T.C.
ISTANBUL GEDİK UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

INFLUNCE OF INTERNAL SULFATE EFFECT ON HIGH STRENGHT CONCRETES IN TERMS OF QULITY MANGEMENT

MASTER THESIS

Mays Ahmad Majeed ALJOMAILY

Engineering Management Department

Engineering Management Master in English Program

DECEMBER 2021

T.C.
ISTANBUL GEDİK UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

INFLUNCE OF INTERNAL SULFATE EFFECT ON HIGH STRENGHT CONCRETES IN TERMS OF QULITY MANGEMENT

MASTER THESIS

Mays Ahmad Majeed ALJOMAILY
181281002

Engineering Management Department

Engineering Management Master in English Program

Thesis Advisor: Assist. Prof. Dr. Gökhan KAZAR

DECEMBER 2021

T.C

İSTANBUL GEDİK ÜNİVERSİTESİ

LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ MÜDÜRLÜĞÜ

Yüksek Lisans Tez Onay Belgesi

Enstitümüz, Engineering Management Department İngilizce Tezli Yüksek Lisans Programı (181281002) Mays Ahmad Majeed Al-Jomaily "Influence of Internal SulfateEffect on High Strength Concretes in Terms of Quality Management adlı tez çalışması Enstitümüz Yönetim Kurulunun 22.12.2021 tarihli kararıyla oluşturulan jüri tarafından Oy Birliği ile Yüksek Lisans tezi olarak Kabul edilmiştir.

Öğretim Üyesi Adı Soyadı

Tez Savunma Tarihi: (22/12/2021)

1) Tez Danışmanı: Dr. Öğr. Üyesi Gökhan KAZAR (İstanbul Gedik Üniversitesi)

2) Jüri Üyesi: Prof. Dr. Ömer Ziya CEBECİ (İstanbul Gedik Üniversitesi)

3) Jüri Üyesi: Dr. Öğr. Üyesi Mert TOLON (Maltepe Üniversitesi)

DECLARATION

I, Mays Aljomaily , do hereby declare that this thesis titled as "Influence of Internal Sulfate Effect on High Strength Concretes in Terms of Quality Management" is original work done by me for the award of the masters degree in the faculty of Engineering Management. I also declare that this thesis or any part of it has not been submitted and presented for any other degree or research paper in any other university or institution. (22/12/2021)

Mays Ahmad Majeed AL-JOMAILY

And they ask you about the Spirit. Say, “The Spirit belongs to the domain of my Lord, and you were given only a little knowledge.”

Great truth of God

(Surah Al-Isra verse 85)

DEDICATION

To the soul of my dear grandmother........................ **may God have mercy on her**

To the best heart in the world…………………………..my dear uncle Ahmed, may God have mercy on him

To the symbol of devotion and devotion, my beloved mother

To the source of goodness, sacrifice and altruism...... Baba (Muhammad)

To whom you gave the most precious and precious for me ...... my beloved aunt

To the example of giving and pride..... my beloved sister

To all who love me sincerely and sincerely

I present to you my research

PREFACE

In the name of Allah, the Merciful And peace and blessings be upon the Messenger of God, our master Muhammad, his family and companions, and whoever followed him with kindness until Day of Judgment and It is my pleasure, as I finish my letter, to extend my sincere thanks and gratitude to (Dr. Gökhan Kazar) who supervised my letter for directing me and for his valuable remarks that had a great impact in producing the message in this way, and may God grant them success to what he loves and pleases I want to express my profound thanks, appreciation, and respect to the (Dr. Mert Tolon) for what he presented for me and was the reason for my reaching this stage. and he who made me know the meaning of being a science student looking for renewal in his life. as well as thank my teachers Dr. Dilek KURT.

December 2022 Mays Ahmad Majeed AL-JOMAILY

TABLE OF CONTENTS

Page

ABBREVIATIONS

ACI	: American Concrete Institute.
ASTM	: American Society for Testing and Materials
C	: Cement
HSC	: High Strength Concrete
HRWR	: High Range Water Reducer
HRM	: High Reactivity Metakaolin
MK	: Metakaolin
MAS	: Maximum Aggregate Size
NC	: Normal concrete
Re	: Research
SP	: Superplasticizer
SCM	: Supplementary Cementing Materials
w/c	: Water/cement
W	: Water
%	: Percentage

LIST OF TABLE

Page

LIST OF FIGURES

Page

INFLUENCE OF INTERNAL SULFATE EFFECT ON HIGH STRENGTH CONCRETES IN TERMS OF QUALITY MANAGEMENT

ABSTRACT

The use of high-strength concrete has received much attention recently; Because the use of high strength concrete reduces the concrete sectors and thus provides more space within the facilities, reduces the weight of the structure,

and allows an increase in the number of floors, while also distinguished by its high durability, with time.

The effect of sulfates entering concrete is one of the most important technical problems facing concrete industries, which negatively affects the quality of the technical properties of concrete, as the internal sulfate attack leads to a large expansion in concrete, which leads to a decrease in the compressive resistance, which causes damage to concrete structures, especially those used in bridges. And giant concrete structures

In this study, the effect of the attack of external sulfur salts on concrete was evaluated by following the changes in the compressive strength of concrete models that are fully and continuously immersed during the immersion period in different sulfate solutions, Magnesium sulfate MgSO4, Sodium sulfate Na2SO4 and Calcium sulfate CaSO4 separately, with different concentrations and different ages.

also, the effect of internal sulfate on the quality of high-strength concrete was highlighted by studying its effect on the quality of materials entering the formation of high-resistance concrete, namely (gravel, sand, and cement).

The results showed that the resistance to compression and direct and indirect tensile strength decreases in the presence of a percentage of sulfate salts in the concrete mixtures, and it exhibits the same behavior accordingly. Also, the total content of the effective sulfur salts may have a better positive effect than the total sulfate content because of its dependence on the size of the grains of the material used.

The study also found that the use of quality tools has a positive and effective effect in improving the properties of high-resistance concrete by diagnosing the main problems of concrete and identifying the sub-causes leading to those problems and then developing appropriate solutions to address them, all through the Diamond cycle and its sub-tools represented by the classic quality tools.

the study recommended The use of sulfate-strength cement, a type of Portland cement, where the amount of tri-calcium aluminate is limited to less than 5% and the oxides of calcium, silicon, and various minerals are less than 25%, which reduces the formation of sulfate salts, at which time the possibility of sulfate attack on concrete is reduced. As recommended by the study Relying on the DAMAC work team for the purpose of continuing to follow up on quality according to its different stages and giving him the time necessary for that for his high ability to diagnose and treat deviations

Keywords: *High-Strength Concrete, Sulfates, Quality*

YÜKSEK MUKAVEMETLİ BETONLARDA İÇ SÜLFAT ETKİSİNİN KALİTE YÖNETİMİ AÇISINDAN ETKİSİ

ÖZET

Yüksek dayanımlı beton kullanımı son zamanlarda çok ilgi gördü; Yüksek dayanımlı beton kullanımı beton sektörlerini küçülttüğü ve dolayısıyla tesisler içinde daha fazla alan sağladığı için yapının ağırlığını azalttığı için, kat sayısının artmasını sağlarken, zamanla yüksek dayanıklılığı ile de öne çıkmaktadır.

Betona giren sülfatların etkisi, beton endüstrisinin karşılaştığı en önemli teknik sorunlardan biridir ve betonun teknik özelliklerinin kalitesini olumsuz etkiler, çünkü dahili sülfat atağı betonda büyük bir genleşmeye neden olur ve bu da betonda bir azalmaya yol açar. Özellikle köprülerde kullanılan beton yapılara zarar veren basınç direnci. Ve dev beton yapılar

Bu çalışmada, farklı sülfat çözeltileri, Magnezyum sülfat MgSO4, Sodyum sülfat Na2SO4 daldırma süresi boyunca tamamen ve sürekli daldırılan beton modellerin basınç dayanımındaki değişimler takip edilerek dış kükürt tuzlarının betona etkisinin beton üzerindeki etkisi değerlendirilmiştir. ve Kalsiyum sülfat CaSO4, farklı konsantrasyonlarda ve farklı yaşlarda ayrı ayrı.

ayrıca, iç sülfatın yüksek dayanımlı betonun kalitesi üzerindeki etkisi, yüksek dirençli betonun oluşumuna giren malzemelerin (çakıl, kum ve çimento) kalitesi üzerindeki etkisi incelenerek vurgulanmıştır.

Sonuçlar, beton karışımlarında belirli bir oranda sülfat tuzlarının varlığında basma direnci ile doğrudan ve dolaylı çekme dayanımının azaldığını ve buna bağlı olarak aynı davranışı sergilediğini göstermiştir. Ayrıca, etkili kükürt tuzlarının toplam içeriği, kullanılan malzemenin taneciklerinin boyutuna bağlı olması nedeniyle, toplam sülfat içeriğinden daha iyi bir pozitif etkiye sahip olabilir.

Çalışma ayrıca kaliteli araç kullanımının, betonun temel sorunlarını teşhis ederek ve bu sorunlara yol açan alt nedenleri belirleyerek ve bunlara yönelik uygun çözümler geliştirerek yüksek dayanımlı betonun özelliklerini iyileştirmede olumlu ve etkili bir etkiye sahip olduğunu bulmuştur. , tüm Diamond döngüsü ve klasik kalite araçlarıyla temsil edilen alt araçları boyunca.

Çalışma, tri-kalsiyum alüminat miktarının %5'ten az ve kalsiyum, silikon ve çeşitli minerallerin oksitlerinin %25'ten az olduğu bir Portland çimentosu türü olan sülfat mukavemetli çimentonun kullanılmasını önerdi. sülfat tuzlarının oluşumunu azaltır, bu sırada betona sülfat etkisi olasılığı azalır. Çalışmanın önerdiği gibi Farklı aşamalarına göre kaliteyi takip etmeye devam etmek ve sapmaları teşhis etme ve tedavi etme konusundaki yüksek yeteneği için ona gerekli zamanı vermek amacıyla DAMAC çalışma ekibine güvenmek

Anahtar kelimeler: *Yüksek Dayanımlı Beton, Sülfatlar, Kalite*

1. INTRODUCTION

The most important of which is high-strength concrete. High-strength concrete gives the possibility of obtaining relatively high-pressure resistances and allows the designer to construct higher buildings and thinner slabs that can be made with smaller columns, which gives more aesthetics to these designs and by using High-strength concrete can be loosened more quickly and reduce the amount of reinforcing iron in tall buildings, thus reducing the dead load in it. We can make high-resistance concrete by combining the same materials used in standard concrete installation with new technology to create a material with a longer life and greater resistance.

In any case, these days are witnessing the beginning of the second revolution in concrete technology, where the contradiction between high resistance and low operability has been overcome by producing and using plasticizers that allow the use of a low water percentage. Some very low water additives may reduce the water percentage to 0.25 weight. Cement at the same time gives high workability and has become popular in European and American countries Japan and even in some countries of the world in Malaysia, where the highest buildings in the world were constructed

The definition of highly strength concrete is constantly evolving. In the year 1950, the definition of highly strength concrete was defined as that which possesses a compressive strength of (34 MPa). Material, manufacturing processes, and testing have all improved in recent decades, necessitating a shift in the concept of high-resistance concrete.

The study contained six chapters:

- Chapter one: Study methodology (study problem, study objectives, the importance of the study, study data, in addition to previous studies)
- Chapter 2: The theoretical side of the study includes detailed information about the research variables.
- Chapter Three Details of work, mixing ratio and test method as well as details of experiments.

