura] and his students conducted research to develop a concrete with high flow ability. With the help of the invention of the high-range water reducer or plasticizer, such a concrete was finally developed. They were so excited that they called this concrete "high-performance concrete" at the beginning. It was corrected later on to SCC, as HPC covers broader meanings.

Durability is a main requirement of HPC. It has been found that many concrete structures could not fulfil the service requirement, due not to lack of strength, but to lack of durability. For this reason, concrete with high performance to meet the requirement of prolonging concrete service life was greatly needed.In the 1990s, a new “concrete” with a compressive concrete strength higher than 200 Mpa was developed in France. Due to the large amount of silica fume incorporated in such a material, it was initially called reactive powder concrete and later on changed to ultra-high-strength (performance) concrete (UHSC), due to its extremely high compressive strength [Richard and Cheyrezy, 1995]. The ultra-high-strength concrete has reached a compressive strength of 800 MPa–with heating treatment. However, it is very brittle, hence, incorporating fibers into UHSC is necessary. After incorporating fine steel fibers, flexural strength of 50 MPa can be reached. The first trial application of UHSC was a footbridge built in [Sherbrooke, Canada (Aitcin et al., 1998)]. [2, 4,5and8]

2.2 Concrete as a Structural Material

In term concrete usually refers to Portland cement concrete, if not otherwise specified. For this kind of concrete, the compositions can be listed as follows:

(i) Cement paste→ consist Portland cement and water (admixtures).
(ii) Mortar→ is fine aggregate
(iii) Concrete →is coarse aggregate

It may be indicate that admixtures are almost always used in modern practice and thus have become an essential component of contemporary concrete. Admixtures are defined as Introduction to Concrete materials other than aggregate (fine and coarse), water, and cement that are added into a concrete batch immediately before or during mixing. The use of admixtures is widespread mainly because many benefits can be achieved by their application. For instance, chemical admixtures can modify the setting and hardening characteristics of cement paste by influencing the rate of cement hydration. Water-reducing admixtures can plasticize fresh concrete mixtures by reducing surface tension of the water. Air-entraining admixtures can improve the durability of concrete, and mineral admixtures such as pozzolans (materials containing reactive silica) can reduce thermal cracking.

Concrete is the most widely used construction material in the world, and its popularity can be attributed to two aspects. First, concrete is used for many different structures, such as dams, pavements, building frames, or bridges, much more than any other construction material. Second, the amount of concrete used is much more than any other material. Its worldwide production exceeds that of steel by a factor of 10 in tonnage and by more than a factor of 30 in volume.

In a concrete structure, there are two commonly used structural materials: concrete and steel. A structural material is a material that carries not only its self-weight, but also the load passing from other members.

Steel is manufactured under carefully controlled conditions, always in a highly sophisticated plant; the properties of every type of steel are determined in a laboratory and described in a manufacturer's certificate. Thus, the designer of a steel structure need only specify the steel complying with a relevant standard, and the constructor needs only to ensure that the correct steel is used and that connections between the individual steel members are properly executed (Neville and Brooks, 1993). On the other hand, concrete is produced in a cruder way and its quality varies considerably. Even the quality of cement, the binder of concrete, is guaranteed by the manufacturer in a manner similar to that of steel; however, the quality of concrete is hardly guaranteed because of many other factors, such as aggregates, mixing procedures, and skills of the operators of concrete production, placement, and consolidation and forming as shown in Fig (2.1). It is possible to obtain concrete of specified quality from a ready-mix supplier, but, even in this case, it is only the raw materials that are bought for a construction job. Transporting, placing, and, above all, compacting greatly influence the quality of cast concrete structure. Moreover, unlike the case of steel, the choice of concrete mixes is virtually infinite and therefore the selection has to be made with a sound knowledge of the properties and behaviour of concrete. It is thus the competence of the designer and specifier that determines the potential qualities of concrete, and the competence of the supplier and the contractor that controls the actual quality of concrete in the finished structure. It follows that they must be thoroughly conversant with the properties of concrete and with concrete making and placing. In a concrete structure, concretes mainly carry the compressive force and shear force, while the steel carries the tension force. Moreover, concrete usually provides stiffness for structures to keep them stable. Concretes have been widely used to build various structures. High-strength concrete has been used in many tall building constructions. In Hong Kong, grade 80 concrete (80 MPa) was utilized in the columns of the tallest building in the region. International Finance Centre was built in 2003 and stands 415m (1362 ft) tall. Concrete has also been used in bridge construction. recently built [Sutong Bridge] that spans the Yangtze River in China between Nantong and Changshu, a satellite city of Suzhou, in Jiangsu province. It is a cable-stayed bridge with the longest main span, 1088 meters, in the world. Its two side spans are 300m (984 ft) each, and there is also four small cable spans. The Sutong Bridge in Suzhou, Jiangsu, China Dams is other popular application fields for concrete. The first major concrete dams, the Hoover Dam and the Grand Coulee Dam, were built in the 1930s and they are still standing. The largest dam ever built is the Three Gorges Dam in Hubei province, China. The total concrete used for the dam was over 22 million m3. Concrete has also been used to build high-speed railways. [Shinkansen, the world's first contemporary high-volume (initially 12-car maximum)], "high-speed rail," was built in Japan in 1964. In Europe, high-speed rail was introduced during the International Transport Fair in

Munich in June 1965. Nowadays, high-speed rail construction is blooming in China. According to planning, 17,000 km of high-speed rail will be built in China by 2012. In addition, concrete has been widely applied in the construction of airport runways, tunnels, highways, pipelines, and oil platforms. As of now, the annual world consumption of concrete has reached a value such that if concrete were edible, every person on earth would have 2000 kg per year to "eat." You may wonder why concrete has become so popular. [4, 5, and24]

2.3 Types of Concrete

2.3.1 Classification in accordance with unit weight

According to the unit weight of concretes, they can be classified into four categories. Ultra-lightweight concrete can only be used to build up nonstructural members. Lightweight concrete can be used to build both nonstructural and structural members, depending on its specified composition.

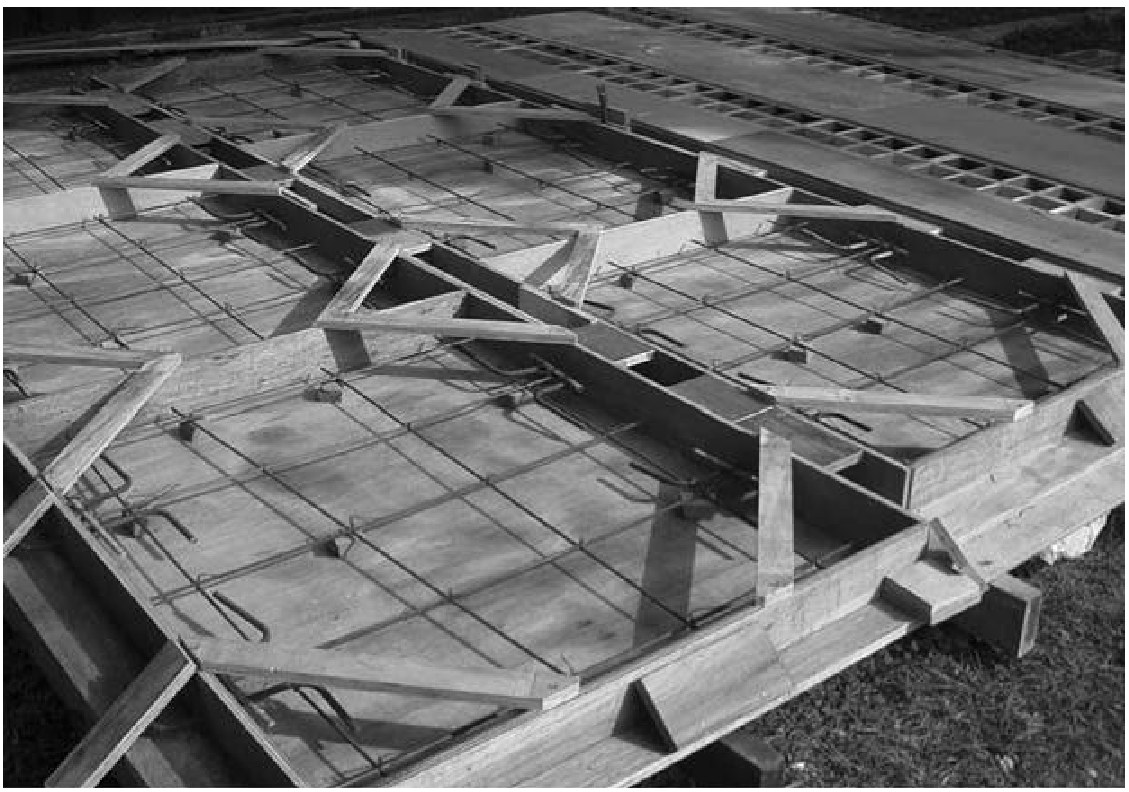

Fig (2.1): Formwork for concrete casting

Normal-weight concretes are commonly used concretes as shown in the Table (2-1)

Table (2.1): Classification of concrete in accordance with unit weight

Classification	Unit weight kg/m^3
Ultra-light weight concrete	< 1200
Light weight concrete	1200< UW <1800
Normal- weight concrete	~ 2400
Heavy- weight concrete	>3200

2.3.2 Classification in accordance with compressive strength

According to its compressive strength, concrete can be classified into four categories, as listed in Table (2-2). Low-strength concrete is mainly used to construct mass concrete structures, subgrades of roads and partitions. Moderate-strength concretes are the most commonly used concretes in buildings, bridges, and similar structures. High-strength concretes can be used to build tall building columns, bridge towers and shear walls. Ultra-high-strength concretes have not yet been widely used in structural constructions. Only a few footbridges and some structural segments, such as girders, have been built using such concretes.

Table (2.2): Classification of concrete in accordance with compressive strength

Classification	Compressive strength(MPa)
Low- strength concrete	< 20
Moderate- strength concrete	20-50
High –strength concrete	50-150
Ultra-high- strength concrete	>150

2.3.3 Classification in accordance with additives

According to the materials other than cement, aggregate and water that are added into concrete mixtures as additives, concretes can be classified into different categories. Four examples are shown in Table (2-3) fiber-reinforced concrete (FRC) is a type of concrete with fibers incorporated. Many different fibers have been used to produce fiber-reinforced concrete, including steel, glass, polymerics, and carbon. The purpose of incorporating fibers into concrete includes toughness enhancement, tension property improvement, shrinkage control, and decoration. Macro-defect-free (MDF) is a cement based composite that incorporates a large amount of water-soluble polymer, produced in a twin-roll mixing process. It was developed to enhance the tensile and flexural properties of concrete. Concrete that has been densified with small particles. (DSP) has incorporated a large amount of silica fume, a mineral admixture with very small particles. DSP has excellent abrasion resistance and is mainly used to produce machine tools and industrial molds. Three methods have been developed to incorporate polymers into concrete: using the polymer as a binder, impregnating the polymer into normal Portland cement concrete members, and using the polymer as an admixture in ordinary Portland concrete. [15]

Table (2.3): Concrete classification in accordance with additives

Classification	Additives
MDF	Polymers
Fiber- reinforced concrete	Different fibers
DSP concrete	Large amount of silica fume
Polymer concrete	Polymers

2.4 Previous Studies

To achieve the results required high strength concrete without additives had to be a study scientific papers in the field of concrete and high strength, among them the following:

Abdullahi. M [1] Is study the Effect of aggregate type on Compressive strength of concrete .The utilization of three types of aggregate for concrete work is investigated in this study. Normal concrete is being produced from different types of aggregate and this imparts different property to the resulting concrete. For the purpose of this work, three types of coarse aggregates, quartzite, granite, and river gravel, were used. The fine aggregate is normal sand obtained from a borrow pit. Preliminary laboratory investigation was conducted to ascertain the suitability of using the aggregates for construction work. Tests conducted include sieve analysis, bulk density, and specific gravity. Nominal mix (1:2:4) was adopted for this work and mix compositions were calculated by absolute volume method. For each type of coarse aggregate 75 cubes (150x150mm) were cast to allow the compressive strength to be monitored at 3, 7, 14, 21, and 28 days' Highest compressive strength was achieved from concrete containing crushed quartzite, followed by concrete containing river gravel. Concrete containing crushed granite shows the least strength development at all ages.

Jonbi[1,a], Binsar Hariandja [1,b] ,Iswandi Imran[1,c], Ivindra Pane[1,d] [12] are study Development of Mix Proportion For High-Performance Concrete Using Locally Available Ingredients Based on Compressive Strength and Durability.The increased use of concrete, apparently bring the impact of environmental damage. This is due to the fact that production of raw materials contributes greatly to CO_2

in the air. One effort to reduce such impact is to use of high performance concretes. Mix proportion of high Performance Concrete is strongly determined by the quality and availability of local materials. The implications of study result from other countries can't be directly used. Therefore is need to the study on development of High Performance Concrete mix using locally available materials. In this study the mix proportions for $f'c$= 60 and 80 MPa are developed using local materials that are commonly used by ready-mix producers. The high Performance Concrete is developed based on compressive strength and durability. The result is expected to be applied to ready-mix industry particularly for construction use in Indonesia. This result shows that local materials with similar composition of the mixture can produce compressive strength higher than $f'c$= 60 MPa and $f'c$= 80 MPa. While the RCPT result as 40 MPa : 1050 coulombs, $f'c$= 60 MPa : 990 Coulombs, and $f'c$= 12,5 coulombs lower. Permeability test result show that $f'c$= 40MPa: 4.0cm, $f'c$ =60 MPa : 3.5 cm dan $f'c$=80 MPa : 2.4 cm. HPC produced a compressive strength and durability is good, because increasing dense and homogeneous concrete.

Mohammad Abdur Rashida and Mohammad Abul Mansurb[17] Are study Considerations in producing high strength concrete .The requirements of ingredient materials and the basic considerations in producing HSC are described as follow Portland cement - Higher content (8 to 10 sacks per cu. yd. of concrete), Potable quality w/c ratio 0.22 to 0.40,sand with rounded particle shape Higher FM (around 3.0) smaller sand content or coarser sand grading is not critical for concrete strength smaller maximum size (10 – 12 mm) is preferred Angular and crushed with a minimum flat and elongated particles type of aggregate depending on the concrete strength targeted gradation within ASTM limits has little effect on concrete strength higher CA/FA ratio than that for normal strength concrete, type of admixture depends on the property of the concrete to be improved reliable performance on previous work can be considered during selection optimum dosage quality materials improved quality of cement paste as well as aggregates denser packing of aggregates and cement paste improved bond between aggregate surface and cement paste minimum numbers as well as smaller sizes of voids in the paste High strength concrete with compressive strength as high as 127 MPa can be obtained using OPC and the naturally available course aggregate. However, use of lower water-cement ratio along with super plasticizer is the most vital factor to be considered in HSC productions.

M. Yaqub*, & Imran Bukhari, [19] Effect of Size of Coarse Aggregate on Compressive Strength of High Strength Concrete .This study describes the influence of aggregate size on the compressive strength of high strength concrete. High strength concrete is a type of high performance concrete generally with a specified compressive strength of 40 Mpa (6000psi) or greater. To investigate the effect of size of aggregate on the compressive strength of high strength concrete an experimental program was carried out in University of Engineering and Technology Taxila Pakistan. Five different sizes of course aggregates were used while developing a mix design. The sizes of coarse aggregate were 37.5mm, 25mm, 20mm, 10mm and 5 mm. Natural sand with fineness modules of 3.48 was used as fine aggregate. Ordinary Portland cement was used as binding material. Different trials of mixing of coarse aggregate were made (37.5mm and 25mm, 25 mm and 20mm, 20mm and 10mm, 10mm and 5mm) to investigate the influence of size of aggregate on compressive strength of concrete. Cylinders of size 150mmx300mm were cast in laboratory and tested in Universal compression testing machine. It was concluded that 10mm and 5mm aggregates showed higher compressive strength than other types of aggregates. Aggregate of sizes 10mm & 5mm the utilizeation of three types of aggregate for concrete work is investigated in this paper. Normal concrete is being produced from different types of aggregate and this imparts different property to the resulting concrete than all other sizes of aggregates. Mix ratio 1:0.75: 1.5 with aggregate sizes 10mm & 5mm gives optimum strength.

Srinivas Allena1 and Craig M. Newtson2 [21] are study Ultra-High Strength Concrete Mixtures Using Local Materials.This study presents the development of ultra- high strength concrete (UHSC) using local materials. UHSC mixture proportions were developed using local materials so that UHSC may be made more affordable to a wider variety of applications. Specifically, local sand with a top size of 0.0236 in. (600 μm), and locally available Type I/II cement and silica fume were used in this study. Each of these material selections is seen as an improvement in sustainability for UHSC. Two mixtures (one with and one without fibers) were recommended as the UHSC mixtures. The greatest compressive strengths obtained in this study were 24,010 psi (165.6 MPa) for UHSC with steel fibers and 23,480 psi (161.9 MPa) for UHSC without fibers. The compressive and flexural strengths obtained from the UHSC mixtures developed in this work are comparable to UHSC strengths presented. Producing this innovative material with local materials reduces the cost of the material, improves sustainability, and produces mechanical performance similar to prepackaged, commercially available products. Compressive strength of fiber reinforced UHSC (EL00) was greater than the compressive strength of plain UHSC (DL00) at all ages. The percentage increases in compressive strength due to steel fibers at 7, 14, and 28 days were 5.43, 5.45, and 2.25 percent, respectively.

In this research from the previous study I knew that the effect of aggregate type and size on Compressive strength of concrete how select to suitable types and size of aggregate with good specifications. And also the use of availability local materials to find the optimum mix proportions that to gives greater compressive strength value of concrete.

CHPTER THREE

THEORETICAL STUDY

CHAPTER TREE
THEORETICAL STUDY

3.1 Introduction

Concrete is one of the most versatile and widely produced construction materials in the world [Penttala, 1997]. Its worldwide annual production exceeds 12 billion metric tons, i.e., more than two metric tons of concrete was produced each year for every person on earth in 2007. The ever-increasing population, living standards, and economic development lead to an increasing demand for infrastructure development and hence concrete materials. As a composite material, concrete is composed of different graded aggregates or fillers embedded in a hardened matrix of cementations material. The properties of major constituents of concrete mixtures, such as aggregates, cementations materials, admixtures, and water, should be understood first to better learn the properties and performance of concrete.

3.2Material Making Concrete

3.2.1Aggregate

Aggregate constitute a skeleton of concrete. Approximately three-quarters of the volume of conventional concrete are occupied by aggregate. It is inevitable that a constituent occupying such a large percentage of the mass should contribute important properties to both the fresh and hardened product. Aggregate is usually viewed as an inert dispersion in the cement paste. However, strictly speaking, aggregate is not truly inert because physical, thermal, and, sometimes, chemical properties can influence the performance of concrete [Neville and Brooks, 1990].

Effects of aggregates:-

When concrete is freshly mixed, the aggregates are suspended in the cement–water–air bubble paste. The behavior of fresh concrete, such as fluidity, cohesiveness, and rheological behavior, is largely influenced by the amount, type, surface texture, and size gradation of the aggregate.

Although there is little chemical reaction between the aggregate and cement paste, the aggregate contributes many qualities to the hardened concrete. In addition to reducing the cost, aggregate in concrete can reduce the shrinkage and creep of cement paste. Moreover, aggregates have a big influence on stiffness, unit weight, strength, thermal properties, bond, and wear resistance of concrete.

Aggregates can be divided into several categories according to different criteria, such as size, source, and unit weight.

In accordance with size, can be divided to

- Coarse aggregate: Generally, the size of coarse aggregate ranges from 5 to 150 mm. Fig(3.1)shown different sizes of coarse aggregates
- Fine aggregate (sand): Aggregates passing through a No. 4 (4.75mm) sieve and predominately retained on a No. 200 (75 μm) sieve are classified as fine aggregate as shown in Fig (3.2)

5~10 mm 10~14 mm 14~20 mm 20~ mm

Fig (3.1) Different sizes of coarse aggregates

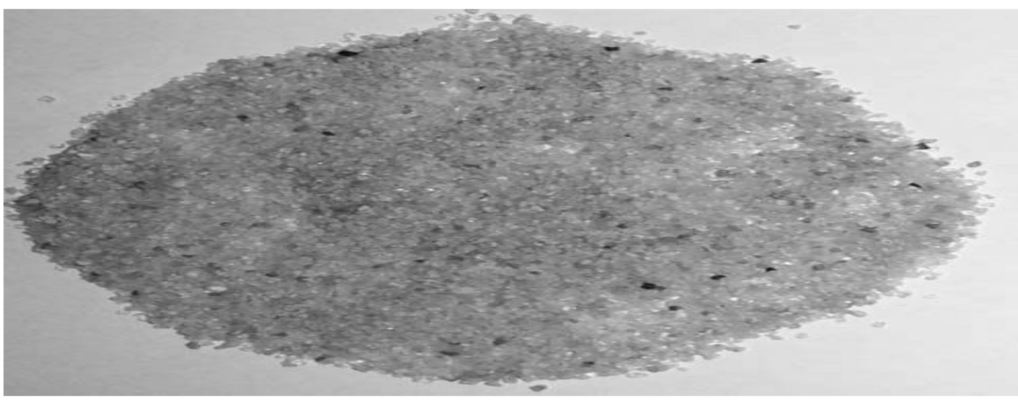

Fig (3.2) Profile of sand

In accordance with source, can be divided to

- **Natural aggregates**: This kind of aggregate such as sand and gravel is taken from natural deposits without changing the nature during production.
- **Manufactured (synthetic) aggregates**: These kinds of aggregate are manmade materials, resulting from products or by-products of industry. Some examples are blast furnace slag and lightweight aggregate.

In accordance with unit weight, can be divided to

- **Ultra-lightweight aggregate**: The unit weight of such aggregates is less than 500 kg/m^3 including expanded perlite and foam plastic.

- **Lightweight aggregate**: The unit weight of such aggregates is between 500 and 1120 kg/m3.Examples of lightweight aggregates include cinder, blast-furnace slag, volcanic pumice, and expanded clay.
- **Normal-weight aggregate**: An aggregate with a unit weight of 1520–1680 kg/m3 is classified as normal-weight aggregate. Sand, gravel, and crushed rock belong to this category and are most widely used.
- **Heavy-weight aggregate**: If the unit weight of aggregate is greater than 2100 kg/m3, it is classified as heavy-weight aggregate. Materials used as heavy-weight aggregate are iron ore, crashed steel pieces, and magnetite limonite.

The moisture condition defines the presence and amount of water in the pores and on the surface of the aggregate. There are four moisture conditions, as follow:

- **Oven dry (OD):** This condition is obtained by keeping the aggregate in an oven at a temperature of 110◦C long enough to drive all water out from internal pores and hence reach a constant weight.

- **Air dry (AD):** This condition is obtained by keeping the aggregate at ambient temperature and ambient humidity. Under such condition, pores inside of aggregate are partly filled with water. When aggregate is under either the OD or AD condition, it will absorb water during the concrete mixing process until the internal pores are fully filled with water.

- **Saturated surface dry (SSD**): In this situation, the pores of the aggregate are fully filled with water and the surface is dry. This condition can be obtained by immersing coarse aggregate in water for 24hours followed by drying of the surface with a wet cloth. When the aggregate is under the SSD condition, it will neither absorb water nor give out water during the mixing process. Hence, it is a balanced condition and is used as the standard index for concrete mix design.

- **Wet (W):** The pores of the aggregate are fully filled with water and the surface of the aggregate has a film of water. When aggregate is in a wet condition, it will give out water to the concrete mix during the mixing process. Since sand is usually obtained from a river, it is usually in a wet condition.

The moisture content (MC) of aggregates can be calculated with respect either the OD or SSD condition.

Since aggregates are porous materials, even a single piece of aggregate contains both solid material volume and pores volume. Hence, two types of aggregate density are defined. Density (D) is defined as the weight per unit volume of solid material only, excluding the pores volume inside a single aggregate:

$$\mathbf{D} = \frac{weight}{V_{solid}} \qquad (3\text{-}1)$$

Bulk density (BD) is defined as the weight per unit volume of both solid material and the pores volume inside a single aggregate:

$$\mathbf{BD} = \frac{weight}{V_{solid+}\,V_{pores}} \qquad (3\text{-}2)$$

Where BD can be either BD SSD or BDAD according to the moisture condition of the aggregate when it is weighed.

The unit weight (UW) is defined as the weight per unit bulk volume for bulk aggregates. In addition to the pores inside each single aggregate, the bulk volume also includes the space among the particles.

Once the BSGSSD is obtained for a type of aggregate, the moisture content of the aggregate under different moisture conditions can be conveniently determined using the following equation:-

$$\text{Mc (SSD)} = \frac{W_{stock} - \frac{W_{water} \times BSG_{SSD}}{BSG_{SSD} - 1}}{\frac{W_{water} \times BSG_{SSD}}{BSG_{SSD} - 1}} \qquad (3\text{-}3)$$

Where W $_{stock}$ is the weight of the sample under the stockpile condition, and W water is the short form of WSSD in water.

If AC is known for the aggregate, MC (SSD) can also be calculated using the absorption capability of aggregates as

$$\mathbf{MC\ (SSD)} = \frac{W_{stock} - \mathbf{WOD}\ (1 + AC)}{\mathbf{WOD}\ (1 + AC)} \qquad (3\text{-}4)$$

The particle size distribution of aggregates is called grading. Grading determines the paste requirement for a workable concrete since the amount of voids among aggregate particles requires the same amount of cement paste to fill out in the concrete mixture. To obtain a grading curve for an aggregate, sieve analysis has to be conducted.

To characterize the overall coarseness or fineness of an aggregate, the concept of a fineness modulus is developed. The fineness modulus is defined as

$$\textbf{Fineness modulus} = \frac{\text{cumulative retained percentage}}{100} \quad (3\text{-}5)$$

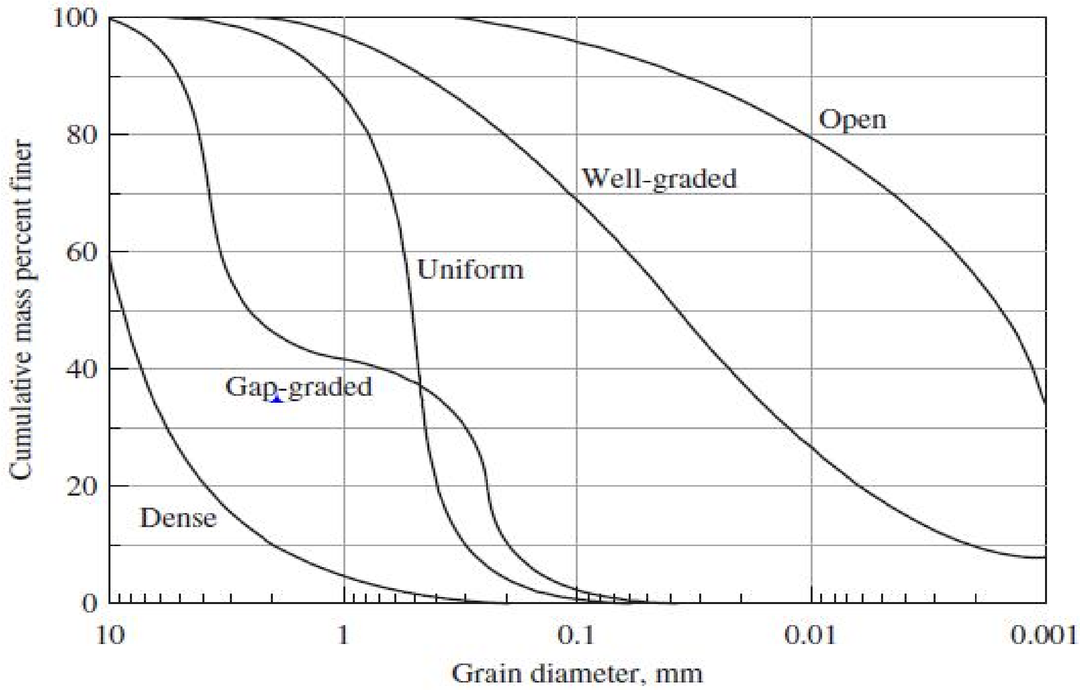

Fig (3.3) Five type of aggregate gradation

Blending of aggregates is undertaken for a variety of purposes, such as to remedy deficiencies in grading. A desired value of the fineness modulus can be calculated if the characteristics of the component aggregate are known. If two aggregates designated A and B, are mixed together, having a fineness modulus of FMA and FMB, respectively, the resultant blend will have the following fineness modulus:

$$\mathbf{FM}_{\text{blend}} = \frac{FMA \times PA}{100} + \frac{FMA \times PB}{100} \quad (3\text{-}6)$$

Where PA and PB are the percentages, by weight, of aggregates A and B in the blend.

The aggregate shape affects the workability of concrete due to the differences in surface area caused by different shapes. Sufficient paste is required to coat the aggregate to provide lubrication.

The typical shapes of aggregates are shown in Figure 2-6. Among these, spherical, cubical, and irregular shapes are good for application in concrete because they can benefit the strength. Flat,

Needle shaped, and prismatic aggregates are weak in load-carrying ability and easily broken. Besides, the surface-to-volume ratio of a spherical aggregate is the smallest.

The surface texture of aggregates can be classified in 6 groups: glassy, smooth, granular, rough, crystalline, and honeycombed. The surface texture of aggregates has significant influence on the fluidity of fresh concrete and the bond between aggregate and cement paste of hardened concrete. According to experimental statistics, the relative effects of the shape and surface texture of aggregates on concrete strength are summarized in Table (3.1) [Waddall and Dobrowolski, 1993].

3.2.2 Cement

Based on the composition, the binder can be classified into organic and inorganic

Table (3.1) effect of aggregate shape and surface texture on concrete strength

Affected strength	Relative affect (%)of	
	shape	Surface texture
Compressive	22	44
Flexural	31	26

An organic binder can be easily burned and thus cannot stand with fire. Polymer and asphalt are two commonly used organic binders. Polymers consist of random chains of hydrocarbons and can be classified into thermoplastics, thermosets, and elastomers (or rubbers).