- Chapter Four: Discuss experiences
- Chapter Five: Statistical Quality Control & Application of the DMAIC methodology
- Chapter six Conclusions and Recommendations
- Sources

2. RESEARCH METHODOLOGY

2.1 General

High resistance concrete is of great interest to many researchers these days due to its widespread use in many fields in civil engineering such as bridges as well as concrete structures with wide seas. Availability of materials required for its manufacture (gravel, sand, cement, and water), as well as the cost of licenses and maintenance, and have a high capacity to withstand loads and a long life if properly manufactured and not exposed to damaging factors.

Availability of materials necessary for its manufacture (gravel, sand, cement, and water), and cost of licenses and maintenance and have a high capacity to withstand loads and long-life if manufactured properly and not exposed to factors that damage it.

The most prominent difficulty facing concrete in the world is the deterioration caused by the attack of internal sulfate. This fact is important for the concrete industry because it reduces the compressive strength and increases the expansion of the concrete and consequently the concrete structure may be damaged by this problem. The effects and contents of total active sulfate on high strength concrete (HSC) will be investigated in this study.

The research included six chapters. The first chapter contained the research method, which contains the importance, objectives and purpose of the research, in addition to the research hypotheses and methods used in it. While the second chapter included the theoretical aspect of the research and previous intellectual readings of the research variables, which include high-resistance concrete and quality management. As for the third chapter, it included the three tests that were worked on for high-resistance concrete. The results that were reached in the fourth chapter were analyzed in addition to a discussion of the results and included the chapter Fifth: Improving the quality of concrete through the Dimenc cycle. Finally, the sixth chapter included conclusions and recommendations.

2.2 Objectives of the Study

- The study aims to produce high resistance concrete according to certain mixing ratios
- Treating sulfate attack on high-resistance concrete
- Improving the quality of the technical properties of high-strength concrete components
- Determine the proportions suitable for mixing high resistance concrete components
- Statistically controlling the quality of concrete through the use of the classic quality tools represented in the Dimenc cycle and the tools it contains such as quality control chart, Ishako chart, Pareto and others.
- The possibility of modifying the content of fine aggregates in concrete mixtures to facilitate their use
- Reducing costs: Quality requires doing the right things the right way the first time, which means reducing or re-accomplishing damaged things and thus reducing costs.
- Reducing the time required to complete the project

2.3 Purpose / Importance

This study derives its importance from the importance of the researched variables, as there are wide, many, and basic uses for high- strength concrete. Therefore, this matter requires in-depth and thorough studies on this topic. Therefore, this study was conducted to control the quality of high-strength concrete through statistical methods used to improve the work Salah al-Din Stadium and its hotel in Salah al-Din Governorate and presenting the best services This study also works to create the correct scientific methods for determining the mixing ratios of materials for highly strength concrete in accordance with international quality standards.

on the other hand, is critical for lowering the cost of employing high-quality materials, as well as the additives utilized, and for quality control.

Therefore, the research draws its importance in addition to the above reasons will follow:

- Simple deviations in the Quality of material mixing scales for high-strength concrete or its technical characteristics used in construction projects may lead to human disasters,
- The need for an integrated system to improve quality and detect deviations in the highly strength concrete industry using statistical techniques and methods,
- Use advanced statistical techniques in quality control properties of concrete high strength great importance to research which contributes to raising the level of quality of concrete and project used in it,
- Despite the increase in costs per cubic meter of high strength concrete in addition to the increase in the cost of quality control, the cost of the final work is much lower due to the higher final evaluation of concrete and masonry
- High-strength concrete has high durability, abrasion resistance, and chemical resistance.

2.4 The Hypotheses

To be tested in this study will be;

- Do the contents of the mixture affect the concrete strength?
- There is considerable variation in the proportions of mixing materials for concrete high strength because of the weak quality control.
- The use of quality tools in controlling the technical characteristics of high-strength concrete leads to raising the level of its quality and reducing deviations from its international standards.

2.5 Field, Data Sources, Location, Time, and Support

The research was applied to the Salah al-Din Stadium project, which is under implementation, and it is one of the large projects in Iraq / Salah al-Din Governorate, where the project includes building a stadium and its other annexes, in addition to building a hotel attached to the stadium to receive guests of the games held on the stadium. The project data was approved and tests were conducted in the university laboratories and Salah El-Din laboratories.

- Study location: Salah al-Din Stadium / Iraq
- Data sources: Study site: Contracting companies and projects

3. INTELLECTUAL BACKGROUND

3.1 High Strength Concrete

Concrete is at the forefront of building materials used in the implementation of projects. Its production and manufacturing methods have evolved and improved tremendously, and the types of production have varied according to the purposes used for it in different fields through the diversity of its components, the use of additives, or the diversity of production methods. Concrete strength and causes expansion, cracking, and surface peeling.It can cause concrete failure within 3-5 years, especially in severe cases of sulfate attack (Nouri, 1983) This depends on the factors that cause it, such as the type of cement and its accompanying sulfur, and the percentage of adhesive with water (w/cm), and the presence of additives (Al-Robayi, 2005).

3.2 Concrete Components

3.2.1 Cement

The hydration processes of calcium silicate and other chemical components such as aluminates are primarily responsible for the hydraulic hardening of cement,(Jassim, 2008) and the total effective calcium oxide ratios (CaO) and effective silicon dioxide (SiO_2) in cement are not lower frome (50%) by mass,(CI Committee 211, 2008) Cement is made up of a variety of elements with statistically homogenous compositions that come from the manufacture and distribution of high-quality ingredients and it (Iraqi Standards, 2984).

3.2.1.1 Active calcium oxide (CaO)

It is a fraction of calcium oxide that can form hydrated calcium silicate or hydrated calcium aluminate under normal hardening conditions. (Ferraris, 2006) To find the effective calcium oxide content, the amount of the corresponding fraction of calcium carbonate is reduced ($CaCO_3$) Calculated on the basis of the laboratory-determined carbon dioxide (CO_2) content as well as the reduction of the corresponding fraction of calcium sulfate ($CaSO_4$) Calculated on the basis of the content of (SO_3) determined laboratory After subtracting the amount of (SO_3) combined with alkali, from the total (Iraqi Standards, 2004)

$$CaCO_3 \Longrightarrow CaO + CO_2 \qquad \textbf{(2.1)}$$

$$CaSO_4 \Longrightarrow CaO + SO_3 \qquad \textbf{(2.2)}$$

3.2.1.2 Active silicon dioxide (SiO_2)

It is the fraction of soluble silicon dioxide. It determines the amount of effective silicon dioxide by subtracting the fraction in the remaining insoluble material, determined by the laboratory, from the total content of the laboratory determined silicon dioxide. Both are determined on a dry method basis.

Note that the maximum cement content in concrete is 500 kg / m3 to avoid cracking resulting from dry shrinkage in thin concrete sectors or thermal stresses in thicker sectors (Hassan, 2000).

3.2.1.3 Magnesia and alkali

(Alkalis, sodium, calcium, potassium) and phosphates and these are present in the clay. The raw materials are ground and mixed well and in specific proportions, and (burned in a large rotary kiln) of diameter About (5m) and its length (150m) with a temperature ranging from (1300-1500) where the material melts (Diah, 2008) and agglomerates in the form of Small balls known as(clinker), then the clinker is cooled and ground into a fine powder after adding sulfate. Hydrated calcium ($CaSO_4.2H_2O$), known as (gypsum), and the gray color of Portland cement is due to the presence of iron (Hooton,1993).

3.2.1.4 Physical properties of portland cement

Portland cement was used in this research

- Portland cement is a gray powder, its granules have a specific weight of (3.15) and a size ranging between (20-80) microns, and the size of the granule depends on the method of grinding and can change according to the requirements of the cement (Abbas, 2013).

- Cement particles are of small size so that it is difficult to measure them by sieve analysis as in the case of aggregates, and thus resort to determining the Specific Surface Area of the unit of weight as an alternative measurement (Melhem, 2008).

The specific surface area of cement in the USA is determined by the method (Blaine), which is the most common, and is based on measuring the velocity of air diffusion under constant pressure through a small compressed model of cement. The values of the specific surface area measured in this way range between (300-500m²/Kg) for most types of cement used (Nilesh, 2007).

3.2.1.5 Properties of portland cement chemical

The raw materials used in the manufacture of Portland cement mainly consist of (ACI Committee, 2008).

1 - limestone	CaO	(symbolized by the letter C)
2 – Silica	$SiO2$	(symbolized by the letter S)
3 - Alumina	$Al2O_3$	(symbolized by the letter A)
4 - iron oxide	$Fe2O_3$	(symbolized by the letter F)

These compounds react with each other inside the furnace until a state of chemical equilibrium is reached, and this reaction results in clinker. The clinker contains four main compounds shown in Table (2.1) below: (Neville, A. M., 2000).

Table 3.1: The main compounds of clinker

Seq	***Compound name***	***Code***	***chemical symbol***
1	*Tricalcium Silicate*	$C_3 S$	$3CaO\ SiO2$
2	*Dicalcium Silicate*	$C2\ S$	$2CaO\ SiO2$
3	*Tri − calcium aluminate*	$C3A$	$3CaO\ Al2O_3$
4	*tetracalcium iron aluminate*	$C4AF$	$4CaO\ Al2O_3\ Fe2O_3$

Sources: (Neville, 2000).

It is possible to determine the percentage of these four major compounds in Portland cement from the percentage

Obtained from chemical analysis by (Bogue) equation on the assumption:

- The chemical equilibrium occurs when these four main compounds interact.

- *The clinker cooling conditions do not affect the phase equilibrium, meaning that the glass does not form in this case (Heinz, 1987).
- *The products of the chemical equilibrium are fully crystallized (ASTM C150, 2006).

C_3S = 4.07(CaO) – 7.60 (SiO2) – 6.72 (Al2O_3) – 1.43 (Fe2O_3) – 2.85 (SO_3) **(3.3)**

S = 2.87(SiO2) – 0.754 (C_3S) C2 **(3.4)**

C_3A = 2.65 (Al2O_3) – 1.69 (Fe2O_3) **(3.5)**

C4AF = 3.04 (Fe2O_3) **(3.6)**

3.3 Aggregates

The aggregate consists of rocky particles of gradual size, including large grains (Gravel) and small ones (Sand) and it includes the relatively inert filler material that is spread through the cement paste in the concreteas it gives the concrete its stability and resistance to external forces and weather factors such as heat, moisture and freezing, and the aggregate reduces the resulting volume changes When the cement paste freezes and hardens or the concrete is exposed to moisture and dryness, (Irassar,1995) so the aggregate gives the concrete better durability than if the cement paste was used alone.

Aggregates can be classified according to size, shape, and origin (Moisture content) We will focus here on the size classification and as shown below (Pheng, 2004).

- (Coarse aggregate) or (Gravel) and most of these granules are kept on a sieve of size mm (5.0). This aggregate is either uncrushed aggregate, crushed aggregate or partially crushed aggregate. It is the group of granules most of which (95 - 100%) passes through the standard sieve 4.76 mm 16/3 (Heizer & Render, 2017).
- (Fine aggregate) or (Sand) and most of these granules pass through a 5.0 mm sieve This aggregate is either natural sand, crushed stone sand or crushed gravel sand.

Thought is the group of granules that most of them (95-100%) is retained by the standard sieve 4.76 ml 16/3(Jan Skalny, 2002).

- All-in aggregate is a mixture of coarse aggregate and fine aggregate.

Concrete is a material consisting of cement, sand, and water with an addition (gravel or crushed or crushed stones). Concrete is one of the most important building materials in the modern era, especially with iron reinforcing it to form reinforced concrete (Santhanam, 2002).

3.3.1 Water (mixing water)

Any potable water, except for bacteriological requirements, can be used in the manufacture of concrete, the water is measured as a ratio of cement W/C water-cement ratio, and the bus is in the range of 0.4 - 0.6.(Santhanam, 2002).

The water contributes to the hydration of the cement to form a cement paste, which works to bind the granules (aggregates), after they were initially formed (about 3 hours) and finally (about 8 hours) and then hardened. and water

It increases the workability of the concrete, but then evaporates and leaves voids that reduce the strength of the concrete (Natalya G,2003).

3.3.2 Admixtures

They are materials added to concrete mixes in very small quantities to improve specific properties of concrete or give it new properties and are divided into 5 groups (Naik NN,2006).

- Accelerators
- Air entraining agents
- Plasticizer
- Retarders
- Waterproofing Agents

3.4 High- Strength Concrete

It is a concrete with a strength of more than (60/ mpa) and it may reach or exceed (140 mpa) and it can be obtained by using the available local materials that are used in the manufacture of traditional concrete.(25/ mpa) of aggregate, cement and water. (Naik NN, 2003).

workability of super-plastics is to reach and give a negative charge to cement granules. As a result, cement particles separate and disperse. The dispersion of cement particles improves concrete workability. In addition, it makes concrete more flowable to the same water to the cement ratio or reduces the water content of the same (Santhanam, M ,2001)operating capacity. The latter leads to increased strength and decreased permeability.

As for pozzolanic materials, such as Silica fume, it may be found first in both types of concrete. In addition (Neville, A.M,2010).

We should differentiate between highly strength concrete and high-performance concrete The high-performance concrete is the concrete that has the properties And certain characteristics that allow it to work in a specific environment and under certain conditions. And the characteristics that distinguish High-performance concrete over other concrete may contain some of the properties of fresh concrete Such as workability, strength, or it may include some properties of hardened concrete such as resistance Abrasion, scratch or frost-strength (Samarai, M.A,1976) or shrink-strength. These properties may be separate Or, combined, give concrete that has a different performance than usual conventional concrete. And high-performance concrete is not required to be highly strength (Saco, Z,1989)

3.4.1 Material properties of high strength concrete

3.4.1.1 Coarse aggregate

It must be strong and durable because it acts as a factor that determines the maximum strength of concrete, (Tehrani, 2010) as cracks in the case of high strength concrete pass through the large particles of aggregate and not around them as in the case of conventional concrete. It has been found that concrete made of granite or dolomite has a strength of about 10-20% greater than that made of gravel (Al-Amoudi, 2002).

3.4.1.2 Fine aggregate

It should be somewhat coarse, with a fineness calibration of 2.8 to 3.0, because the mixture is rich in fine materials such as cement and silica dust, if any.

3.4.1.3 Cement

It should be of high quality and compatible with any additives used. This depends on the properties, quantities and p roportions of the rest of the ingredients and whether the mixture contains silica dust or not (Silva,2009).

3.4.1.4 Silica fume

It is a pozzolanic substance that reacts with free calcium hydroxide resulting from the reaction of cement with water, forming insoluble compounds such as calcium silicate, which works to bridge the internal gaps and capillary pores, thus increasing resistance and improving permeability (Al-Janabi,2007).

In general, the increase in pressure resistance due to the effect of silica fume may not exceed 20%. It should be noted that the optimum proportion of silica dust ranges from 10 to 15% of the weight of cement (Pheng, 2004).

3.4.1.5 Super plasticizers

It is the most important component for obtaining high-resistance concrete, whereby we can reduce the proportion of mixing water to 0.25 of the weight of cement only, and thus we can obtain the highest resistance. An investigation must be made to verify the compatibility of this material with the cement used (Yuniarto, 2008).

3.4.2 High strength concrete applications

The use of high-strength concrete has long been confined to several Classical Applications Its sole objective is to exploit the high strength value to obtain the least section area, the lowest structure size and the lowest structure weight. Therefore, these applications were limited to three main things:

- High Rise Buildings
- Bridges
- Offshore Structures

Recently, high-resistance concrete has been used in a variety of other applications, and these applications may take the name Non-Classical Applications and these applications include (Prassad, 2005):

- Nuclear Power Plants

- Underground Concrete Pipes
- Pavements
- Improving Stiffness
- High Early Strength
- Arch Girder
- Screwing Piles

3.4.3 General advantages of high strength concrete

Its compressive strength ranges from 60 to 140 nits/mm2 (7-5 times that of conventional concrete):

- The modulus of elasticity is approximately equal to two to two and a half times the modulus of elasticity of conventional concrete, which helps in reducing deflection and deformation.
- It is characterized by durability, abrasion resistance and chemical resistance.
- The resulting benefits, such as reducing sectors, increasing spaces and reducing weight (more than the increase in production costs).

One of the disadvantages of high- strength concrete is that it is more Brittleness than traditional concrete and its sudden collapse, where the fracture is through the large aggregate and not around it Figure (3.1) as in conventional concrete, and this problem can be overcome in many ways, including the use of fibers with concrete. Also, the use of high strength concrete requires a high degree of quality control and control.

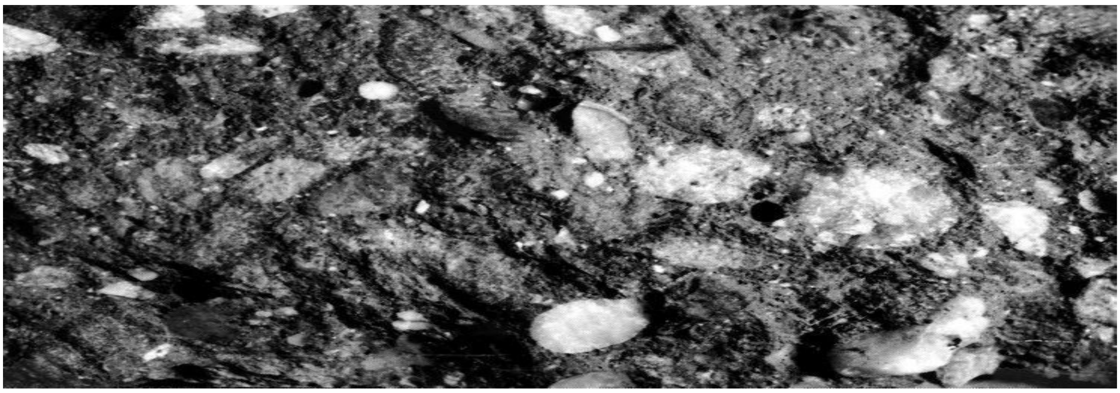


Figure 3.1: The Fracture in High Strength Concrete Passes Through the Aggregate and Not Around It

3.5 Strength of Concrete and İts Tests

Concrete strength is one of its most important other properties such as durability and impermeability. It gives a comprehensive picture of the quality of concrete and a good guide to most of its other properties.

- Mortar . Resistance
- The strength of adhesion between the mortar and the coarse aggregate.
- Resistance of coarse aggregate granules to applied stresses.

3.5.1 Types of concrete strength

- Compressive Strength
- Tensile Strength
- Flexural Strength
- Shear Strength
- Bond Strength

3.5.2 Pressure resistance check

It includes the following:

3.5.2.1 The purpose of the test

The test to determine the compressive strength of hardened concrete is usually carried out after (28) days have passed since the samples have been poured, and sometimes after (7) days or after another period as needed to know the amount of strength that causes failure of the concrete cubes.

3.5.2.2 Apparatus and device

- Molds, either a cube with a side length of (15) cm or a cylinder with a diameter of (15) cm and a height of (30) cm.
- A square-section metal stacking rod with a side length of 25 mm.
- compression testing device.

3.5.2.3 Test method

- The necessary quantities of cement, fine aggregate, coarse aggregate and water shall be weighed. When calculating the weight, it is taken into account that the amount of mixed concrete exceeds the concrete needed to fill the molds by about 15%, in order to compensate for any loss that may occur during the test.
- The test mold is prepared and the inner sides of the mold are covered with a thin layer of light oil (Prassad, 2005).
- Mix the concrete components, either mechanically or manually, well until their color becomes homogeneous.
- Once the mixing is finished, texture (drop) tests are conducted, for example, and any other tests that are required such as workability tests (compacting factor).
- After the fresh concrete tests, the mold is filled directly with concrete on 3 layers and each layer is tamped either with a vibrating machine or manually until the concrete is completely compacted without granular separation.
- The molds are covered immediately after pouring and placed at a temperature of 15 to 20 degrees Celsius for a period of 24 hours, and it is noted that they are not exposed to any vibrations.
- Concrete samples are then marked, then loosened from the molds and immediately immersed in purified water at a temperature of about 15-20 degrees Celsius and left until the time of testing. It is preferable to leave spaces between the cubes in the treatment basins (Saito, H, 2000).
- The sample is tested by placing it with the test device where its axis is in line with the axis of the head of the device. In the case of a cubic sample, the two sides of the sample touching the two surfaces of the device head must be the two faces opposite the inner surface of the metal mold to ensure their flatness and parallelism. In the case of the cylindrical sample, it is necessary to make a pillow for the surface of each end of the cylinder in such a way that the surface of the two ends are flat and parallel. Figure (3.2) shows the position of the cube and cylinder in the pressure device (Kai Yang, 2012).

Figure 3.2: Position of the Cube and Cylinder in the Pressure Device

Source: (Al-Khalaf & Nouri, 1983)

3.5.3 Tensile strength

The relationship between tensile and compressive strengths can be determined Ordinary, hardened concrete bears pressure resistance to a large extent. Therefore, concrete is designed as it primarily resists compressive stress. As for its resistance to tensile forces (whether direct or indirect), it is considered weak. However, researchers paid attention to the tensile strength (Brittle) to tensile strength when compared to its resistance to compression. This is because it is a bombshell.

3.5.3.1 Direct tensile strength

The shapes of concrete samples were developed in the direct tensile test

- Prepare samples for testing. By conducting the mixing, pouring, stacking and processing operations in the same way mentioned in the pressure test.
- The test is carried out by holding the sample at its ends with the testing machine and by applying the tensile load gradually and slowly. It determines the load causing the sample to break, as most of it breaks in the middle. The tensile strength is calculated in this case by dividing the maximum load (Pmax) by the sample cross-sectional area (A).

Direct tensile strength = $\frac{Pmax}{A}$ net/mm^2 **(3.7)**

In view of the difficulty of conducting a direct tensile test as a result of the relative difficulty in casting and loosening the test specimen, and due to the presence of concentrated pressure stresses between the clamping gratings and the test specimen, as well as the possibility of tensile load de-centralization, indirect methods are used to measure the tensile strength.

3.5.3.2 Indirect tensile strength

The standard test sample is a concrete cylinder with a diameter of 15 cm and a length of 30 cm. This cylinder is placed between the two heads of the testing machine in a horizontal position and on its sides between two strips of wood or rubber with a width of 2 cm. Acceptable for stress and also compensates for any irregularities in the surface. This compressive force results in a transverse tensile stress, which is constant along the vertical diameter, thus weighing the tensile failure along the vertical diameter of the cross section.