Portland cement was developed by Joseph Aspdin in 1824, so named because its color and quality are similar to a kind of limestone, Portland stone (Portland, England) as shown in table (3.2)

Table (3.2) Development of Portland cement

1796	James Parker	England	Patent on natural hydraulic cement
1813	Vicat	France	Artificial hydraulic lim
1824	Joseph Aspdin	England	Portland cement

Portland cement is made by blending an appropriate mixture of limestone and clay or shale together, and by heating them to 1450C in a rotary kiln. Currently, the capability of a rotary kiln can reach 10,000 metric tons daily.

Hydration of cement is the reaction between cement particles and water, including chemical and physical processes. The properties of fresh concrete, such as setting and hardening, are the direct results of hydration. The properties of hardened concrete are also influenced by the process of hydration.

Basic Portland cement tests are

- **Fineness** (=surface area/weight): The fineness of Portland cement is an important quality index. It represents the average size of the cement grains. The fineness of Portland cement can be measured by different methods.

- **Normal consistency test:** This test is undertaken to determine the water requirement for the desired cement paste plasticity state required by the setting and soundness test for Portland cement. The normal consistency test is regulated in ASTM C187.

- **Setting time test:** is undertaken to determine the time required for the cement paste to harden. The initial set cannot be too early due to the requirements of mixing, conveying, placing, and casting. Final setting cannot be too late owing to the requirement of strength development. Time of setting is measured by the Vicat apparatus with a 1-mm-diameter needle. The initial setting time is defined as the time at which the needle penetrates 25 mm into the cement paste. The final setting time is the time at which the needle does not sink visibly into the cement paste.

- **Soundness:** Unsoundness in cement paste results from excessive volume change after setting. Unsoundness in cement is caused by the slow hydration of MgO or free lime. Their actions are:

$$MgO+H_2O \rightarrow Mg(OH)_2 \quad (3\text{-}6)$$

And

$$CaO+H_2O \rightarrow Ca(OH)_2 \quad (3\text{-}7)$$

- **Strength:** The strength of cement is measured on mortar specimens made of cement and standard sand (silica). Compression testing is carried out on a 50-mm cube with an S/C ratio of 2.75:1 and w/c ratio of 0.485, for Portland cements.

- **Heat of hydration test**: Hydration is a heat-release process. The heat of hydration is usually defined as the amount of heat released during the setting and hardening at a given temperature, measured in J/g. The experiment is called the heat of solution method. Basically, the heat of solution of dry cement is compared tothe heats of solution of separate portions of the cement that have been partially hydrated for 7and 28 days.

Any pozzolanic compound or source of silicates or alumino-silcates that is readily dissolved in alkaline solution will suffice as a source for the production of a geo polymer. Geo polymers do not require large energy consumption. A great amount of CO2is emitted during the production of Portland cement, which is one of the main reasons for global warming.

Magnesium phosphoric cement (MPC**)**: is a type of artificial stone made from an acid – base reaction of magnesia and phosphates. They possess some properties that Portland cements do not possess according to the previous studies. Therefore, they can be utilized in fields in which Portland cements are not suitable [Kingery, 1950; Yoshizake et al., 1989; Seehra et al., 1993; Yang et al., 2002; Singh et al., 1997; Wagh et al., 1999].

Magnesium oxy chloride cement (MOC), also known as Sorel cement (Sorel, 1867), is a type of non-hydraulic cement. It is formed by mixing powdered magnesium oxide (MgO) with a concentrated solution of magnesium chloride (MgCl2). Magnesium oxy chloride cement has many superior properties as compared to ordinary Portland cement (Bensted and Barnes, 2002). It has high fire resistance, low thermal conductivity, and good resistance to abrasion, and is unaffected by oil, grease, and paint. It also has high early strength and is suitable for use with all kinds of aggregates in large quantities, including gravel, sand, marble flour, asbestos, wood particles, and expanded clays.

3.2.3 Admixtures

An admixture is defined as a material other than water, aggregates, cement, and reinforcing fibers that is used in concrete as an ingredient and added to the batch immediately before or during mixing. Admixtures can be roughly divided into the following groups.

(a)Air-entraining agents (ASTM C260): This kind of admixture is used to improve the frost resistance of concrete.

(b)Chemical admixtures (ASTM C494 and BS 5075) are any chemical additive to the concrete mixture that enhances the properties of concrete in the fresh or hardened state. The general-purpose chemicals include those that reduce the water demand for a given workability (called water reducers), and those chemicals that control the setting time and strength gain rate of concrete (called Accelerators and retarders). Apart from these chemicals, there are others for special purposes—viscosity-modifying agents, shrinkage-reducing chemicals, and alkali – silica reaction-mitigating admixtures.

(c)Mineral admixtures: consist of finely divided solids added to concrete to improve its workability, durability, and strength. Slag and pozzolans are important categories of mineral admixtures.

(d) Admixtures include all those materials that do not come under the above-mentioned categories, such as latexes, corrosion inhibitors, and expansive admixtures.

Table (3.3): beneficial effects of different kinds of admixtures on concrete properties

Concrete Property	Admixture Type	Category of Admixture
Workability	Water reducers Air-entraining agents Inert mineral powder Pozzolans Polymer latexes	Chemical Air entraining Mineral Mineral Miscellaneous
Set control	Set accelerators Set retarders	Chemical Chemical
Strength	Pozzolans Polymer latexes	Mineral Miscellaneous
Durability	Air-entraining agents Pozzolans Water reducers Corrosion inhibitors Shrinkage reducer	Air entraining Mineral Chemical Miscellaneous Miscellaneous
Special concrete	Polymer latexes Silica fume Expansive admixtures Color pigments Gas-forming admixtures	Miscellaneous Mineral Miscellaneous Miscellaneous Miscellaneous

3.2.4 Water

Water is an important ingredient of concrete, and a properly designed concrete mixture, typically with 15 to 25% water by volume, will possess the desired workability for fresh concrete and the required durability and strength for hardened concrete. The roles of water have been discussed earlier and are known as hydration and workability. The total amount of water in concrete and the water-to-cement ratio may be the most critical factors in the production of good-quality concrete. Too much water reduces concrete strength, while too little makes the concrete unworkable. Because concrete must be both strong and workable, a careful selection of the cement-to-water ratio and total amount of water are required when making concrete.

Water can exist in a solid form as ice, a liquid form as water, or a gaseous form as vapor. Mixing water is the free water encountered in freshly mixed concrete. It has three main functions: (1) it reacts with the cement powder, thus producing hydration products; (2) it acts as a lubricant, contributing to the workability of the fresh mixture; and (3) it secures the necessary space in the paste for the development of hydration products. The amount of water added for adequate workability is always greater than that needed for complete hydration of the cement in practice.

The unique ability of water in dissolving, to some extent, virtually every chemical compound and supporting practically every form of life means that raw water supplies contain many contaminants. Water impurities can be either dissolved in the water or present in the form of suspensions. Water should be avoided if it contains large quantities of suspended solids, excessive amounts of dissolved solids, or appreciable amounts of organic materials. The major categories of impurities found in raw water include (1) suspended solids; (2) dissolved solids, and (3) dissolved organic material.

The requirements for curing water are less stringent than those discussed above, mainly because curing water is in contact with the concrete for only a relatively short time. Such water may contain more inorganic and organic materials, sulfuric anhydride, acids, chlorides, and so on, than acceptable mixing water, especially when slight discoloration of the concrete surface is not objectionable. Nevertheless, the permissible amounts of the impurities are still restricted.

3.3 properties of Fresh Concrete and Harden Concrete

3.3.1 Fresh Concrete

When considering high strength concrete (HSC), firstly, high strength should be defined the perception of what level of compressive strength constitutes “high strength” has been continually revised upwards over the past 20 years or so [FIP-CEB, 1990] and may well continue to rise in the near future In the UK this would include concrete with a characteristic compressive strength of 60 MPa or more , concrete with a characteristic concrete (cube) strength greater than 80 MPa will be considered as ‘high strength’. Furthermore concerned here with essentially conventional type concretes that can be used with currently accepted construction techniques and not more specialized cement-based materials such as reactive powder concretes (RPC)[O’Neil et ---al., 1996] or heavily fiber reinforced concretes [Aarup, 1994; Newman, 2000][5]

In order to achieve high compressive strength (HSC), it is important to understand the factors that govern the strength of concrete, i.e.

- The properties of the cement paste
- The properties of the transition zone between the paste and the aggregate
- The properties of the aggregate
- The relative proportions of the constituent materials

In conventional concrete technology, the strength of the paste is a function of its water/cement ratio. A reduction in water/cement ratio will produce a paste in which the cementations particles are initially closer together in the freshly mixed concrete. Theis results in less capillary porosity in the hardened paste and hence a greater strength. The capillary porosity can also be reduced by optimizing the particle size distribution of the cementations materials in order to increase the potential packing density. Special high strength cements are available and the inclusion of finely divided reactive materials such as silica fume will also contribute to an increase in packing density and reduced capillary porosity. The role of super plasticizers in enabling workable concretes to be produced at very low water/cement ratios (and without the need for excessively high cement contents) is critical. In order to improve the strength of the paste as a whole, all such flaws must be minimized.

If the transition zone to the aggregate is weak, the strength of the concrete will not increase commensurately. In conventional (say, 40 MPa) concretes, this transition zone is quite large and is characterized by a high porosity and large crystalline hydration products (such as Portlandite $Ca(OH)_2$). Reducing the water/paste ratio and the incorporation of silica fume into the concrete both contribute to reducing the width and improving the strength of the transition zone [Mindess et al., 1994]. The rapid conversion of $Ca(OH)_2$ to CSH by silica fume is thought to be of particular importance. Reduced bleeding within the paste also reduces the potential for accumulation of water around aggregate particles.

Crushed rock aggregates are generally preferred to smooth gravels as there is some evidence that the strength of the transition zone is weakened by smooth aggregates [Aitcin and Mehta, 1990]. The aggregate should have a high intrinsic strength and granites, basalts and lime stones have been used successfully, as have crushed glacial gravels. During the crushing process, aggregate particles may be severely micro cracked. The number of micro cracks will be greater in larger particles, consequently it is common practice to use smaller particles (10–14 mm nominal size) for high strength concrete [Mehta and Aitcin, 1990a] It is assumed that small aggregate particles will contain less internal flaws and hence produce a higher concrete strength.

It should be recognized that there is no single or unique composition for high strength concrete. HSC can be made with a range of materials and mix designs which will produce slightly differing properties.

HSC can be produced with most available Portland cements, but those cements that are particularly coarsely ground are usually unsuitable [Mehta and Aitcin, 1990a]. Special cements have been developed for HSC in Norway which are more finely ground and with lower tricalcium aluminate (C3A) content [Helland, 1996] but elsewhere normal commercial products are generally employed. Silica fume is almost ubiquitous in HSC as it has approximately three times the cementing efficiency (on a weight for weight basis) as Portland cement. This facilitates the achievement of high strength without excessive cement contentsAs different sources of cementations materials may interact with different efficiency, trials to establish the optimum combination and sources of materials may often be required. All cements should comply with appropriate national or international standards.

To produce workable concretes at very low levels of water/cement ratios (typically below 0.30), without needing unacceptably high cement content, requires the use of super plasticizers. The dosage rates of the super plasticizers can be very high (up to 3 per cent by weight of cement) in order to achieve the required workability .Compatibility between different admixtures used in combination as well as compatibility between admixtures and different cement types, must be considered when materials are selected (again flow cone tests may be useful).

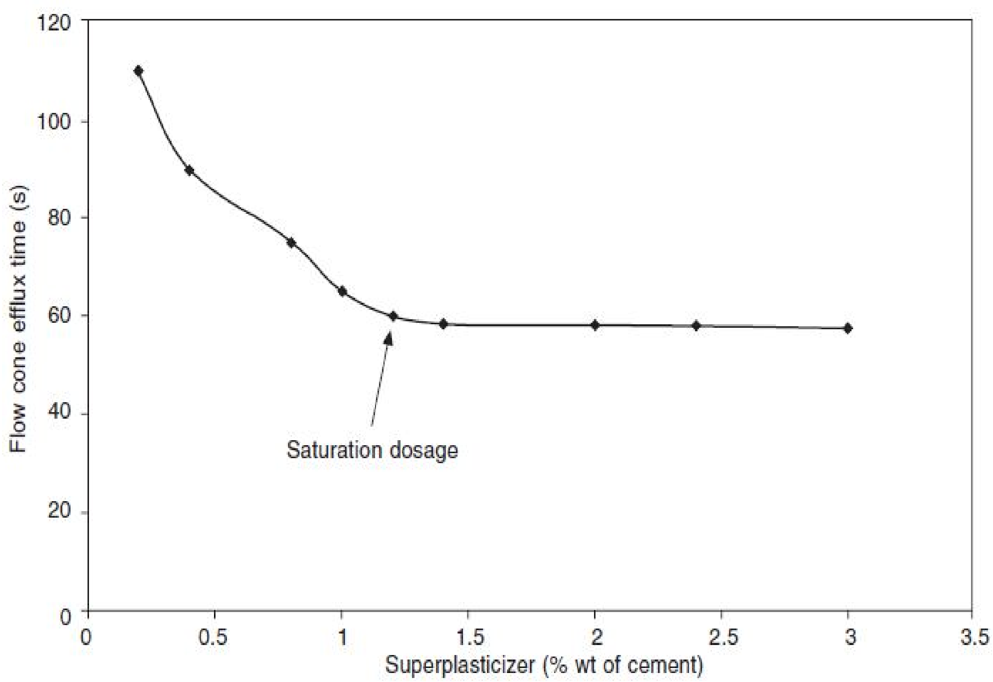

Fig (3.4) Idealized effect of super plasticizer dosage on flow cone efflux time (at constant w/c ratio)

Fine aggregates for HSC should be selected to reduce the water demand. Rounded particles are thus preferred to crush rock fines where possible. The silt, clay and dust content of both fine and coarse aggregates should be kept as low as possible. . The finest fractions of the fine aggregate are no longer essential to increase workability or prevent segregation; a coarser grading (fineness modulus 2.7 to 3.0

or BS 882 Class C) (British Standards Institution, 1992) is therefore appropriate. The grading's curve of the fine aggregate should, however, generally be smooth and free of gap grading to optimize the water demand. The requirements for coarse aggregates have been examined earlier. However, the particle shape should ideally be equidimensional (i.e. not elongated or flaky) and the grading should once again be smooth with no gaps in the grading between fine and coarse fractions. A maximum aggregate size of 10–14 mm is usually selected [Mehta and Aitcin, 1990a] although aggregates up to 20 mm may be used if they are strong and free of internal flaws or fractures. This can, however, only be evaluated from trial mixes.