Indirect tensile strength $\sigma = \frac{2p}{\pi DL}$ net/mm^2 **(3.8)**

P = maximum load (net)

D = cylinder diameter (mm)

L = length of cylinder (mm)

that. The tensile strength value calculated in this way is about 15% more than the value estimated by the direct examination method. Figure (3.3) illustrates this

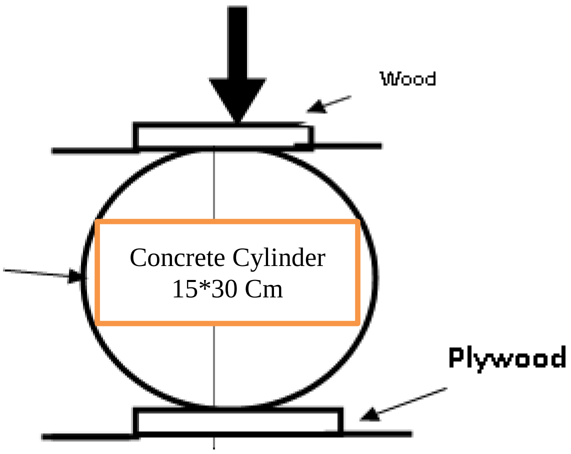


Figure 3.3: Load Arrangement of the Indirect Tensile test Model (Tighten Fission)

3.5.4 Flexural strength check

When concrete is subjected to bending, it can calculate the bending strength (which is also a measure of indirect tensile strength and is called the Modulus of Rupture). The values of the stresses of the fracture calibrator in the bend range between 12% - 20% of the compressive strength. Thus, the flexural strength exceeds the tensile strength of concrete by 60-100%, and generally the tensile strength of concrete is taken equal to 60% of the flexural strength value. The bending test is conducted to determine the strength of hardened concrete to bend and to study the behavior of concrete when subjected to bending loads, as well as the shape of the fracture resulting from the collapse of this concrete (Getting,1993).

3.5.4.1 Examination method

The concrete is placed according to its internal dimensions (15 * 15 * 70) cm or (10 * 10 * 50) cm for the aggregate whose nominal size does not exceed 20 mm. Concrete is mixed, molds filled, compacted and treated in the same way as pressure and pressure samples are made from the same concrete mixture to give an idea of the relationship between pressure and bending. The molds are placed in the testing machine on two pillars as shown in Figure (3.4). It is taken into account that both the bearing and the loading are of a length greater than the width of the beam, and the loading is gradually and at a regular rate that leads to reaching the final value of the load in a period of about 5 minutes. It is preferable to perform a bending test. Concrete is allowed to load the test threshold at two-point loading, because this makes the part of the beam in which the fracture occurs is exposed to a pure bending torque without the presence of shear in that part, which makes the fracture the result of resistance to bending only. The test results express the extent to which concrete is affected by bending, as in Figure (3.5)

The fracture stress (F_{tb}) is calculated according to the fracture site from the equation:

$$Ftb = \frac{M.y}{1} = \frac{Pmax.L}{b.d21} \quad \text{(in case of fracture in the middle third of the sample)} \qquad \textbf{(3.9)}$$

$$Ftb = \frac{M.y}{1} = \frac{3*Pmax.a}{b.d2b.d21} \; (a \leq 0.05L) \text{ in case of breakage outside} \qquad \textbf{(3.10)}$$

the middle third of the sample) effective load P

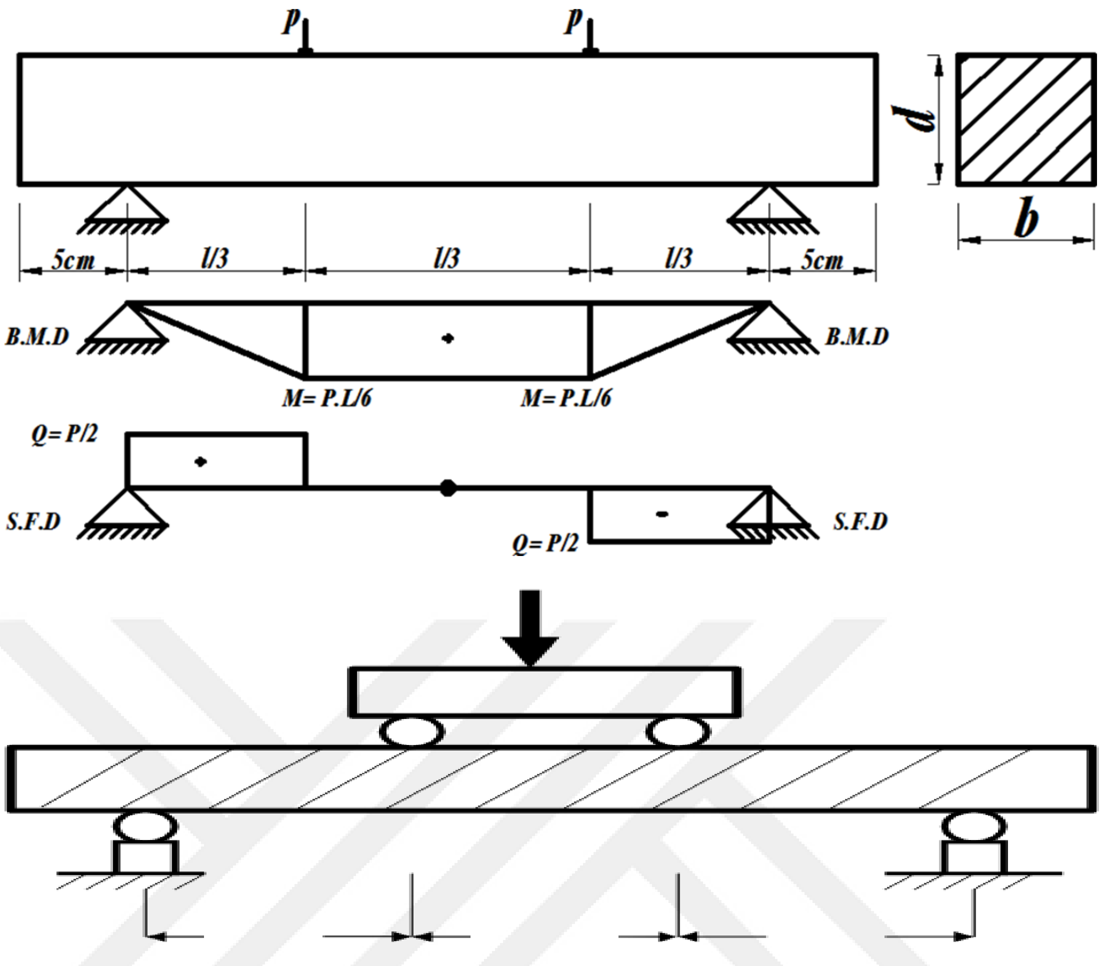


Figure 3.4: Molds are Placed in the Testing Machine on Two Pillars

Soures: Source: (Al-Khalaf & Muayyad Nouri, 1983)

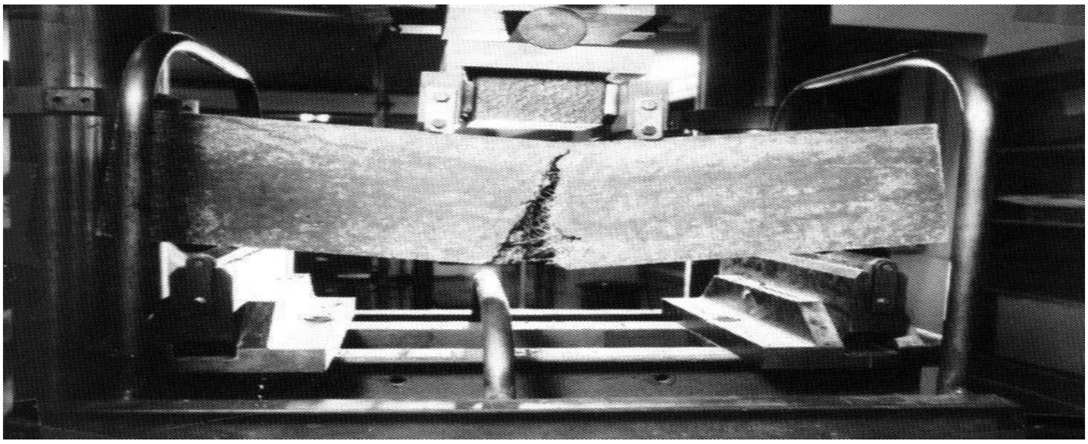


Figure 3.5: Fracture for a Bench in a Curvature Test

Source: (Al-Khalaf & Muayyad Nouri, 1983

Write down the fracture load, Pmax, and calculate the flexural strength (fracture calibrator) from the equation (ASTM C642,2006):

Fb = = $\frac{Pmax.L}{bd^2}$ net/mm^2 **(3.11)**

Pmax → Maximum total weight applied to the threshold

L → span distance

b → Threshold width

d → Threshold depth

3.6 Sulfate Attack on Concrete

The source of sulfate salts and their effect on concrete comes from two sources: the first is the external effect, which comes from sulfate salts found in soil, ground water or sea water (in this case, sulfate interacts with hardened and cohesive cement) and the second is the internal effect, which comes from sulfate salts found in materials The mixtures used in the production of concrete, such as sand and water, mainly or in very small quantities, in gravel (Geffen, 2013).

3.7 Admixtures

They are materials (other than aggregates, cement and water) that are added to the concrete mixture during the mixing process in very small quantities in order to give fresh concrete or hardened concrete certain required properties such as (Pierre,1998):

- Improved Workability Fresh Concrete.
- Accelerate the process of freezing and solidification to obtain high resistance in the early times.
- Slow down the freezing process in hot weather.
- Reducing the heat emitted by the hydration process.
- Reduce Bleeding
- Shrinkage Reduction or Equation
- Improving corrosion resistance.
- Reducing the water needed for the mixing process.
- Improved Durability
- Reducing the permeability of concrete to liquids.
- Preventing rusting of steel reinforcement immersed in concrete.

- Reducing the expansion resulting from the interaction between Alkalis present in cement and some types of active silica in aggregates.
- Increasing the bonding strength between concrete and steel reinforcement.
- Give color to concrete to be used for architectural purposes.
- Reducing the cost of concrete.
- Production of types of lightweight concrete.

What are the general conditions required when using add-ons?

General requirements required when using add-ons (Prassad, 2005)

- It must not adversely affect concrete or steel reinforcement.
- The benefits resulting from the use of additives should be commensurate with the increase in costs.
- Calcium chloride or chloride-based additives should not be added at all to reinforced concrete, prestressed concrete, or concrete containing buried minerals.
- The suitability and effectiveness of any of the additives must be confirmed by experimental mixtures.

3.8 Quality Management / The Concept of Quality

Companies have increased awareness of the need to pay attention to quality, which is one of the most important aspects that were and are still gaining great importance for companies, whether they are industrial or providing a service, as they are an important dimension of competition (critical factors for success) that enable companies to face internal challenges (Achieving efficiency and effectiveness of production processes and providing appropriate quality products/services (on the one hand and challenges outside the company (achieving and improving the competitive site compared to their counterparts from companies providing similar products/services) on the other hand, and they can be considered an integral part of the products/services, (Srinivasu,2010) as He is in the Nowadays, providing customers' requirements with the required quantity is no longer sufficient to earn his satisfaction and loyalty, and therefore it can be considered a strategy of survival. And before touching on the meaning of quality as a term, we turn to the linguistic meaning of it, which is derived from Arabic monuments, where the intermediate dictionary indicates that quality means "the good thing", and it is a source of serious action (Schroeder, 2008).

As for the convention, it can be defined according to Goran

"Suitability of the product for use",

As for Crosby, he defined it as "conforming to the requirements and affirmed that it arises from prevention and not from correction".

Or as he defined it (Sokovic, 2005) as "goods and services suitable for use". The suitability for use includes two main aspects which are product design and conformity to design (optimal design).

As for Deming, he described it as "the degree of compatibility with the customer's requirements and needs" (Srinivasu, 2010).

Visionbaum defined it as "the overall characteristics of the product that expand to include quality manufacturing, engineering, marketing and maintenance through which the company can meet customer expectations and fulfill their desires.". (Stamatis, 2004). They defined it as "a set of general characteristics and features of a product/service, which affect the latter's ability to meet the explicit and expressed (and) expressed needs and desires of customers".

As for others, it was known through several entries:

- The comprehensive approach (distinction): It is an approach that looks at quality in a very general view, as it is difficult for companies to measure/analyze quality, as they knew in this entrance that they are producing good quality products that prevent sales returns and receive complaints from customers.(Tehrani, 2010)
- The portal based on products: In this portal, quality is defined by the specifications and characteristics that the product possesses, which the customer desires, for example, the customer has a desire to pay a higher price for a car with leather seats and a disk drive system, as it is considered high quality, unlike those Missing the operating system and leather seats (Tutesigensi, 2008)
- The portal based on customers: where the quality is defined as being related to users who know the important specifications and characteristics that must

be available in the product, as this entrance is based on the definition of Juran of quality "as being appropriate to use", and based on this entrance, the definition of quality is different According to the different users and how they use the products, the producers must produce products that possess multiple elements and specifications to "suit" the different uses effectively (Society for Quality,1998).

Through this review of the definitions of quality, it can be said that there is no specific and accurate definition of quality because each has its own concept of it and everyone sees it from his point of view, so the customer sees that quality is what he desires and what he needs and features and features in the product, but the producer sees it as Methods that provide appropriate quality products to achieve customer satisfaction by achieving his desires and needs. Even customers, their points of view may differ from quality according to their different uses of the product and the different times used (Wiele, 2000).

Delegation The approach described in 2.7.2 has been followed and is based on the characteristics of the product.and The researcher believes that quality can be defined as a measure of corporate excellence by providing products/services without defects and problems.

2.9 The Origin and Development of Quality

that the interest in quality was before the industrial revolution, where the craftsman was the person who is fully responsible for the quality of the product, and that his skill and expertise is specific to the quality of the product, and later during the industrial revolution he entered the assembly line and specialized in work The production process has become more productive and more complex (Yuniarto, 2008).

After that, modern production systems appeared that were characterized by an increase in the number and size of the manufactured parts and consequently the change in assembly processes and the change in the quality of the manufactured parts became a major obstacle in production, so some measures had to be taken to prevent damage to a large batch of production due to a small number of defective parts, Accordingly, there was an urgent need to control these differences and variations and sort the defective parts, and this was the motivation that led to the creation of modern systems and methods of quality (Wiele, 1997).

As for [74] he divided the stages of quality development into seven stages that started with the responsibility of the chief of the workers for quality control during the beginning of the twentieth century, passing through the quality control phase by examination during the period (1920-1946), and the stage of quality control statistically between one year (1940) and (1960), then the stage of total quality control during the period (1960-1980), followed by the stage of total quality management during the years (1980) and the year (2010), up to the last stage, which is the stage of customer happiness, which started from the year (2010) until the present day.

3.10 The Dimensions of Quality

Dimensions of quality occupy an advanced position in the priorities of modern organizations when thinking about designing a new product or developing an old product to achieve competitive advantage and customer satisfaction and increase the percentage of its profits, especially since the dimensions of quality are an expression of the desires and preferences of customers, so the organizations for a pioneer are those organizations that are able to achieve Aligning the quality dimensions with the design of the commodity product. In other words, its product designs are distinguished by having the largest possible number of quality characteristics. The writers and specialists in the field of quality differed with regard to the number and names of properties, or the so-called quality dimensions.

Discussed the opinions of writers and researchers on quality and its dimensions, The following dimensions of the commodity product (Racine, 2005).

- Performance: It means the operational characteristics and general characteristics of the commodity
- Special Features: That is, the additional features and features that distinguish the commodity
- Reliability: It means the product's ability to perform the required work under certain operating conditions and during a specific period of time, and it also means the possibility of a product failure during a certain period of time.

- Conformance: It means the product's ability to perform the required work under certain operating conditions and during a specific period of time, and it also means the possibility of a product failure during a certain period of time.
- Durability: This is the amount of time a product will survive before it expires, deteriorates in performance, or loses its properties; it is thus a measure of the product's life.
- Serviceability: It means the possibility of modifying or repairing the product, the cost and time of repair, as well as the availability of tools, spare parts, and after-sales services.
- Aesthetics: It includes the external appearance, aesthetics, taste standards, and the feeling that the product creates in the same consumer.
- Perceived Quality: It indicates the consumer's impression and the extent of feeling confident about the product.
- The first five dimensions of quality were emphasized in the research

3.11 Quality Control

3.11.1 The concept of quality control

Recent decades have witnessed a growing trend to improve quality control processes using modern concepts and tools, such as systematic planning for the quality control process and with the participation of all and reliance on feedback to make improvements and take corrective actions by individuals (as a delegation of authority and the ability to make decisions by the workforce were relied upon) In the event of any deviations.

In Britain, activities and techniques in production-based screening were called "quality control". In America, statistical quality control was referred to as "quality control" (Pyzdek, 2003).

What is meant by quality control:

A system that maintains the required level of quality through feedback from the characteristics of the product/service, and making corrections if any deviation from the specified standard specifications is found

It is a procedure for measuring the quality of products, and the administration makes decisions if any deviation in the characteristics and specifications subject to measurement is discovered, and the goods are returned to the manufacturing processes to be repaired if they are determined to be defective, as proven by repeating the measurement process in the same operation. It is the group of technologies and activities that seek to monitor manufacturing activities in order to deliver products on time and to check products to determine their conformity with specifications and thus deliver them with specified specifications (Racine, 2005).

As defined by (Pepper, 2010) it is the process of selecting the product characteristics and specifications that correspond to the design requirements, collecting information after performing the measurement process, and with appropriate measurements and units of measurement for those characteristics to be performed, conducting a comparison with the established standards and taking the necessary procedures when there is a difference between the actual and specific product. quality control during concrete pouring include the following (Krajewski, 2018).

- Proportions of the components of concrete mixes.
- Take the necessary measures to deal with unusual circumstances such as casting hot weather, cold weather casting, underwater casting,
- The homogeneity of concrete mixes.
- Handling and pouring concrete.
- Ram the concrete
- Finishing concrete (Yuniarto, 2008).
- Preparing and pouring test samples on-site for fresh and hardened concrete. Monitor and record operating conditions at the site, its equipment, as well as weather conditions. And emergency circumstances that cause interruption or interruption of work.

Often, the strength of concrete produced on site varies from mixture to mixture and also during a single mixture. This change is due to many factors, including:

- The difference in the quality and properties of the components (cement - aggregates - water - additives).

- The change in the percentage of water in the mixture.
- The change in the steps of the concrete industry (the method of mixing - transport - casting - compaction - workmanship)
- Change in temperature or treatment process.
- Change due to errors in the manufacture of casting molds.
- Errors occur during testing (machine speed - sample eccentricity - machine not calibrated

3.11.2 Quality control tools

Ishikawa developed a tool for quality control in the eighties of the last century and was applied in Japan and widely to move then to America and Europe, and some have called them tools for improving quality and performance, which are as follows:

3.11.2.1 Pareto chart

It is a graphical representation of the problems of the process, consisting of several columns (rectangles) whose rules are the types of problems that affect the process and its height represents the occurrences of those problems and is based on a basic rule which is that (80%) of the problems belong to (20%) of the causes and vice versa, and accordingly, it helps the management and the working group to solve the few problems affecting the process (the few who influence), which is (20%) to get rid of (80%) of the problems. The Pareto principle was coined by Italian economist Valfredo Barreto, who discovered that the revolution is concentrated in the hands of a few people and used this fact to establish the Pareto principle (Heizer, 2017). The basic concept behind a Pareto analysis involves the ranking of data in descending order. The diagram may be used with or without a cumulative curve which represents the percentage sum of the vertical bars in the Pareto diagram Its only *weakness* is that the ‘vital few’ could be misleading if only the number of occurrences is analyzed without regard to costs per defect (Khudair, 2013).

3.11.2.2 Checklists

It is one of the quality improvement techniques that are used to collect and record data on the process in a simple, fast and easy way, as it shows the progress of the process in fact through the data, and therefore it is possible to know the return from the improvement process by comparing the data on the process before and after the improvement. It can be used for all data on qualities (scratches in the product, for example, or the degree of smoothness of the surfaces), or on variables, and it may be used for identifying problems and their nature, assessing the causes of their development, and assessing methods to solve them (weight or height, for example) [65] Many different formats can be used for a check sheet. One frequently used form of check sheet deals with the type of defect, another with the location of defects (Naaman, 200).

3.11.2.3 scatter diagrams

It is considered one of the tools to improve quality as it is used to analyze data on the production process in graphical ways through which the relationship between two variables affecting the process can be known (by showing the relationship between cause and effect), or the relationship between a cause and another reason for Focusing on the reasons that most affect the process and neglecting the ineffective ones or not related to the problem, and the diffusion schemes show the type of association as well if it is expulsive (positive) or reverse (negative), and also shows the degree of strength (strong or weak) (Natalya, 2003).

3.11.2.4 Cause and effect diagram

(Ishikawa Map) (Fishbone Map): Developed by the Japanese scientist Kaoru Ishikawa in 1943 One of the fundamentals of the process improvement process is identifying the root causes of the problems facing the process, and therefore it is an effective and simplified method for analyzing problems and an illustration of the reasons that affect On these problems, the effect (the problem) that is expressed in the head of the fish is determined by drawing a horizontal line and then drawing lines on its sides with the main causes of this problem and the secondary causes branch off from it. It can be used to improve the process, whether it is a manufacturing process or a service delivery process (Patel, 2007).

3.11.2.5 Flow maps (path)or flowcharts

It is a chart that shows the processes and their sequence and the steps that the product/service passes through and clarifies the main processes required to produce that product or provide that service, and clarify the bottlenecks and activities and steps that do not add value, thus determining the points that need actions Correct and has to work to improve the process (Pande, 2002).

3.11.2.6 Histogram

(Iterative distribution): it is a graphical representation of the set of data taken from a process, as it is analyzed in order to know the quality of its outputs or the detection of defects and problems in it, and it consists of columns (rectangles) whose rules represent the lengths of categories of one of the process variables and the height of iterations Corresponding to these categories (Prassad, 2005).

3.11.2.7 Quality control chart

These are illustrations that are drawn based on the results of a process, and are used to see how disciplined the production process is. It consists of an upper bound (UCL), a lower bound (LCL), and a center line (CL).

Most of these above-mentioned tools have been applied to control and imperoving the quality of concrete through the DEMENIC methodology.

DMAIC methodology: It is a methodology used to improve quality and reduce variance in the current process and is one of the elements of simplifying the production process, and the DMAIC method has been increasingly used to solve problems in several areas, including administrative, productivity, and construction to improve the consistency of operations Figure (3.6) shows the stages of the DMAIC methodology (Srinivasu, 2010).

- Define stage:

Identifying the process or product that needs improvement, this stage aims to define the scope and boundaries of the project.

- Measure stage:

This stage defines what types of data are required, how to collect it, and sources for data collection. It also includes selecting the measurement factors to be improved and providing a structure for evaluating current performance.