Of concrete mix design for HSC [de Larrard, 1999; Mehta and Aitcin, 1990b], no widely accepted method is currently available. The main requirements for successful and practical HSC are a low water/cement ratio combined with high workability and good workability retention characteristics. In the absence of a standard mix design method, the importance of trial mixes in achieving the desired concrete performance is increased. The following factors should, however, be considered when designing a high strength concrete mix (see Table 3.3)

- The appropriate free water/cement ratio should be selected either from experience or by reference to published data. This will typically be in the range 0.25–0.30.
- The cement composition should be selected to maximize strength and other performance requirements. At its simplest this will be Portland cement blended with 5–10 per cent silica fume.
- Proportion coarse and fine aggregates to give a smooth overall grading curve in order to keep the water demand low. The proportion of fine aggregate is generally around 5 per cent lower (as a proportion of total aggregate) than for normal strength concrete. Care must be taken, however, not to make the mix too deficient in fine aggregate, particularly where the concrete is to be pumped.
- Use the saturation dosage of admixture (or admixtures), determined with a flow cone, to produce workability. It should be noted (see section 3.5) that most HSC is also high workability concrete, of, say, 600 mm flow table spread.

Table (3.4): Commercial HSC mix design from North America [data from Burg and Ost, 1992]

	1	2	3	4	5
Cement (kg/m^3)	564	475	487	564	475
Fly ash (kg/m^3)	-	59	-	-	104
Micro-silica (kg/m^3)	-	24	47	89	74
Coarse aggregate (kg/m^3)	1068	1068	1068	1068	1068
Fine-aggregate (kg/m^3)	647	659	676	593	593
Water(L/m^3)	158	160	155	144	151
Super plasticizer (L/m^3)	11.61	11.61	11.22	20.12	16.45
Retarder(L/m^3)	1.12	1.04	0.97	1.47	1.51
Free w/c ratio	0.281	0.287	0.291	.0220	0.231
90 day cylinder strength(MPa)	86.5	100.4	96.0	131.8	119.3

3.4 Properties of High Strength Concrete (HSC)

3.4.1 Fresh Concrete

Normal practice (particularly in North America, but also in Europe), is to produce high workability HSC. Slumps in excess of 200 mm are common, particularly where high strength concrete HSC is used in areas of congested reinforcement. HSC is essentially thixotropic in that whilst it flows easily under the influence of vibration, flow ceases once the vibration is removed. HSC is also characterized by significantly lower bleeding than more conventional Concretes. The absence of bleeding can lead to difficulties with finishing and also increase the importance of effective early curing in order to prevent plastic cracking. As the total content of cementations materials in HSC is typically high (often in excess of 500 kg/m3), the heat of hydration of the concrete would also be expected to be high. Whilst the heat generation is higher than for lower strength concrete, it does not rise in proportion to cement content. HSC is used in massive sections; the normal precautions will still be required to minimize thermal cracking [Bamforth and Price, 1995].

3.4.2 Hardened Concrete: the properties of harden concrete define as follow:

HSC is obviously characterized by high ultimate compressive strength. When measured on standard water cured cubes, however, the rate of early strength gain is similar to that of lower strength concrete. In some cases when retarding admixtures or very high super plasticizer levels are used the early strength gain -may even be lower than normal. Another characteristic of HSC (particularly when containing silica fume) is that continued strength gain beyond 28 days is often very small, and this is even more so when in-situ strength is considered. However, long-term strength gain is dependent on the type and combination of cementations materials in the concrete.

Using temperature-matched curing techniques to monitor the development of In-situ strength has indicated that in-situ strength can rise rapidly from about 8 hours after casting (see Figure 3.5). Greater than 100 MPa has been recorded at an age of 24 hours (Price, 1996). As with conventional normal strength concrete, the tensile strength of HSC increases as compressive strength rises.

The elastic modulus of HSC is generally higher than that of normal strength concrete. The increase of elastic modulus is not pro-rata to increases in compressive strength and some existing relationships between these properties are thought to overestimate the elastic modulus at compressive strengths over 100 MPa[American Concrete Institute, 1992].

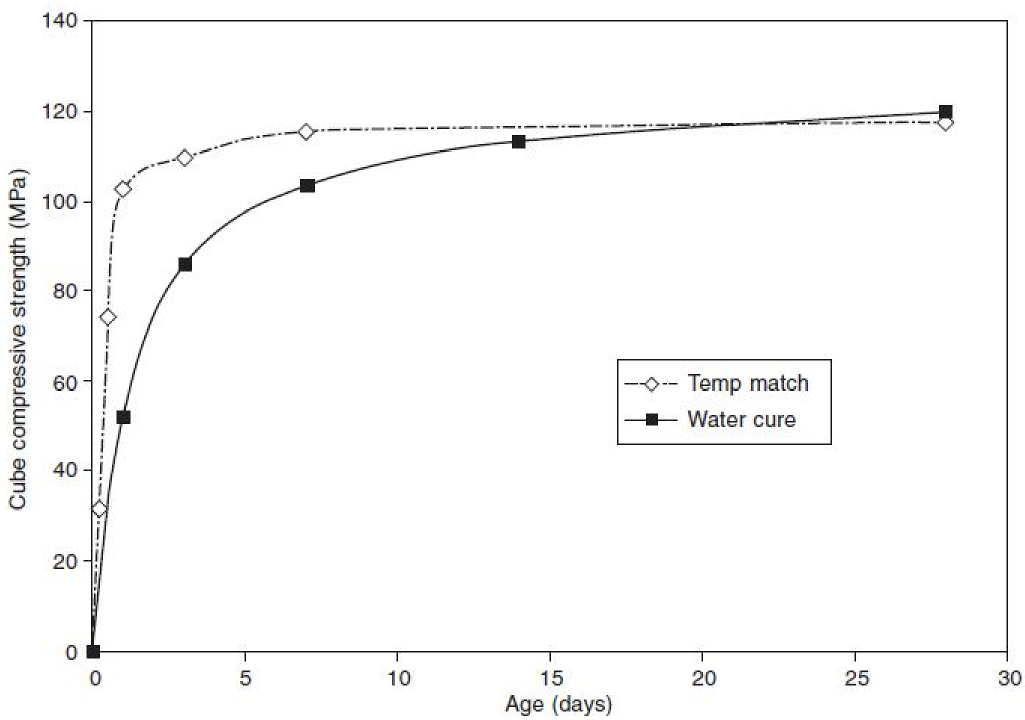

Fig (3.5): Strength development of a high strength concrete slab (after Price, 1996)

Stiffer aggregates such as siliceous flints etc. will achieve a much higher modulus than softer granites and lime stones at a given level of compressive strength [Nilsen and Aitcin, 1992]. It is recommended that if elastic modulus is an important factor in the design, the modulus of the concrete is actually measured on the concrete proposed for use in the project (Concrete Society, 1998).In HSC, the ascending part of the stress–strain curve becomes steeper and more linear, remaining linear to a higher proportion of the ultimate stress (see Fig (3.6). The increased compatibility in elastic modulus between a high strength binder and aggregate particles reduces the degree of micro cracking around the aggregate during loading. This in turn results in increased linearity of the ascending limb

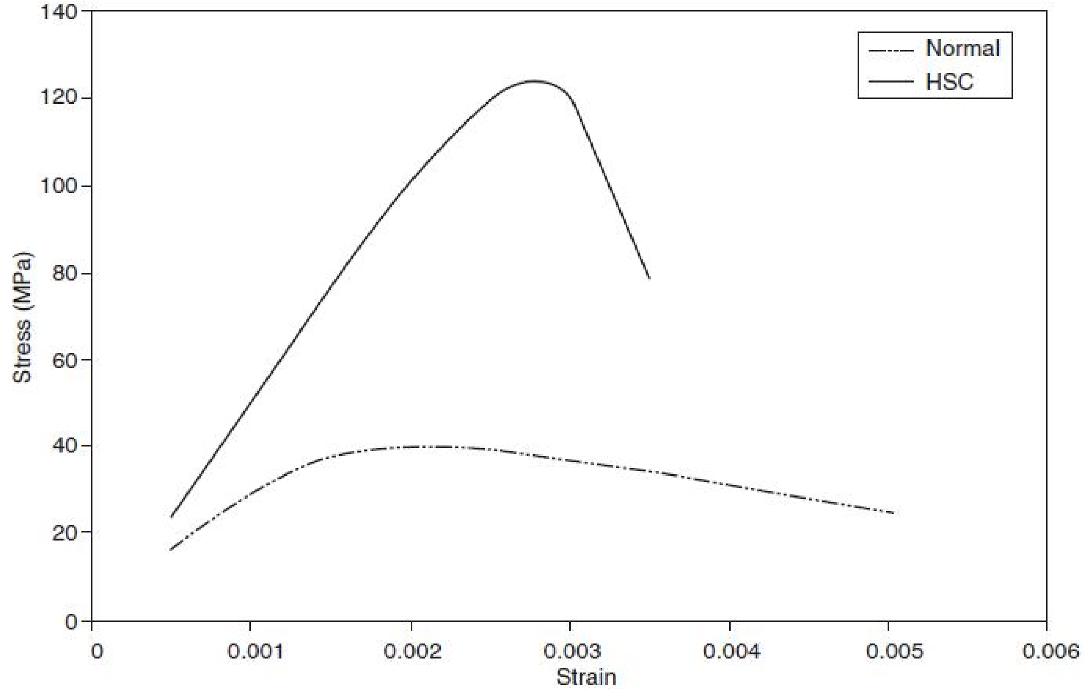

Fig (3.6): Idealized comparison of stress–strain curves of high strength and normal strength concrete

The creep of HSC (expressed as either specific creep or creep coefficient) appears to be significantly lower than that of normal strength concrete. However, the available information on creep of HSC is relatively limited and further research is required.

In general due to the low initial water content of the concrete and its low Intrinsic vapour permeability, drying shrinkage is thought to be lower than for normal strength concrete. On the other hand, autogenously shrinkage of HSC can be significant. Autogenously shrinkage is a reduction in volume occurring without loss of water to the atmosphere (Aitcin, 1999). In one study, the autogenously shrinkage of a 100 MPa concrete was 110 micro strain,Compared with only 40 micro strains for a 40 MPa concrete [de Larrard and Le Roy, 1992].In certain circumstances, the high autogenously shrinkage may be a significant influence on the proposed design.

It is not possible to give a detailed description here of the durability aspects of HSC. However, this can be summarized as follows:

- The low free water/cement ratio required to produce HSC also generally confers enhanced durability on the concrete. Other areas, in which HSC has found applications on durability grounds, are as a

- Consequence of its improved abrasion resistance compared to normal strength concrete [Gjorv et al, 1990] and its increased resistance to attack by aggressive chemicals [Nischer, 1995].
- When used in severe freezing and thawing conditions, some air entrainment should still be used even though adequate protections will be achieved at lower air content than that required by normal strength concrete [Hammer and Sellevold, 1990].
- Although HSCs generally contain high cement contents, the presence of silica fume is thought to prevent ASR [Gudmundsson and Olafsson, 1996]

3.5 Production and USE of High Strength Concrete (HSC)

3.5.1 Production

The key to successful production of HSC is maintaining a consistent and low water/ cement ratio together with effective mixing. HSC has been produced successfully in both wet batch and dry batch plants but in all cases, stringent control of all sources of water in the mix is critical. These include:

- Added mix water
- Water in liquid admixtures or silica fume slurry
- Free moisture on fine and coarse aggregates. It should be noted that small changes in the moisture content of the fine aggregate have a proportionately greater effect on water/cement ratio and hence strength of HSC, than it does for normal strength concrete.
- Other sources of water such as washout or cleaning water in mixers and transport vehicles.

Production of HSC requires particular attention to detail as factors causing only second- order effects in normal strength concrete can have major implications at very high strength levels. HSC is relatively a high-cost material, but it can produce overall savings when used in appropriate situations. Producers should be selected on the basis of proven experience with HSC specifically, rather than general experience or cost alone.

3.5.2 Use on-site

Properly proportioned HSC can be easily placed by skip and has been successfully pumped over large distances at only slightly higher pump pressures than normal (Page, 1990). The possibility of limited workability retention time must, however, also be kept in mind. The behavior of HSC is different in certain respects from conventional strength concrete.

3.5.3 Examples of use of HSC

High strength concrete has been utilized in many structures around the world (CEB, 1994), but perhaps the most common use of the material has been in the columns of high- rise buildings, particularly in North America and Australia. HSC columns often with reduced reinforcement are an economical solution to providing heavily loaded elements in high-use buildings. The dimensions of columns can also often be reduced by using HSC although possible buckling of very slender elements needs consideration (Concrete Society, 1998). This enables the amount of rentable floor space to be maximized and also minimizes interruption of parking spaces in basement garages. In Chicago, a number of tall buildings have utilized HSC in columns included 311 S. Wacker Drive (see Figure 3.4) where high strength columns (Design strength 83 MPa (cylinder)) were used at the base of the building, with lower strength concrete (69 and 62 MPa) being used in the more lightly loaded upper floors (Russell, 1994). The HSC was used in conventionally reinforced columns and nearby all the concrete was placed using pumps. In Seattle, a different form of construction with HSC has been employed. Large diameter (3 m) steel tubes form the core of the building with smaller steel tubes around the perimeter. These tubes contain shear studs on the internal face but not reinforcement. High strength concrete (Design strength 97 MPa (cylinder)) is pumped into the tubes from the bottom of each storey and without any vibration. This forms a very economic and stiff structure. During the construction of 2 Union Square in Seattle, a 58-storey structure (Russell, 1994), the designer also wished to achieve an elastic modulus of at least 50 GPa. Consequently the actual strength of the concrete was much higher than the design strength in order to produce the desired modulus. Long-term compressive cylinder strengths in excess of 130 MPa (approximately equivalent to cube strength of 145 MPa) were measured during construction.

3.5.4 Summary

High strength concrete (HSC) is made possible by the development of high strength cementing materials and super plasticizing admixtures. The selection of constituent materials is critical in achieving a high compressive strength, but compressive strength in excess of 100 MPa is now routinely achievable in the UK and elsewhere. Maintaining a consistent low water/cement ratio is the most important factor for successful production. HSC can be used with most

conventional construction techniques, but special attention must be given to avoiding delays during placing, finishing and curing. HSC is also characterized by an increased elastic modulus and tensile strength as well as lower drying Shrinkage. Auto genous shrinkage, however, can be very high. The main applications of HSC have been in the columns of high-rise buildings, offshore structures and long-span bridges.

CHAPTER FOUR

EXPERIMENTAL METHODOLOGY

CHAPTER FOUR

EXPERIMENTAL METHODOLOGY

Quality control of materials can only be ensured through certain standard test procedures designed by ASTM, BIS, RDSO and others described as follow:

4.1 Cement Tests: there are different tests of cement described as follows:

4.1.1Fineness

The aim of test is:

To determine the fineness of cement by dry sieving as Per IS: 4031 (Part 1) – 1996 as shown in Fig (4.1).

Fig (4.1): Sieve No 200

The procedure of cement fineness is as follows:

1) Weight approximately 10g of cement to the nearest 0.01g and place it on the sieve.
2) Agitate the sieve by swirling, planetary and linear movements, until no more fine material passes through it.
3) Weight the residue and express its mass as a percentage R1, of the quantity first placed on the sieve to the nearest 0.1 per cent.
4) Gently brush all the fine material off the base of the sieve.
5) Repeat the whole procedure using a fresh 10g sample to obtain R2. Then calculate R as the mean of R1 and R2 as a percentage, expressed to the nearest 0.1 percent.