- Analyze stage:

Analyze the results of the measurement phase using different tools and methods to detect root causes, assess risks and analyze data

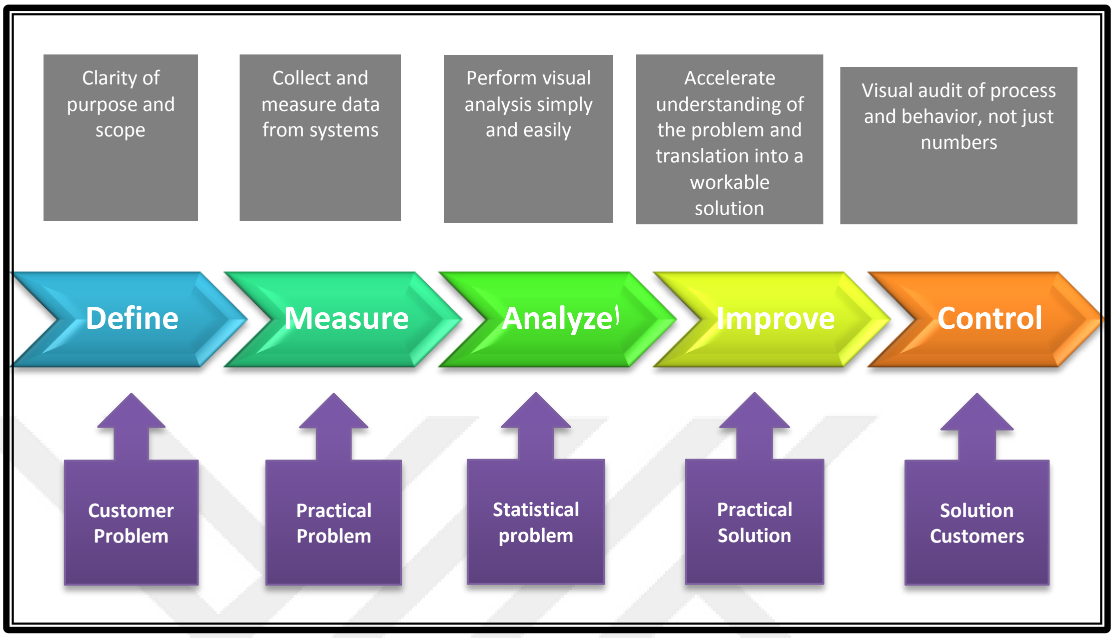


Figure 3.6: DMAIC Methodology

Source: (Geffen & Niks, 2013)

- Improve stage:

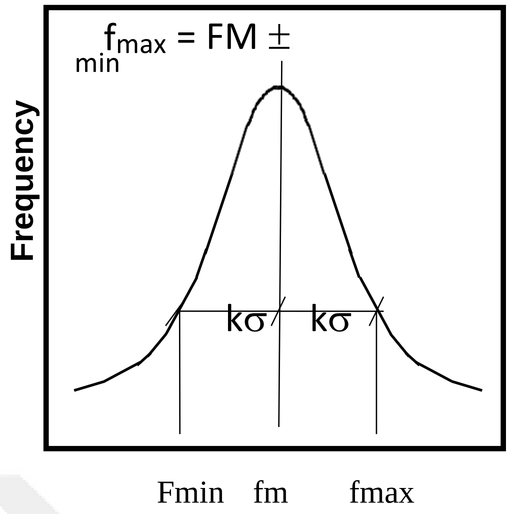
At this stage, alternative ways are searched in a creative way to do things better and faster at low cost and different approaches are used to develop a new approach and introduce statistical methods for continuous improvement

- Control stage:

It is the process of controlling process performance improvement to ensure sustainable results are achieved after implementing improvements and new procedures

3.12 Frequency distribution curves

The goal of statistically controlling concrete quality is to examine the results in order to assess the uniformity and quality of the concrete, as well as its conformance to specifications. When we have a large number of results (Pressure resistance), so it would be useful to organize the data set in the form of a frequency distribution (histogram) as in the figure (3.7),(3.8) where the horizontal axis represents the resistance value, which is (Intervals) (the vertical axis represents the number of samples(frequency) at each given resistance (Geffen, 2013).



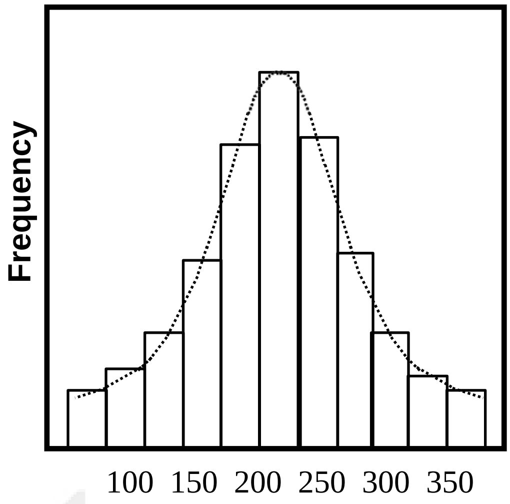


Figure 3.7: Frequency distribution curve **Figure 3.8:** Repetitive histogram

Source: (Geffen & Niks, 2013)

When the period width reaches a very small value (= 0), (the number of samples is very large = ∞) the histogram turns into a curve known as the frequency distribution curve, and when the results are on equal dimensions of the mean value and the largest number of samples are equal value of the mean, this means The samples are distributed normally, then it is known as the normal distribution curve. The characteristics of the normal distribution curve depend on the two mean values (FM) and standard deviation (σ) (Geffen, 2013).

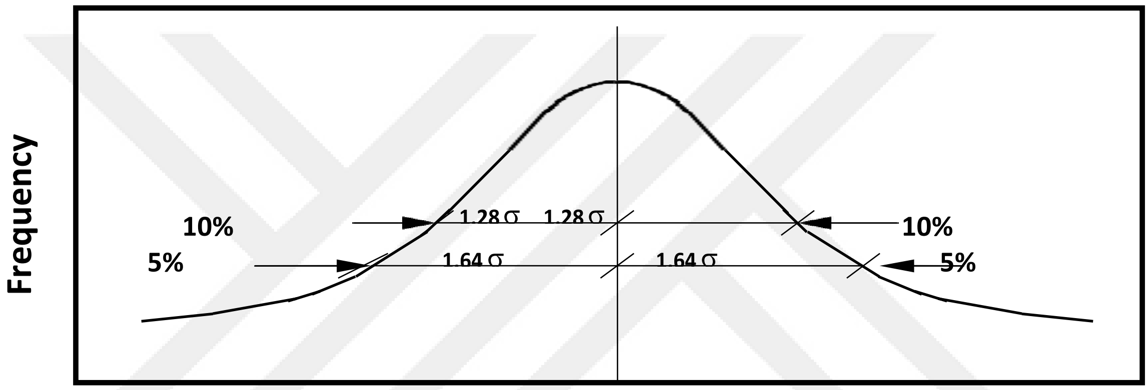
$$f_{min,max} = f\,m \pm k\sigma \qquad \textbf{(3.12)}$$

Where the k is the probability coefficient and expresses the probability of a certain resistance falling outside the boundary (FM ± k σ) and (σ) is the standard deviation, while the f m represents the mean value and the standard deviation value is defined as the root mean square of the value of the deviations, as shown in the table (2.2) and figure (2.9)

$$\sigma = \sqrt{\frac{\sum (x-\bar{x})^2}{n-1}} \quad n > 20 \quad \textbf{or} \quad \sigma = \sqrt{\frac{\sum (x-\bar{x})^2}{n}} \quad n \le 20 \qquad \textbf{(3.13)}$$

Table 3.2: Value of the Probability Factor

K	The probability of a given resistance falling outside $(f_m \pm k\ \sigma)$	The probability of a given resistance falling outside $(f_m - k\ \sigma)$
1.3	2.0 %	1%
23.2 46.1	2 % 0.1 %	1 % 5 %
82.1	0,2 %	0.1 %
0.1	8.13 %	9.51%



Compression resistance FM

Figure 3.9: Properties of the normal distribution curve

Source: (Al-Qazzaz & at al., 2009)

3.13 Quality control levels

Use the standard deviation (σ) as a measure of the degree of quality control for concrete, as the higher the standard deviation value, this indicates poor quality control and vice versa (Al-Qazzaz,2009).

Table 3.3: Levels of control over the concrete quality,according to the American Concrete Research Institute.

Degree of control	Excellent	very good	good	Is acceptable	Lousy
$KJ\ /\ cm2$	less than 28	$28 - 35$	$35 - 42$	$42 - 49$	Bigger 49

Since the value of the standard deviation depends on the value of the resistance, it is relatively large in the case of high strength concrete, it is better to use the coefficient of variation instead of (v) the standard deviation (σ) in determining the level of quality control as in Table (3.3) (Al-Qazzaz, 2009).

$$v = \sigma / f_m \tag{3.15}$$

$$f_m = f_{cu} + k\,v\,f_m \rightarrow f_{cu} = f_m\,(1-kv) \tag{3.16}$$

$$f_m = \frac{f_{cu}}{1-kv} \tag{3.17}$$

If the degree of confidence is 95%, then the value of k is 1.64

But if the degree of confidence is 90%, then the value of k is 1.28

4. EXPERIMENTAL WORK

4.1 Preamble

In construction, concrete structures are exposed, along with loads and misuse, to influences arising from the sub-layer, such as permanent mechanical stresses and groundwater. Natural or polluted groundwater has a significant impact on concrete. This can eventually lead to a loss of strength, expansion and tension of the surface layers and eventually to disintegration, so some concrete mixtures that are strength to these conditions are manufactured, including high-strength concrete and sulfate-strength concrete (Saco, 1989).

There are two sources of sulfur salts that attack hardened concrete, they are external and internal, and the external ones are found in groundwater and surface water or the soil surrounding the concrete. As for the internal ones, they are found within the structures of internal materials in concrete such as both types of aggregate, cement, water and additives. The usual sulfate salts are hydrated calcium sulfate (gypsum).With sulfates, it leads to the generation of tensile stresses in the hardened cement paste. Concrete attacked by sulfate appears whitish, and the damage usually begins at the edges and corners, followed by cracks and increased splintering that makes the concrete easy to crumble (Yuniarto, 2008) Table (4.1) shows a brief overview of the study sample

Table 4.1: Brief overview of the study sample project

project name	*Salah El Din Stadium*
Duration of the contract for the e	3 *years*
The date of commencement	8/2020
The total area	$85000m2$
construction area	40000 *m2 consisting of* 3 *stadiums and a*
Capacity	3000 *spectators*
Amount of foundation	10000 *m3*
casting type	*C*35
Casting columns type	*C*40
casting stands type	*C*35
The company implemented	*Turkish company Dka*
the beneficiary	*Ministry of Youth and Sports*
The project sponsor	*Ministry of Youth and Sports*

4.2 Materials

4.2.1 Cement

Two different concentrations of sulfate were used with ordinary Portland cement, the first with low SO3 (2%) and the second with SO3 (2.75%). Table (4.2) and Figure (4.1) , (4.2) show the chemical composition and Table (3.3) show physical properties of them.

Table 4.2: Chemical Requirements of Cement Portland / Iraq –Sulaymaniyah / Tasluja

No.	*Compound composition*	*Chemical composition*	*Weight of cement SO3 = 2.%*	*Weight of cement SO3 = 2.75%*	*IQS* 5/1984(8) (*moderate salt resistance*)
1	*Lime*	(*CaO*)	62.25	61.70	
2	*Silicon Dioxide*	*SiO2*	20.65	20.51	21
3	*Aluminum oxide*	*Al2O3*	4.91	5.99	6
4	*Ferric oxide*	*Fe2O3*	3.54	3.92	6
5	*Lime saturation factor*	*L.S.F*	0.79	0.85	1.02 − 0.66
6	*Magnesium oxide*	*Mgo*	2.71	3.12	5
7	*Sulfur trioxide*	*So3*	2.35	2.63	2.5
8	*Loss on ignition*	*L.O.I*	0.97	0.89	4

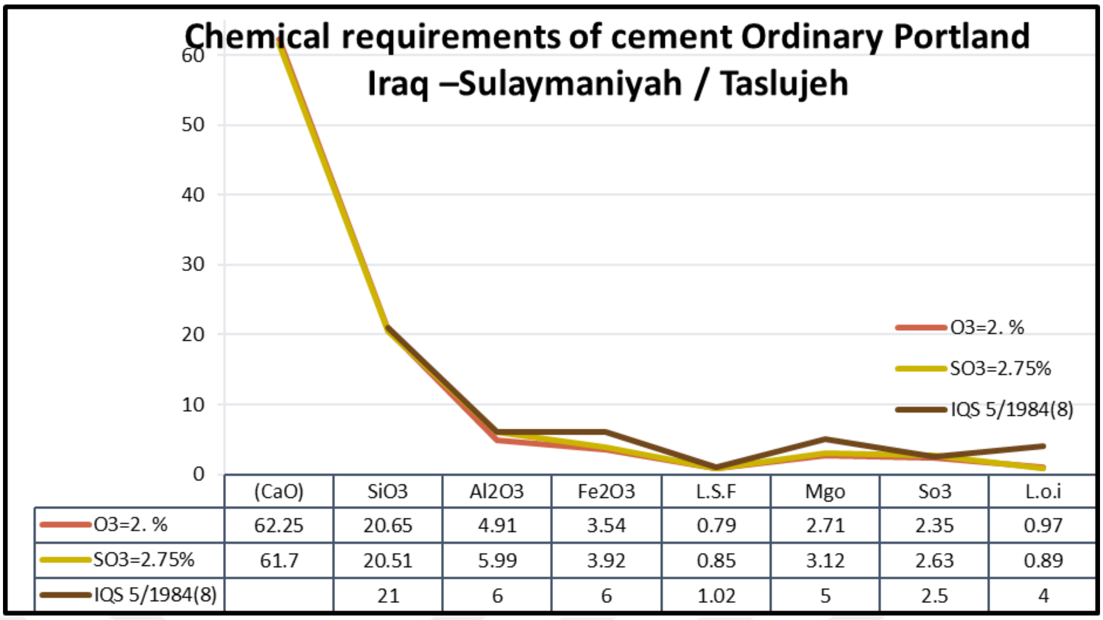


Figure 4.1: Chemical Requirements of Cement Ordinary Portland

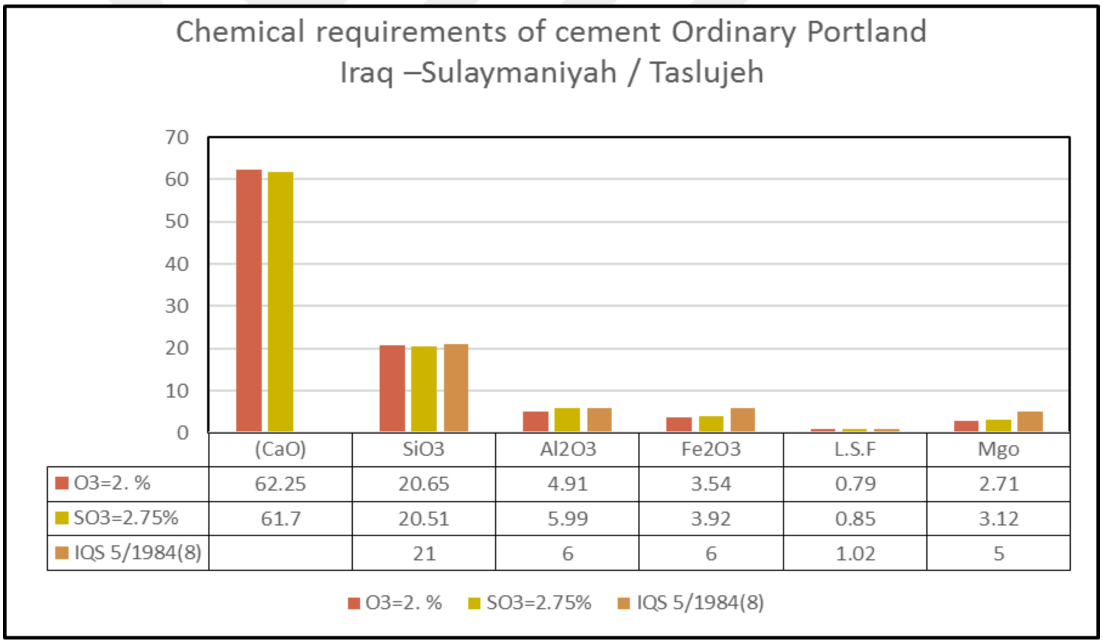


Figure 4.2: Chemicl requirements of cement Ordinary Partland

Table 4.3: Physical Adjectives of Cement Ordinary Portland Iraq –Sulaymaniyah / Taslujeh

Physical properties	Weight of cement SO3 = 2. %	Weight of cement SO3 = 2.75%	Limit of IQS 5/1984{8}
Specific surface area (Blaine method) M^2 /g	359	362	230 m2 /kg lower limit
Setting time −initial time (min) −final time (min)	100 OR 1.6 200 OR 3.3	100 OR 1.6 200 OR 3.3	Not less than 45 min Not more than 10 hrs
Compressive strength 3 − days (mpa) 7 − days (mpa)	25.2 31.5	26.2 31.9	15 Mpa lower limit 23 Mpa lower limit
Expansion by Autoclave Method %	o. 39	0,25	0.8% upper limit

4.2.2 Fine aggregate

The chemical and physical properties of cement for both types of cement are in accordance with the Iraqi specifications used in the research and as shown in Tables (4.4), (4.5) and Figure (4.3), (4.4)

Table 4.4: Physical Requirements Of Fine Aggregate Iraq –Sulaymaniyah / Tasluja

Physical properties	$SO3:\ 0.02$	$SO3:\ 0.04$	$IQS\ 45/1984(11) < 0.5$
$Material\ finer\ Than\ 0.075mm(\%)$	3.7	1.08	$IQS\ 45/1984(11) \leq 5.0$
$Specific\ gravity\ (SSD)$	2.92	2.3	$ASTM\ C\ 128 - 01\{12) *$
$Absorption\%$	2.6	1.2	$ASTM\ C\ 128 - 01\{12)$
$Dry\ loose\ unit\ weight$	1584	1589	$ASTM\ C\ 29 - 03(22)$

Table 4.5: Chemical Requirements Fine Aggregate

Sieve size (mm)	*Cumulative retained*	*Passing SO3 : 0.02*	*Cumulative retained*	*Passing SO3 : 0.04*	*Limits of IQS 45 /1984 (ZONE 3)*
10	0	100	0	100	100
4.75	5.87	94.13	8.54	91.46	90 – 100
3.36	13.75	86.25	11.91	88.09	85 – 100
1.18	37.57	62.43	19.28	80.72	75 – 100
0.6	45.58	54.42	57.88	42.12	60 – 79
0.7	85.69	14.31	69.49	30.51	12 – 40
0.15	96.49	3.51	95.88	4.12	0 – 10

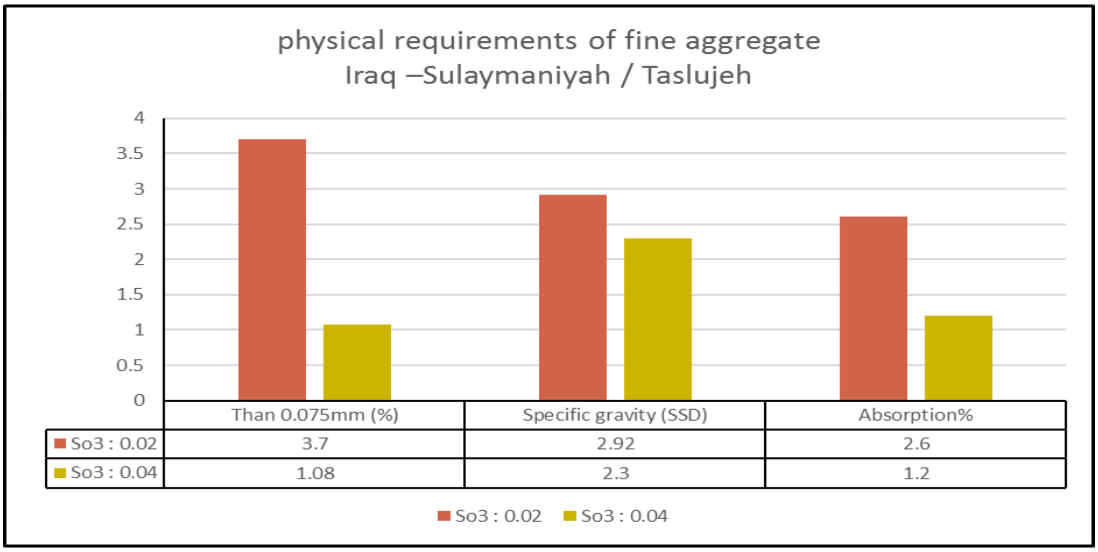


Figure 4.3: Physical requirements of fine aggregate Ira-Suleymaniyah Taslujeh

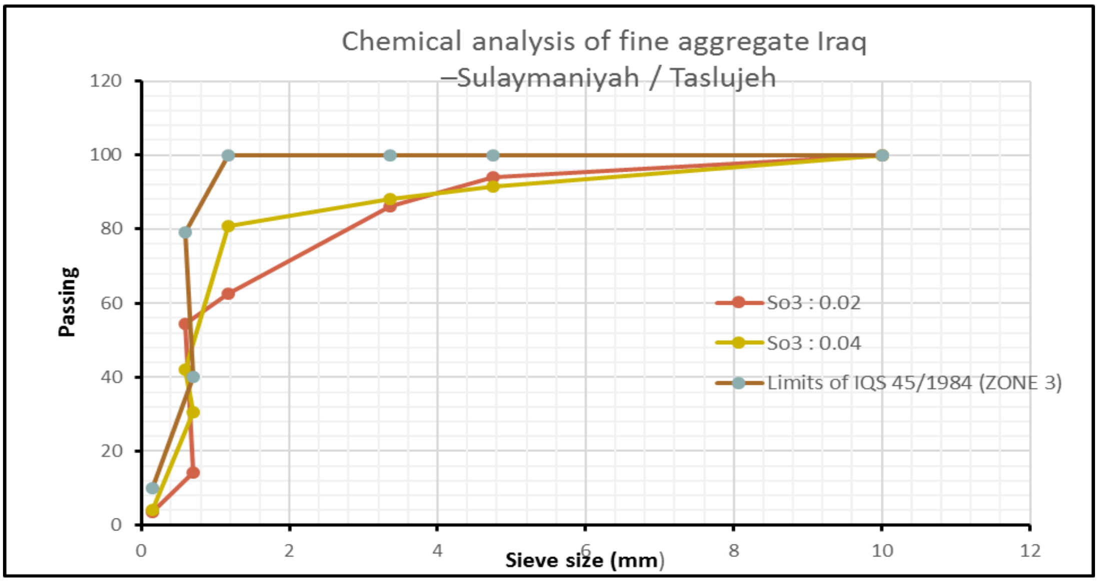


Figure 4.4: Chemical analysis of fine aggregate Iraq-Suleymaniyah/ Taslujeh

4.2.3 Coarse aggregate

The chemical and physical properties of cement for both types of cement are in accordance with the Iraqi specifications used in the research and as shown in Tables (4.6) and (4.7) and figure (4.5)

Table 4.6: Physical Properties of Coarse Aggregate Iraq –Sulaymaniyah / Taslujeh

$SO3 = 0.05\%$	$SO3 = 0.52\%$	$IRAQI\ SP.45/1984(10)$
$Specific\ gravity = 2.6$	$Specific\ gravity = 2.42$	$--$
$Absorption = 0.7$	$Absorption = 4.3$	$--$
$So3 = 0.05$	$So3 = 0.52$	$< 0.1\%$
$Dry\ rodded\ density = 1570\ kg/m^3$	$Dry\ rodded\ density = 1498\ kg/m^3$	$---$