Report the value of R, to the nearest 0.1 per cent, as the residue on the 90μm sieve.

4.1.2 Consistency

The aim of test is:

To determine the quantity of water required to produce cement paste of standard consistency as per IS: 4031 (Part 4) - 1988. By using Vicat Apparatus as in Fig (4.2)

/

Procedure of consistency test is as follows:

(1) Weigh approximately 400g of cement and mix it with a weighed quantity of water the time of gauging should be between 3 to 5 minutes.
(2) Fill the Vicat mould with paste and level it with a trowel.
(3) Lower the plunger gently till it touches the cement surface.
(4) Release the plunger allowing it to sink into the paste.
(5) Note the reading on the gauge.
(6) Repeat the above procedure taking fresh samples of cement different quantities of water until the reading on the gauge is 5 to 7mm.

Express the amount of water as a percentage of the weight of dry cement to the first place of decimal.

4.1.3 Initial and Final Setting Time

The aim of test is:

To determine the initial and the final setting time of cement as per IS: 4031 (Part 5) - 1988.

Procedure of test is as follows:

1. Prepare a cement paste by gauging the cement with 0.85 times the water required to give a paste of standard consistency.
2. Start a stop-watch, the moment water is added to the cement.
3. Fill the Vicat mould completely with the cement paste gauged as above, the mould resting on a non-porous plate and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared in the mould is the test block.

A) Initial Setting Time

1. Place the test block under the rod bearing the needle. Lower the needle gently in order to make contact with the surface of the cement paste and release quickly, allowing it to penetrate the test block.
2. Repeat the procedure till the needle fails to pierce the test block to a point 5.0 ± 0.5mm measured from the bottom of the mould.

The time period between the time, water is added to the cement and the time, the needle fails to pierce the test block by 5.0 ± 0.5mm measured from the bottom of the mould, is the initial setting time.

B) Final Setting Time

1. Replace the above needle by the one with an annular attachment.
2. The needle makes an impression therein, while the attachment fails to do so.

The period elapsing between the time, water is added to the cement and the time, the needle makes an impression on the surface of the test block, while the attachment fails to do so, is the final setting time.

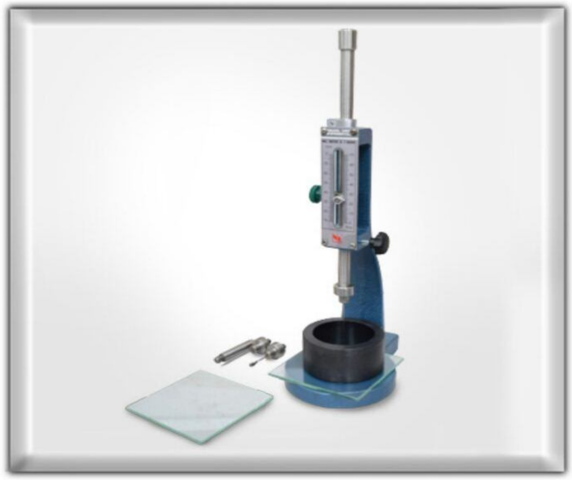

Fig (4.2): Vicat Apparatus

4.1.4 Soundness

The aim of soundness test is

To determine the soundness of cement by [Le-Chatelier method as per IS: 4031 (Part 3) - 1988].By using Le Chatelier Apparatus for Soundness as shown in Fig (4.3)

Procedure of test is as follow:

1. Place the mould on a glass sheet and fill it with the cement paste formed by gauging cement with 0.78 times the water required to give a paste of standard consistency.
2. Cover the mould with another piece of glass sheet, and immediately submerge the whole assembly in water at a temperature of 27 ± 2oC and keep it there for 24hrs.
3. Measure the distance separating the indicator points to the nearest 0.5mm (say d l).
4. Submerge the mould again in water at the temperature prescribed above.
5. Bring the water to boiling point in 25 to 30 minutes and keep it boiling for 3hrs.
6. Remove the mould from the water, allow it to cool and measure the distance between the indicator points (say d 2).
7. (d 2 – d l) represents the expansion of cement.

Calculate the mean of the two values to the nearest 0.5mm to represent the expansion of cement.

Fig (4.3): Le Chatelier Apparatus for Soundness

4. 2 Tests on Aggregates

4. 2.1Sieve Analysis

The aim of sieve analysis is

To determine the particle size distribution of fine and coarse aggregates by sieving as per IS: 2386 (Part I) - 1963.Fig (4.4) illustrated Sieves Size

Test procedure is as follows:

1. The test sample is dried to a constant weight at a temperature of 110 + 5oC and weighed.
2. The sample is sieved by using a set of IS Sieves.
3. On completion of sieving, the material on each sieve is weighed.
4. Cumulative weight passing through each sieve is calculated as a percentage of the total sample weight.
5. Fineness modulus is obtained by adding cumulative percentage of aggregates retained on each sieve and dividing the sum by 100.

Reporting of Result is as follows:

1. The results should be calculated and reported as:
2. The cumulative percentage by weight of the total sample.
3. The percentage by weight of the total sample passing through one sieve and retained on the next smaller sieve, to the nearest 0.1 percent.
4. The results of the sieve analysis may be recorded graphically on a semi-log graph with particle size as abscissa (log scale) and the percentage smaller than the specified diameter as ordinate.

Fig (4.4): Sieves Size

4.2.2 Specific Gravity and Water Absorption

The aim of test is

The test covers the procedures for determining the specific gravity, apparent specific gravity and water absorption of aggregates. Fig (4.5) illustrated Specific Gravity Apparatus

Test procedure is as follows:

(1) The sample shall be screened on a IO-mm IS sieve, thoroughly washed to remove fine particles of dust.

(2) immersed the sample in distilled water in the glass vessel; it shall remain immersed at a temperature of 22 to 32°C for 24 f l/2 hours.

(3) Air entrapped in or bubbles on the surface of the aggregate shall be removed by gentle agitation. This may be achieved by rapid clockwise and anti-clockwise rotation of the vessel between the operator’s hands.

(4) The vessel shall be overfilled by adding distilled water and the plane ground-glass disc slid over the mouth so as to ensure that no air is trapped in the vessel.

(5) The vessel shall be dried on the outside and weighed (weight A).

(6) The vessel shall be emptied and the aggregate allowed to drain. Refill the vessel with distilled water.

(7) The vessel shall be dried on the outside and weighed (Weight B).

(8) The aggregate shall be placed on a dry cloth and gently surface dried with the cloth, transferring it t a second dry cloth when the first will remove no further moisture.

(9) The aggregate shall then be weighed (weight C).

(10)The aggregate shall be placed in the oven in the shallow tray, at a temperature of 100 to 110°C for 24 f l/2 hours. It shall then be cooled in airtight container and weighed (weight D).

Calculations - Specific gravity, apparent specific gravity and water absorption shall be calculated as follows:

Specific gravity = $$\left(\left(\frac{D}{C-(A-B)}\right)*100\right) \quad (4.1)$$

Apparent specific gravity = $$\left(\left(\frac{D}{D-(A-B)}\right)*100\right) \quad (4.2)$$

Water absorption % = $$\left(\left(\frac{C}{B-(A-C)}\right)*100\right) \quad (4.3)$$

Where

A = weight in g of vessel containing sample and filled with distilled water,

B = weight in g of vessel filled with distilled water only,

C = weight in g of saturated surface-dry sample, and

D = weight in g of oven-dry sample.

Fig (4.5): Specific Gravity Apparatus

4.2.3 Bulk Density and Voids

This method of test covers the procedure for determining unit weight or bulk density and void of aggregates.

Test procedure is as follows:

1. Measure the volume of the cylindrical metal measure by pouring water into the metal measure and record the volume “V” in liter.
2. Fill the cylindrical metal measure about one-third full with thoroughly mixed aggregate and tamp it 25 times using tamping bar.
3. Add another layer of one-third volume of aggregate in the metal measure and give another 25 strokes of tamping bar.
4. Finally fill aggregate in the metal measure to over-flowing and tamp it 25 times.
5. Remove the surplus aggregate using the tamping rod as a straightedge.
6. Determine the weight of the aggregate in the measure and record that weight “W” in kg.

Compacted unit weight or bulk density = W/V

Where,

W = Weight of compacted aggregate in cylindrical metal measure, kg

V = Volume of cylindrical metal measure, liter

The percentage of voids is calculated as follows:

Percentage of voids = $[(G - \Upsilon)/G]*100$

Where

G = Specific gravity of the aggregate

Υ = Bulk density in kg/liter

4.3Tests on Fresh Concrete

Concrete is tested to ensure that the material that was specified and bought is the same material delivered to job site. There are a dozen different tests for freshly mixed concrete as follow:

4.3.1 Workability (Slump Test)

The aim of slump test is

To determine the workability of fresh concrete by slump test as per IS: 1199 - 1959. Shwon in Fig (4.6)

Test procedure is as follows

(1) The internal surface of the mould is thoroughly cleaned and applied with a light coat of oil.

(2) The mould is placed on a smooth, horizontal, rigid and non-absorbent surface.

(3) The mould is then filled in four layers with freshly mixed concrete, each approximately to one-fourth of the height of the mould.

(4)Each layer is tamped 25 times by the rounded end of the tamping rod.

(5)After the top layer is rotted, the concrete is struck off the level with a trowel.

(6)The mould is removed from the concrete immediately by raising it slowly in the vertical direction.

(7)The difference in level between the height of the mould and that of the highest point of the subsided concrete is measured. This difference in height in mm is the slump of the concrete.

The slump measured should be recorded in mm of subsidence of the specimen during the test. Any slump specimen, whom collapses or shears off laterally, gives incorrect result and if this occurs, the test should be repeated with another sample.

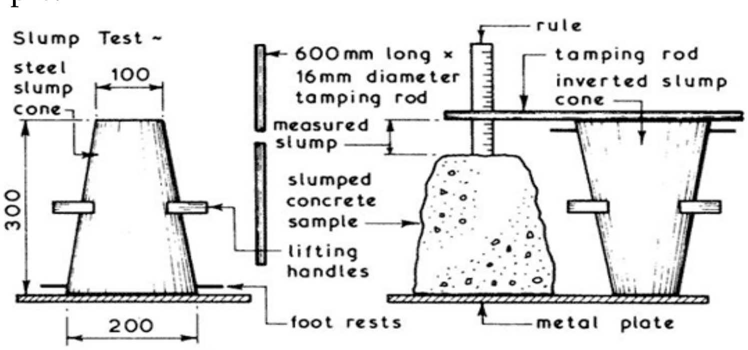

Fig (4.6): Slump Test Mould

4.4 Tests on Hardened Concrete

There are a dozen different tests for harden concrete as follow:

4.4.1 Compression Test

The aim of compression test is

To determine the compressive strength of concrete specimens as per IS: 516 - 1959. Fig (4.8) shows Crashing Machine

Test Procedure is as follows:

1. The specimens, prepared according to IS: 516 - 1959 and stored in water, should be tested immediately on removal from the water and while still in wet condition. Specimens when received dry should be kept in water for 24hrs before they are taken for testing. The dimensions of the specimens, to the nearest 0.2mm and their weight should be noted before testing.
2. The bearing surfaces of the compression testing machine should be wiped clean and any loose sand or other material removed from the surfaces of the specimen, which would be in contact with the compression platens.
3. In the case a of cubical specimen, the specimen should be placed in the machine in such a manner that the load could be applied to the opposite sides of the cubes, not to the top and the bottom. The axis of the specimen should be carefully aligned with the centre of thrust of the spherical seated platen. No packing should be used between the faces of the test specimen and the steel platen of the testing machine. As the spherically seated block is brought to rest on the specimen, the movable portion should be rotated gently by hand so that uniform seating is obtained.
4. The load should be applied without shock and increased continuously at a rate of approximately 140kg/sq.cm/minute until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen should then be recorded and the appearance of the concrete and any unusual features in the type of failure should be noted.

The measured compressive strength of the specimen should be calculated by dividing the maximum load applied to the specimen during the test by the cross - sectional area, calculated from the mean dimensions of the section and should be expressed to the nearest kg/sq.cm. An average of three values should be taken as the representative of the batch, provided the individual variation is not more than ±15% of the average. Otherwise repeat tests should be done. A correction factor according to the height/diameter ratio of the specimen after capping should be obtained from the curve given in figure (4.7)

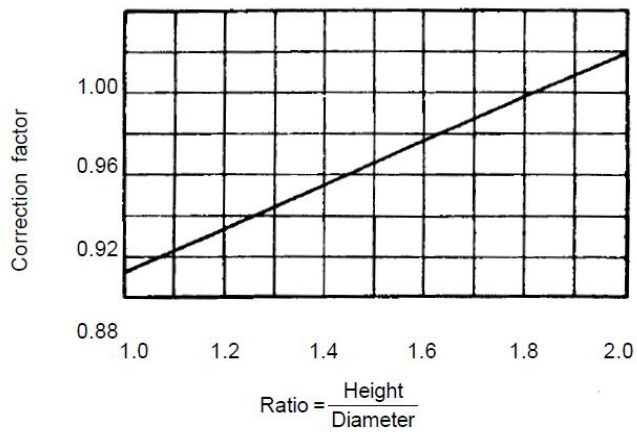

Fig (4.7): Correction factor for height-diameter ratio of a core

The product of this correction factor and the measured Compressive strength is known as the corrected compressive Strength, this being the equivalent strength of a cylinder having a Height/diameter ratio of two. The equivalent cube strength of the

Concrete should be determined by multiplying the corrected Cylinder strength by 1.25.

The following information should be included in the report on each test specimen:

1. Identification mark.
2. Date of test.
3. Age of specimen.
4. Curing conditions, including date of manufacture of specimen.
5. Weight of specimen.
6. Dimensions of specimen.
7. Cross-sectional area.
8. Maximum load.
9. Compressive strength.
10. Appearance of fractured faces of concrete and type of Fracture, if unusual.

Fig (4.8): Crashing Machine

4.5 Mix Design of Trail Mixes

There is different trail mix proportions were made by using two type of aggregates in this section, material used and their proportion were presented.

4.5.1Portland Cement

An ordinary Sudanese Portland Cement PC 42.5 manufactured by mass was used conforming to EN 197-1 cement. The physical properties and the chemical composition of the cement used throughout the tests are presented in Tables (4.1) and (4.2).

Table (4.1): chemical composition of the cement

Oxide	Determined as (%)	EN197-1 Limits
CaO	64.92	-
SiO_2	17.703	-
Al_2O_3	4.377	-
Fe_2O_3	3.440	-
MgO	0.748	Max. 6.0%
SO_3	3.838	Max 3.5%
K_2O	0.306	-
Na_2O	0.401	-
LOI	2.200	Max 3.0%

Table (4.2): Physical properties of the mass cement

Physical properties	Result Obtained	Specification
Vicat initial setting time (minutes)	110min	≤ 60min
Vicat final setting time (minutes)	323	≤ 390 min
Compressive strength 2-day	19.5	≥ 10MPa
Compressive strength 28-day	46.5	≥ 42.5MPa
Specific gravity	3.15	-

4.5.2 Coarse Aggregates

Crushed Basalt stones of size 20mm from Jabal Toryia and UnCrashed granite stones from Satat – Gadarif State were used as coarse aggregate as shown in Table (4.3).

Table (4.3): Properties of the coarse aggregate

Properties	Determined as	
	Basalt	Granite
Specific gravity	2.855	2.54
Apparent	2.88	2.69
Absorption	0.6	1.8
Bulk density (kg/m^3)	1769	1650

4.5.3 Fine aggregates

The fine aggregate used in the experimental program was natural river sand as shown in Table (4.4).

Table (4.4): properties of the fine aggregate

Properties	Determined as
Specific gravity	2.59
Apparent	2.65
Absorption%	0.91
Bulk density (kg/m^3)	1692

4.5.4Water

Portable water from the Nile used in the concrete mix at a temperature of 4 ℃ Has been cooling using ice after conducting chemical analysis of the water the Table (4.5) shows chemical composition of water.

Table (4.5): chemical composition of the water

P.P.M	Determined as (%)
Na	31.98
K	5.773
Mg	19.18
Fe	0.051
Cd	0.018
Pb	0.126
Zn	0.089
So_4	0.0014
Cl	0.0716
PH	7.0

4.5.6 Concrete Mix Design by ACI Method

The ACI 211.1 is a “Recommended practices of selecting properties for concrete” the steps are as follow:

Step No (1): choice of Slump

If slump is not specified, a value appropriate for the work can be selected from the below Table (4.6) which is reproduced from the text book below*, (note that the table numbers are given from the text book rather than the ACI standard) the slump was chosen in range 25-100mm

Table(4.6):Slump

Type of Construction	Slump (mm)	(inches)
Reinforced foundation walls and footings	25-75	(1-3)
Plain footings, caissions and substructure walls	25-75	(1-3)
Beams and reinforced walls	25-100	(1-4)
Building columns	25-100	(1-4)
Pavements and slabs	25-75	(1-3)
Mass concrete	25-50	(1-2)

Step No (2): choice of Maximum aggregate size

Large maximum sizes of aggregates produce fewer voids than smaller sizes. Hence, concretes with the larger-sized aggregates require less mortar per unit volume of concrete, and of course it is the mortar which contains the most expensive ingredient, cement. Thus the ACI method is based on the principle that the Maximum Size of Aggregate Should Be the Largest Available So Long It Is Consistent with the Dimensions of the Structure. In practice the dimensions of the forms or the spacing of the rebar's controls the maximum CA size .ACI 211.1 states that the maximum CA size should not exceed:

- one-fifth of the narrowest dimension between sides of forms,
- One-third the depth of slabs.
- 3/4-ths of the minimum clear spacing between individual reinforcing bars, bundles of bars, or pre-tensioning strands.
- Special Note: When high strength concrete is desired, best results may be obtained with reduced maximum sizes of aggregate since these produce higher strengths at a given w/c ratio. Maximum aggregate size is 20mm.

Step No (4) Estimation of mixing water and air content.

The ACI Method uses past experience to give a first estimate for the quantity of water per unit volume of concrete required to produce a given slump. In general the quantity of water per unit volume of concrete required to produce a given slump is dependent on the maximum CA size, the shape and grading of both CA and FA, as well as the amount of entrained air. The approximate amount of water required for average aggregates is given in Table (4.7).

Approximate Mixing Water and Air Content Requirements for Different Slumps and Maximum Aggregate Sizes.

Table (4.7):Water contnt,Kg/M^3(IB/Yd^3) of concrete for indicated maximum aggregate size - Non-air-entrained concrete

Workability or air	**Water contnt,Kg/M^3(IB/Yd^3) of concrete for indicated maximum aggregate size**							
	10mm	12.5mm	20mm	25mm	40mm	50mm	70mm	150mm
Slump	Non-air-entrained concrete							
30-50mm	205	200	185	180	160	155	145	125
80-100 mm	225	215	200	195	175	170	160	140
150-180 mm	240	230	210	205	185	180	170	0
Approximate entrapped air content	3	2.5	2	1.5	1	0.5	0.3	0.2

Table (4.8): Water contnt,Kg/M^3(IB/Yd^3) of concrete for indicated maximum aggregate size - Air-entrained concrete

Workability or air	Water contnt,Kg/M^3(IB/Yd^3) of concrete for indicated maximum aggregate size							
	10mm	12.5mm	20mm	25mm	40mm	50mm	70mm	150mm
Slump	Air-entrained concrete							
30-50mm	180	175	165	160	145	140	135	120
80-100 mm	200	190	180	175	160	155	150	135
150-180 mm	215	205	190	185	170	165	160	0
Recommended average Mild exposure %	4.5	4	3.5	3	2.5	2	1.5*	1.0*
Moderate exposure	6	5.5	5	4.5	4.5	4	3.5*	3*
Extreme exposure	7.5	7	6	6	5.5	5	4.5*	4*

From Table (4.8) the mixing water content for non- air-entrained concrete with slump=100 mm and maximum aggregate size = 20 mm then the maximum Water content = 200 Kg/m^3

Approximate entrapped air = 2%

Step (5) Selection of water cement ratio

The required water/cement ratio is determined by strength, durability and finish

Table (4.9) Water-Cement Ratio and Compressive Strength relationship

Average compressive strength at 28 days MPa.	Effective W/C material ratio, by mass	
	Non- air entrained concrete	Air entrained concrete
41.4	0.41	0
34.5	0.48	0.4
27.6	0.57	0.48
20.7	0.68	0.59
13.8	0.82	0.74

The appropriate value is chosen from prior testing of a given system of cement and aggregate or a value is chosen from Table (4.9) and/or Table (4.10)

Step No (6) Calculation of cement content.

The amount of cement is fixed by the determinations made in Steps 4 and 5 above.

$$\text{Weight of cement} = \frac{\text{Weight of Water}}{W/C} \quad (4.4)$$

Weight of cement = 384.615kg

Step No (7) Estimation of coarse aggregate content

The most economical concrete will have as much as possible space occupied by CA since it will require no cement in the space filled by CA. Table (4.9) Volume of Coarse Aggregate per Unit Volume for Different Fine aggregate Fineness Modulus.

Table (4.10): Volume of Coarse Aggregate per Unit Volume for Different Fine aggregate Fineness Moduli given by ACI 211.1-91

Maximum size of aggregate		**Dry bulk volume of rodded coarse aggregate per unit volume of concrete for fineness modulus of sand of:**			
mm	in	2.4	2.6	2.8	3
10	(3/8)	0.5	0.48	0.46	0.44
12.5	(1/2)	0.59	0.57	0.55	0.53
20	(3/4)	0.66	0.64	0.62	0.60
25	1	0.71	0.69	0.65	0.67
40	(11/2)	0.75	0.73	0.69	0.71
50	2	0.78	0.76	0.74	0.72
70	3	0.82	0.8	0.78	0.76
150	6	0.87	0.85	0.83	0.81

Note:

- This value can be increased by up to about 10 percent for pavement application.
- Coarse aggregate value is based on oven-dryrodded weights obtained in accordance to ASTM C 29.

  The ACI methods is based on large numbers of experiments which have shown that for properly graded materials, the finder the sand and the larger the size of the particles of CA , the more volume of CA can be used to produce a concrete of satisfactory workability

Step (8) Estimation of Fine Aggregate Content

At the completion of Step 7, all ingredients of the concrete have been estimated except the fine aggregate, Its quantity can be determined by difference if the absolute volume displaced by the known ingredients-(i.e., water, air, cement, and coarse aggregate), is subtracted from the unit volume of concrete to obtain the required volume of fine aggregate. Then once the volumes are know the weights of each ingredient can be calculated from the specific gravities.

Table (4.11): First estimate of density (unit weight) of fresh concrete as given by ACI 211.1-91

Maximum size		**First estimate of density (unit weight) of fresh concrete**					
of aggregate		**Non-air-entrained**			**Air- entrained**		
mm	in	KG/M3		IB/YD3	KG/M3		IB/YD3
10	(3/8)	2285		3840	2190		3690
12.5	(1/2)	2315		3890	2235		3760
20	(3/4)	2355		3960	2280		3840
25	1	2380		4010	2285		3850
40	(11/2)	2415		4070	2320		3910
50	2	2445		4120	2345		3950
70	3	2495		4200	2400		4040
150	6	2530		4260	2440		4110

OR

$$\rho = 10\gamma a(100 - A) + C\left(1 - \left(\frac{\gamma a}{\gamma}\right)\right)W(\gamma a - 1) \qquad (4.5)$$

Where

ρ − dencity (unit weigth)offresh concrete kg/m3

γa = weighted average of bulk specific dencity (SSD)copmbind coarse and fine aggregate this be to determined from tests

A = air content pecent kg/m3

C= Cement content kg /m3

r = specific gravity of cement usually

W= water content requirement kg/L

Fine aggregate SSD Basis= $\rho - (W + C + coarse\ aggregate\ SSD\ Basis)$ (4.6)

OR

$$Af = \gamma f\left(1000 - \left(W - \left(\frac{C}{\gamma}\right) + \left(\frac{AC}{\gamma c}\right) + 100A\right)\right) \qquad (4.7)$$

Remarks:

In this research is used ACI method above steps but because it has problem for calculation of W/C ratio it's modified the results of content of materials to nears quantities as trail and trying to decreased w/c ratio and increased CA/FA ratio to achieve HCS and good Workability.

Methods of concrete sampling:-

To product a high strength concrete without additives we need at first selected materials, with high specification and using special production techniques, in this research the firstly select two types of aggregate crushed Basalt and un crushed granite aggregate with properties as presented in Table (4.3).

Secondly selected from different manufacturing of Portland cement one of them (an ordinary Portland cement manufactured by mass has physical properties as shown in Table (4.2) and chemical properties as shown in Table (4.1).

Thirdly selected fine aggregate with properties as shown in Table (4.4)

And portable water from River Nile and make test in chemical laboratory in ministry of minerals as shown in Table (4.5) .

Finally different proportions of Ordinary Portland cement (410,430 and 450) kg/m3 with different crashed Basalt and uncrushed Granite coarse aggregate amount (1120 and 1050) kg/m3and fine aggregate with fine modulus of 3.65 were used. Eight concrete mixes were prepared: two as control mix for crashed Basalt and uncrushed Granite, three with crashed Basalt and three with uncrushed Granite coarse aggregate with mix amount(410:680:1120,430:610:1050 and 450:550:1050) kg/m3,(cement: fine aggregate: coarse aggregate) , respectively. and the compressive strength of concrete was measured at ages of 7.28 and 56days.

CHAPTER FIVE

ANALYSIS OF RESULTS AND DISCUSSION

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5.1 General

Laboratory tests were conducted on the components of concrete (mix) (cement, coarse aggregate, fine aggregate and fresh concrete, concrete hardened) in order to determine how quality grade of these components and their influence on the compressive strength of concrete without used any kind of additives.

5.2 Presentation of Result Tests

Laboratory tests have been obtained for the results as shown below:-

Cement tests were made are (w/c ratio, consistency, the initial and the final setting time, fineness and soundness) for different companies (A, B, C) those manufacturing, ordinary Portland cement. Results were

Presented in Table (5.1):

Table (5.1): The results of cement tests

Test No	Test	Result A	Result B	Result C	Requirement of SSMO 164:2002
1	Consistency	0.35	0.275	0.37	
2	Initial Setting Time	105 min	112min	110min	Not less than 60 min
3	Final Setting Time	280min	348min	323min	Not more than390min
4	Compressive Strength N/mm^2 2days 28days	 25.0 43.0	 23.0 34.5	 19.5 46.5	Equal or greater than 10 N/mm^2 Equal or greater than 42.5N/mm2
5	Fineness	2.30%	7.40%	1.20%	Not more than 10%
6	Soundness	3	4	1	Not more than 10mm(+1mm)

Tests for coarse and fine aggregate has been presented as shown in the Table (5.2) and the maximum size of aggregates 20 mm.

The gradation tests was carried for two types of coarse aggregate test (crushed Basalt aggregates and un crushed Granite aggregate) obtained were presented in Table (5.2)-(5.3) and Figures (5.1) and (5.2).

Table (5.2) :A sample of coarse aggregate (crushed Basalt) with mass of 1000g is passed through the sieves shown in the following and masses retained on each sieve

Sieve size	Mass retained g individual on each sieve	Individual retained%	Total % retained	Total % passing
25.0 mm (1 in.)	0	0.0	0	100
19.0 mm (3/4 in.)	221	22	22	78
12.5 mm (1/2 in.)	103	10	32	68
9.5 mm (3/8 in.)	425	43	75	25
4.75 mm (No. 4)	232	23	98	2
2.36 mm (No. 8)	18	2	100	0
Pan	0	0	100	0
Total	999	100	-	-

Table (5.3): A sample of coarse aggregate (uncrushed Granite) with mass of 1000g is passed through the sieves and masses retained on each sieves

Sieve size	Mass retained g individual on each sieve	Individual retained%	Total % retained	Total % passing
25.0 mm (1 in.)	0	0.0	0	100
19.0 mm (3/4 in.)	131	13	13	87
12.5 mm (1/2 in.)	125	13	26	74
9.5 mm (3/8 in.)	568	57	83	16
4.75 mm (No. 4)	165	16	99	1
2.36 mm (No. 8)	6	1	100	0
Pan	0	0	100	0
Total	995	100	-	-

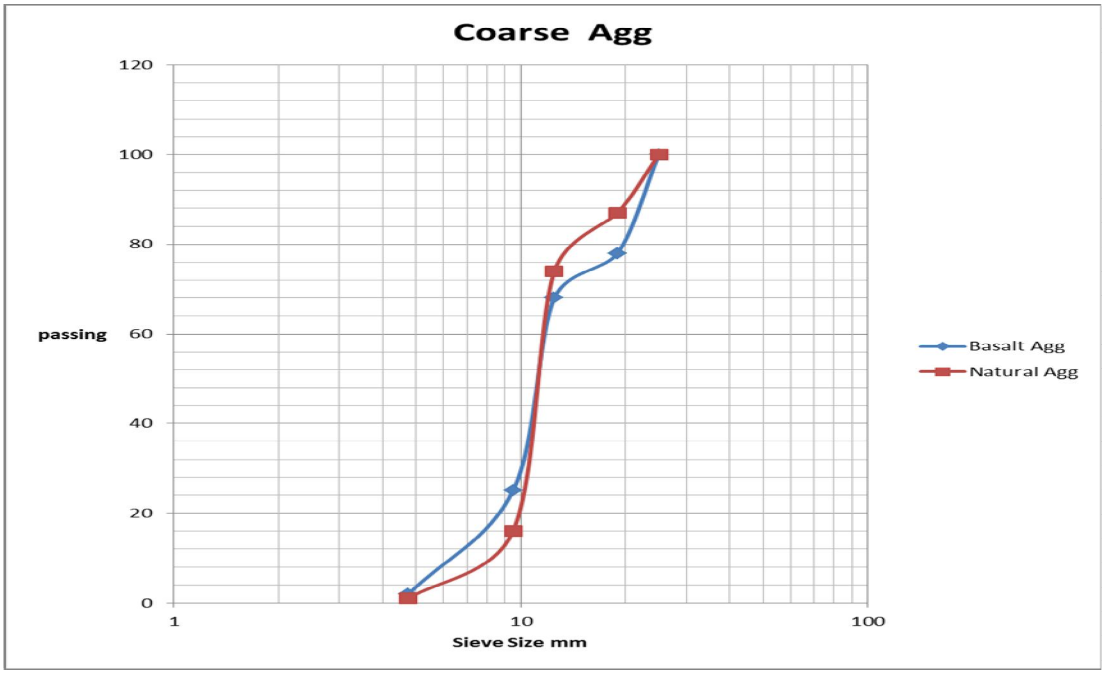

Fig (5.1): Logarithmic curve explain sieve analysis of coarse aggregate Basalt &Granite

Calculations was of sieve analysis of a sample of fine aggregate with mass of 1282g was passed through the sieves as shown in Table (5.4)

Table (5.4) Sieve analysis of Fine aggregate

Sieve size	Mass retained g individual on each sieve	Individual retained%	Total % retained cumulative
3/8	0	0.0	0
4.75mm (No. 4)	21	3	3
2.36mm (No. 8)	268	21	24
1.18mm (No. 16)	489	39	63
600 µm (No. 30)	273	21	84
300 µm (No. 50)	131	10	94
150 µm (No. 100)	31	3	97
75 µm (No. 200)	21	2	99
Pan	7	1	100
Total	1241	100	-
Fineness modulus= 365/100 =3.65			

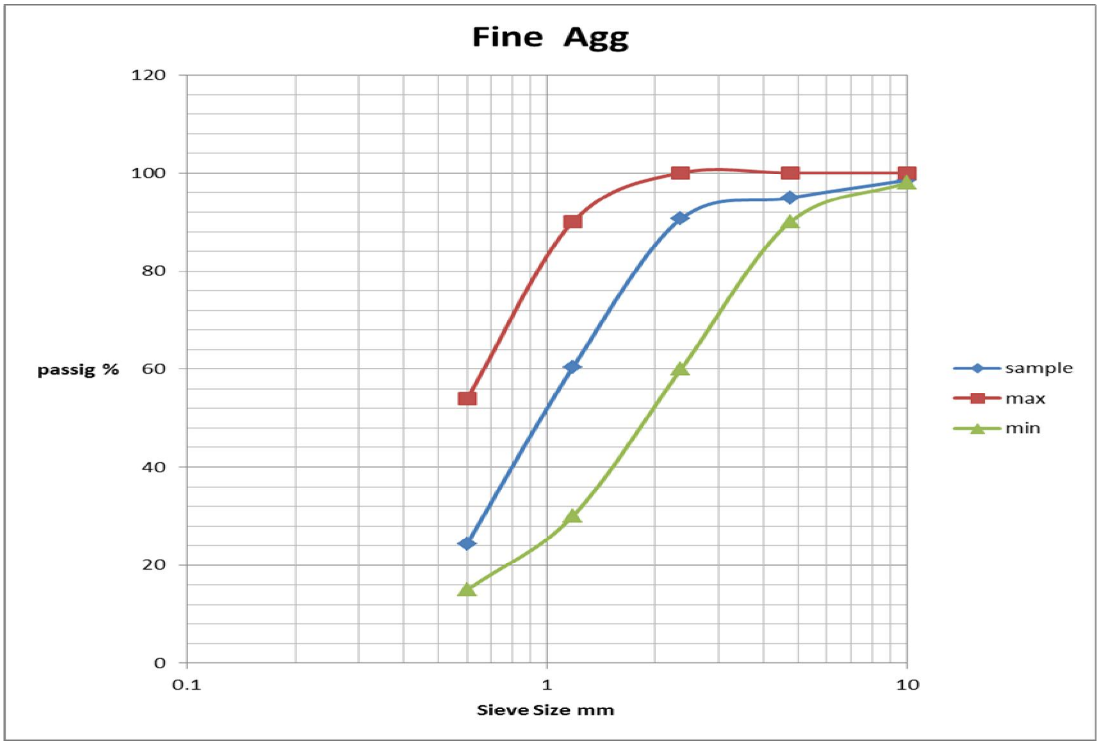

Fig (5.2): logarithmic curve explain Sieve Analysis of Fine Aggregate

Table (5.5): Shows trail mixes design Proportions using Basalt and Granite.

MIXES NO	MIX proportion	Cement(kg)	Fine Aggregate(kg)	Course Aggregate(kg)	W/C Ratio
Basalt Mix1	1:1.66:2.73	410	680	1120	0.5
Basalt Mix 2	1:1.42:2.44	430	610	1050	0.43
Basalt Mix3	1:1.22:2.33	450	550	1050	0.46
Basalt Mix4	1:1.51:2.49	450	680	1120	0.46
Granite Mix1	1:1.66:2.73	410	680	1120	0.5
Granite Mix2	1:1.42:2.44	430	610	1050	0.43
Granite Mix3	1:1.22:2.33	450	550	1050	0.46

Tests were carried out for trail mixes mentioned as shown in Table (5.6)

Table (5.6): Compressive strength test for trail mixes.

MIXES NO	Average of compressive strength N/mm^3			Slump mm
	7days	28days	56days	
Basalt Mix1	48.0	55.0	61.0	100
Basalt Mix2	45.5	52.0	63.5	80
Basalt Mix3	43.0	52.0	57.0	70
Granite Mix 1	40.0	50.5	56.5	80
Granite Mix 2	52.5	56.5	60.5	80
Granite Mix 3	54.0	56.0	64.0	90

Table (5.7): Results of (mix3) for Granite and Basalt aggregate compared with control mix of Granite and Basalt

Type of aggregate	Slump	Average Compressive strength N/mm^2		
		7days	28days	56days
Control mix(Basalt)	0	28.5	33.0	39.0
Control mix(Granite)	50	40.5	49.0	54.0
Basalt mix3	70	43.0	52.0	57.0
Granite mix3	90	54.0	56.0	64.0

All the concrete tests were made according to the ACI method mix proportion and make adjustments trail mix proportion.

Note:

In (Mix3) and (Mix4) in Basalt crashed aggregate there are optimum total quantities aggregate to achieve the HSC. When we reduced the total aggregate in mix3 the strength is decreased because for Basalt needs more aggregate service area bounding rather than Granite aggregate (Settat stone)because the Granite aggregate had good adhesion between the area of bounding for this reason when we used the same (mix) proportion we get the good result in Granite (Settat stone) (mix3).

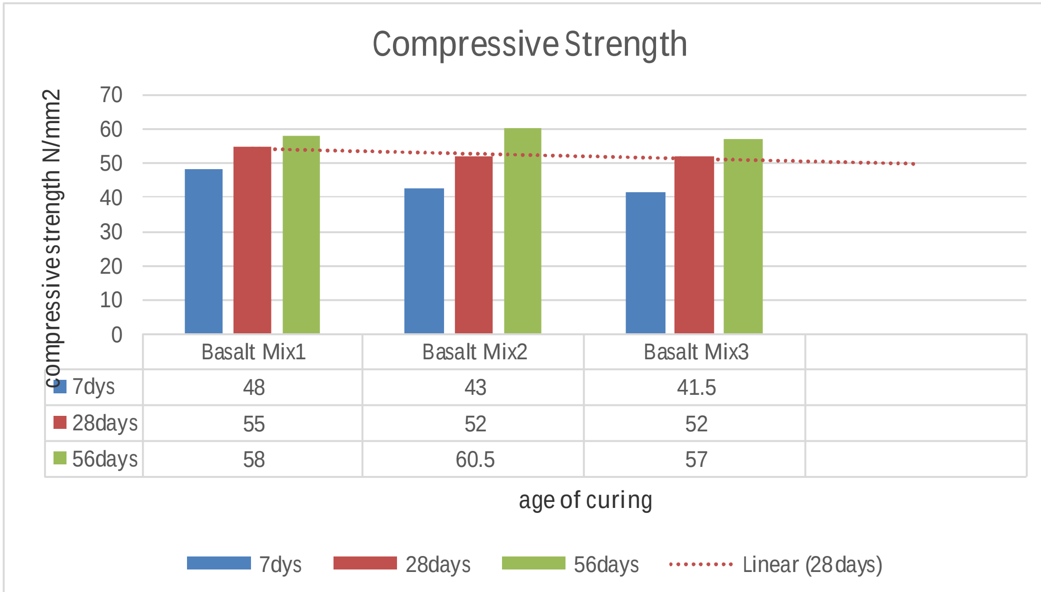

Fig (5.3): Compressive strength development throughout the ages of 28days for Basalt crushed aggregate for different mix proportion

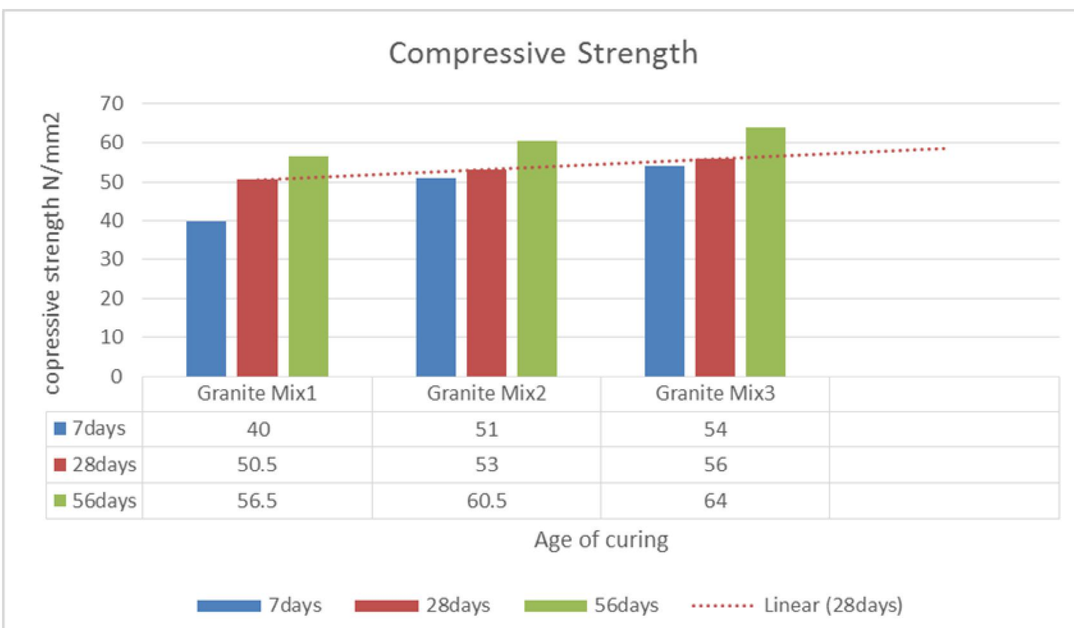

Fig (5.4): Compressive strength development throughout the ages of 28days for Granite un crushed aggregate for different mix proportion

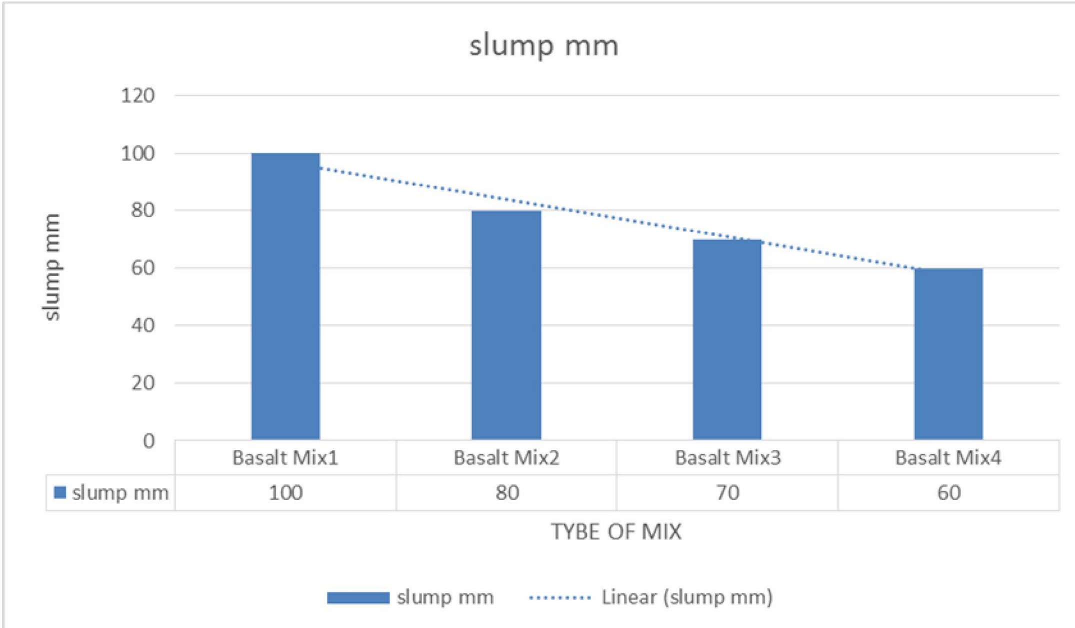

Fig (5.5) slump for Basalt mix proportion

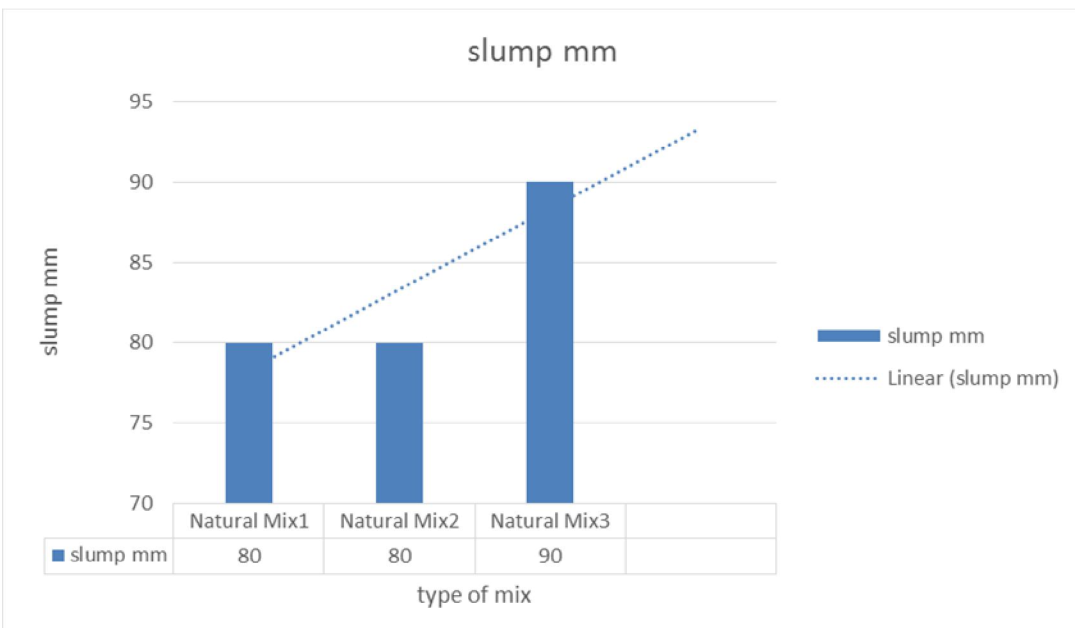

Fig (5.6): slump for Granite aggregate mix proportion

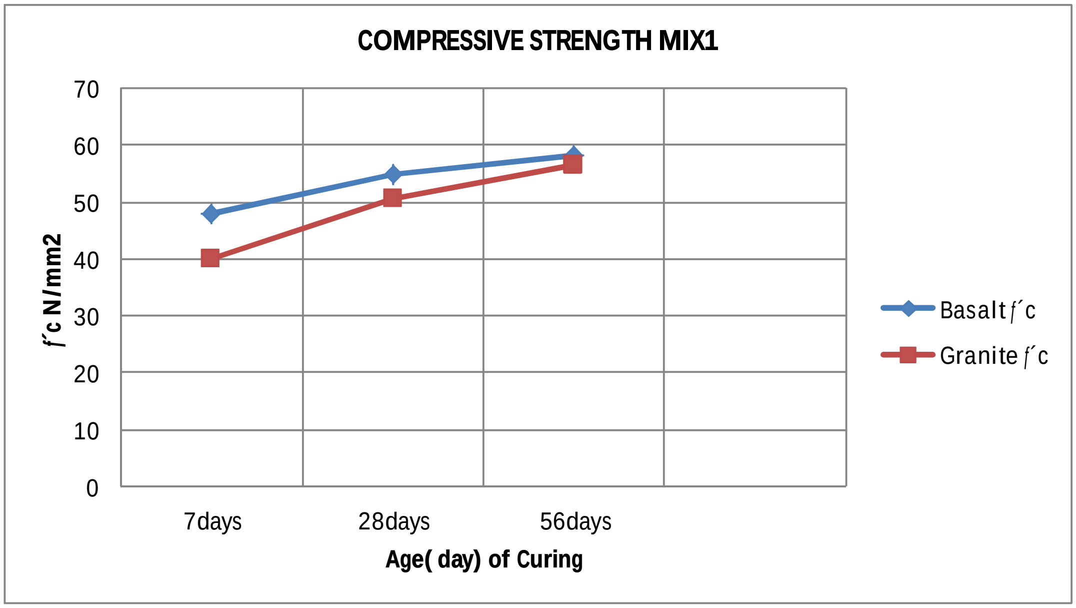

Fig (5.7): Comparison between strength developments of MIX1 for Basalt &Granite Aggregate

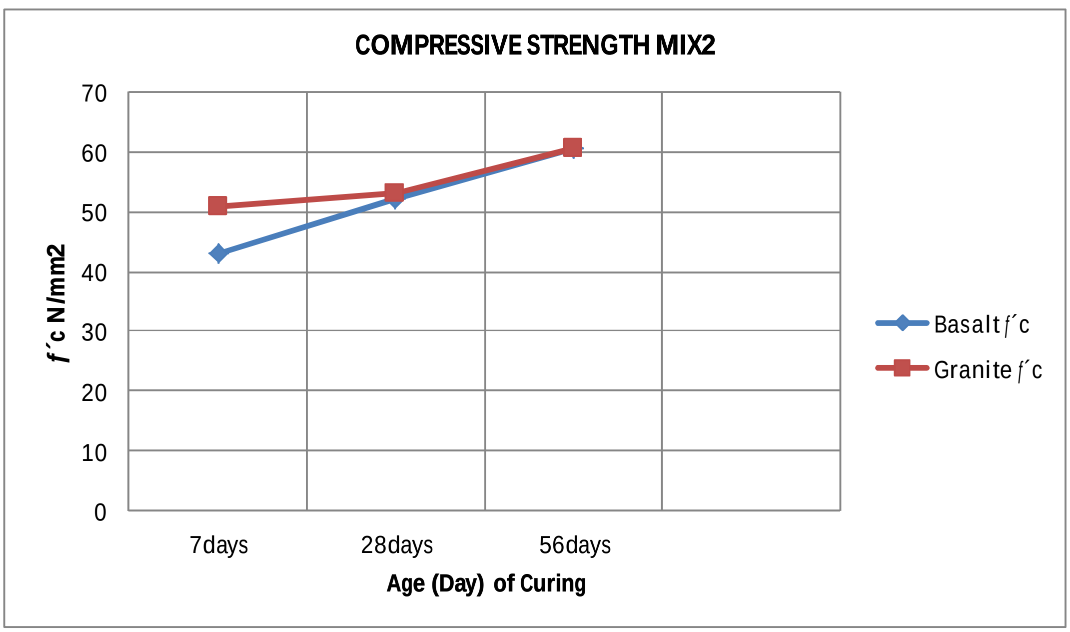

Fig (5.8): Comparison between strength developments of MIX2for Basalt &Granite Aggregate

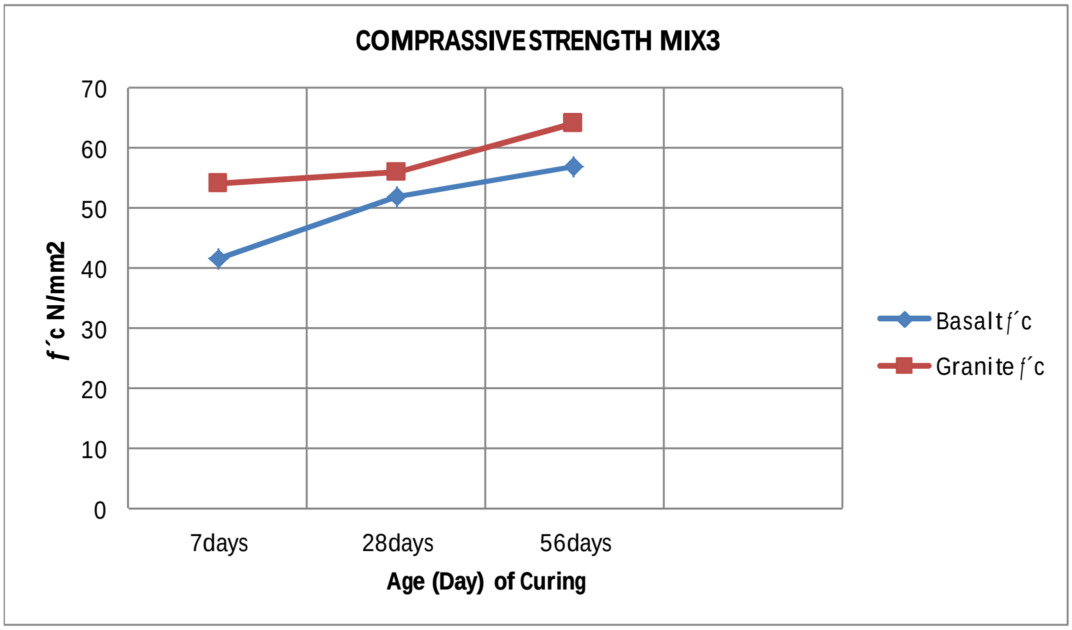

Fig (5.9) Comparison between strength developments of MIX3 for Basalt &Granite Aggregate

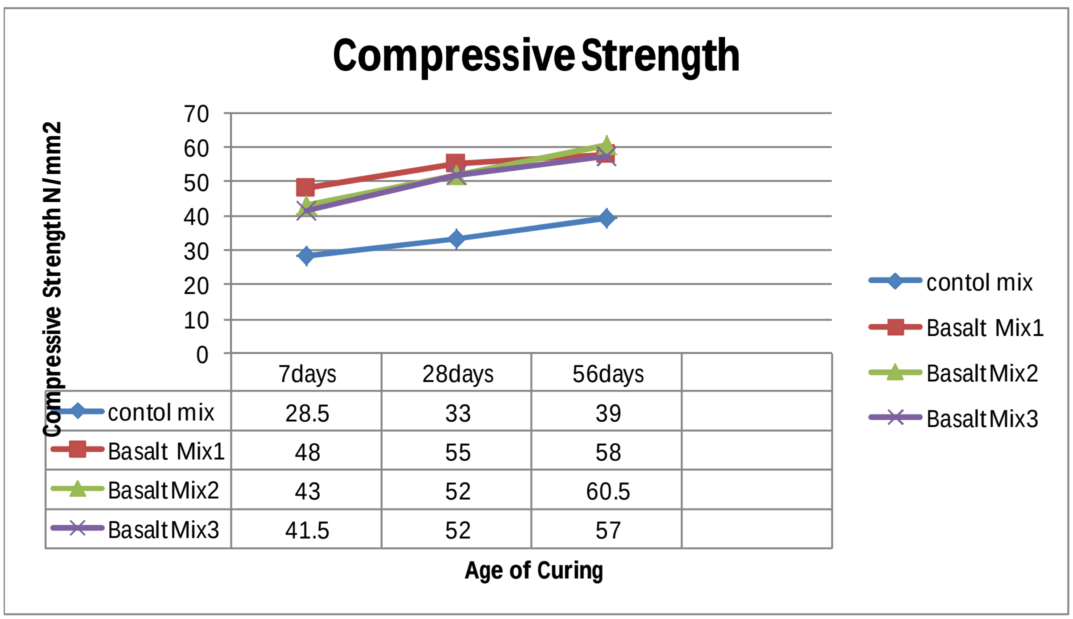

Fig (5.10): Comparison between strength developments of control mix and all mixes for Basalt aggregate

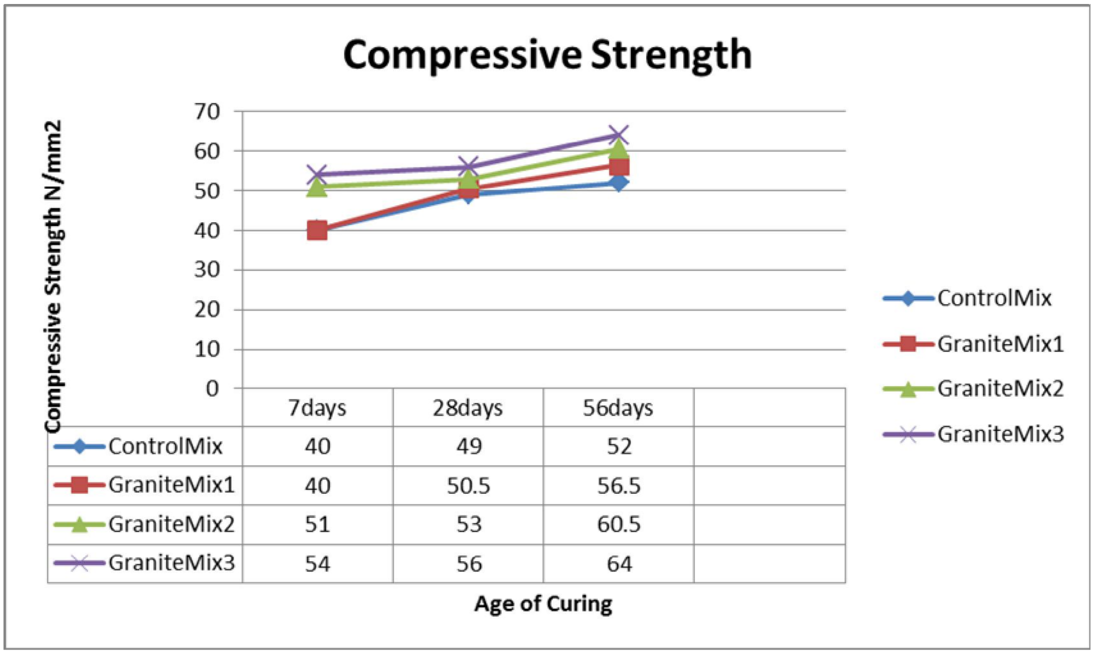

Fig (5.11): Comparison between strength developments of control mix and of all mixes with Granite aggregate

Result Discussions:

The results of the experimental investigation were analyzed as follow:

1. From Fig (5.3),the compressive strength is developed in 7, 28 and 56 days for Basalt aggregate but the strength is decreased by increasing of cement content in mix1,mix2&mix3 .From Fig(5.4) Granite mixes were found that the compressive strength is increased with increasing of cement content in different mixes of Granite aggregate . (Mix3) with Granite aggregate in 56days is gave the greater compressive strength in comparison with other mixes.
2. From Fig (5.5) and (5.6),it’s clear that the slump value is decreased with increasing cement content for Basalt aggregate mixes, and slump value is increased with increasing of cement content for the Granite aggregate mixes but both of them within range accordance to ACI mix design 25-100.
3. From Fig (5.6), (5.7), (5.8) the comparison all mixes results of compressive strength in 28 days was found that the higher value of strength Granite (mix2) Fig(5.7) 56.5 in same quantities of material and conditions of mix and was found that clearly the Granite aggregate gives early strength as we seen that in Fig (5.8) Mix3

4. Heavy weight of concrete mix due to reach Mix of cement trail mix design comes from density of Basalt 2.88 and Granite 2.69 see the classification of concrete in accordance with unit weight in [Table (2.1)]

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

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CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

The results obtained from the different mix proportions using high quality crushed basalt and uncrushed granite coarse aggregate are summarized and discussed as following:

1. Figure (5.5) and (5.6) shows that the slump values is decreased with in increased of the cement content for basalt aggregate mixes, and its increased within increased of the cement content for granite aggregate mixes but both of them within range accordance to ACI mix design (25-100) mm.
2. Figure ((5.7), (5.8) & (5.9)) & Table (5.6) shows that the compressive strength is developed in 7, 28&56 days for basalt and granite course aggregate.
3. From Fig ((5.3) & (5.10)) & Table (5.6) the compressive strength is decreased with in increased of the cement content in mix1, mix2&mix3 for basalt aggregate mixes.
4. From Fig ((5.4)&(5.11)) & Table (5.6) Granite mixes it was found that the compressive strength is increased with in increased of the cement content in different mixes of Granite aggregate .also the Figure shows that in (Mix3) Granite aggregate mixes in 56days gives the maximum compressive strength than other mixes.

6.2 Recommendations

In this study the crashed basalt and uncrushed granite coarse aggregate with high quality for basic material, was used to produce high compressive strength concrete in different ages. From the results obtained it can be concluded that:

1. The significant effects of the high quality uncrushed granite coarse aggregate occurred at mix proportion of (1:2.33:1.22:0.46) kg/m3, (cement: coarse aggregate: fine aggregate: water), respectively.
2. The production of 1m3 HSC strength of concrete mix proportion (mix3) of material of as follow: cement content 450kg /m3, fine aggregate 550kg/m3 ,coarse aggregate 1050kg/m3 for Granite aggregate in Water temperature 4°C mix temperature 28°C and w/c 0.46 .
3. The compressive strength of concrete with in increased of cement content in granite aggregate mixes.
4. The slump values of all mixes, when use high quality crashed basalt and uncrushed granite coarse aggregate within range accordance to ACI mix design (25-100) mm. From this study it can be recommended that the uncrushed

granite with high material quality, suitable concrete mix proportion and extra quality control procedures can be used to produce high compressive strengthconcrete.

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