Table 4.7: Sieve Analysis of The Coars Aggregate

$Sieve\ size\ (mm)$	$Cummulative\ coarse\ aggregate$	$Passing\ coarse\ aggregate$	$Limits\ of\ IQS\ 45/1984\ (Zone\ lll)\{11\}$
14	92.81	7.19	$90 - 100$
10	25.76	24.21	$50 - 85$
4.75	5.48	4.52	$0 - 10$

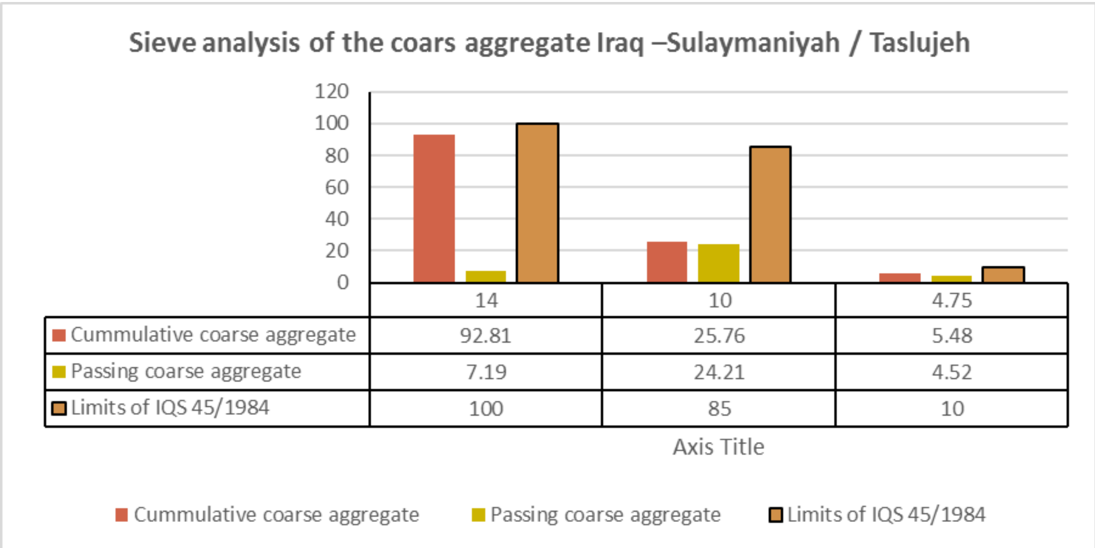


Figure 4.5: Sieve Analysis of the Coarse Aggregate Iraq-Suleymaniyah Taslujeh

4.2.4 Mixing water

Natural water was used in concrete mixtures and sample treatment.

4.2.5 High range water reducing admixture (HRWRA)

Plasticizers Figure (4.6) are used as additional materials to improve the properties of concrete and get rid of the effect of harmful substances, as they work to increase the compressive strength in the early and late ages. As in Table (4.8)

Table 4.8: Technical Explanation of Plasticizer

Properties	*Technical description*
Colour	*Light reddish yellow liquid*
Sodium oxide equivalent Na2O (gml)	1.5 >
Chloride content	*less than* 0.1 %
The value of the PH	6.5

Figure 4.6: Superplasticizer

4.3 Concrete Mix

Concrete contains aggregates, cement, and water. Concrete may also contain (additives) to improve the workability and other properties of concrete.

It was adopted (ACI 211.4R / 2008) in the design of concrete mixtures to obtain a compressive strength of (65 MPa) with a lifespan of 28 days.

The mixing ratio is determined by the mixture design technique (1: 1.44: 1.87). The mixture was screened using two percentages of SO_3 in cement (Type 1 with SO_3 content = 1.5 percent) and (Type 2 with SO_3 content = 2.77 percent). These mixtures were examined using different percentages of sulfate in fine aggregate (3.02,5.04 0.04) per cent, and coarse aggregate (0.73, 0.07) per cent, and the effect on compressive strength, flexural strength, and tensile strength. At the age of 7, 28 and 90 days. Several mix designs have been used to make concrete samples with different profiles for the sulfate content of the mixture composition. As in Table (4.9) and (4.10) the assignment is described as follows:-

m = "mix"

Reference = a reference mixture with sulfate contents as follows: cement = 1.5%, sand = 0.4%, and gravel = 0.07%.

G = increase in sulfate in gravel so that SO_3 = 0.73% (in gravel).

C = Increase in sulfate in cement so that SO_3 = 2.77 (in cement).

Sm = increase in sulfate in sand so that SO_3 = 3.2% (in sand by mixing 0.4%, 5.4%).

Sh = increase in sulfate in sand so that SO_3 = 5.4% (in sand).

Table 4.9: Blend Nomination As Sulfate Contents In Each Species

$SET\ .NO$	$SO3\ in\ CEMENT\%$	$SO3\ in\ SAND\%$	$SO3\ in\ Gravel\%$
$MRef$	1.5	0.4	0.07
MG	1.5	0.4	0.73
MC	2.77	0.4	0.07
MCG	2.77	0.4	0.73
MSm	1.5	3.2	0.07
$MSmG$	1.5	3.2	0.73
$MCSm$	2.77	3.2	0.07
$MCSmG$	2.77	3.2	0.73
MSh	1.5	5.4	$O.07$
$MCShG$	1.5	5.4	0.73
$MCSh$	2.77	5.4	0.07
$MCShG$	2.77	5.4	0.73

Table 4.10: The Combinations Used In These Experiments

$Set\ no$	$Total\ SO3\%$ *	$Total\ effective$ Mix *	$Type\ I\ cem$ kg/m^3	$Coarse\ aggreg$ $/m^3$	$Fine\ aggrega$ $/m^3$
$MReF$	2.545	2.235	513.5	960.73	737.5
MG	3.779	2.666	513.5	960.73	737.5
MC	3.295	2.985	513.5	960.73	737.5
MCG	4.529	3.416	513.5	960.73	737.5
MSm	6.577	4.178	513.5	960.73	737.5
$MSm($	7.811	4.611	513.5	960.73	737.5
$MCSm$	7.327	4.929	513.5	960.73	737.5
$MCSm$	8.561	5.361	513.5	960.73	737.5
MSh	9.745	5.776	513.5	960.73	737.5
$MShG$	10.979	6.208	513.5	960.73	737.5
$MCSh$	10.495	6.526	513.5	960.73	737.5
$MCSh$	11.729	6.958	513.5	960.73	737.5

* The calculation of total SO3% and total effective SO3% are mentioned in appendix A.

4.4 Preparation of Concrete Mixing

Use a (mixer) with a horizontal trough capacity (0.07m3) in order to ensure the homogeneity of mixing and the quality of the concrete

The mixture (0.045 m3) is sufficient for pouring 1 set (3 cubes, 3 cylinders and three beams with dimensions (150 x 200 x 1000 mm), one cube with dimensions (150 x 150 x 150 mm) and a cylinder with dimensions (150 x 300 mm) i.e. to complete) . The quantities of materials used from the aggregates are distributed and pre-packed to maintain the moisture content until the time of mixing, and samples are taken from the aggregates to measure their moisture in order to adjust the amount of water.

4.5 Measurement of Workability of Concrete

This characteristic specifies the effort required to handle a mixed quantity of concrete with minimal heterogeneity Tested according to ASTM C143 (2006). The workability of concrete directly affects the strength, quality and appearance of the casting processes, and an increase in the water-cement ratio indicates an increase in the workability of concrete. Therefore, the strength of concrete is inversely proportional to the workability of concrete. Several slack tests were performed as shown in Figure (4.7) to select the appropriate dose of HRWRA to give equal (75-100 mm) slack workability for all mixtures.

Figure 4.7: Specimen of Slump Test

4.6 Testing of Hardened Concrete

Figure (4.8) shows the types of tests for hard concrete. The researcher will focus on the destructive tests because of their great importance for high-strength concrete, and he will choose the most important of these tests, which are the compression strength test, tensile strength test and bending resistance test.

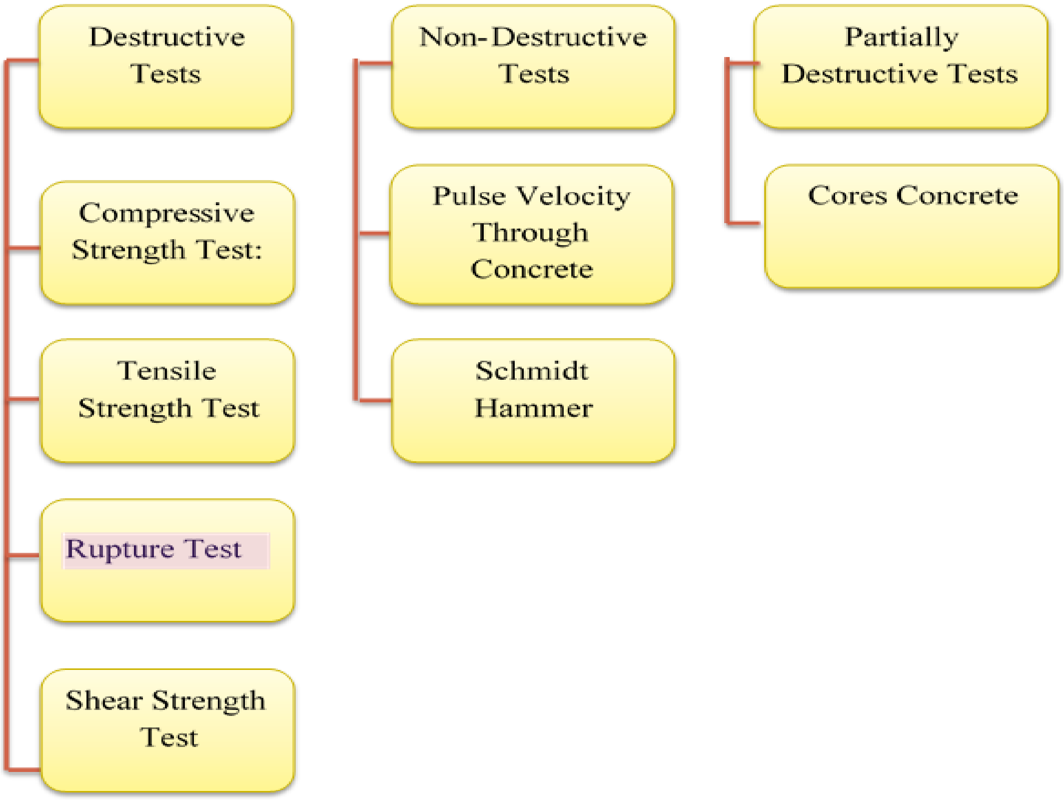


Figure 4.8: Types of Hardende Concrete Tests

4.6.1 Compressive strength test

The load is applied to two opposite sides of the cube when testing the compressive strength of the cubes according to BS. 1881 Part 116 (1989) Dimensions (150 x 150 x 150 m), loaded in uniaxial direction using an electric test machine (Wicub) with a capacity of 2500 kN and a loading speed (3 kN) per second as shown in Figure (4.9) b, The compressive strength is adopted with a lifespan of (7, 28, 90) days, calculated from the moment of mixing. Water has been added to the concrete components with the number of three cubes for each type of concrete and the neutrality of its rate and the neglect of each test result less than (90% of the average value for three cubes). The compressive strength is calculated using the following equation:

$$fcu = \frac{p}{A} \quad \textbf{(4.1)}$$

Fcu: cube compressive strength (MPa)

P: highest shed load (N)

A: Form section area (mm^3)

$$f'c = \frac{nfcu}{1.2} \quad \textbf{(4.2)}$$

f'c : Cylinder compressive strength

Figure 4.9: Compressive strength test machine

4.6.2 Bending strength test (modulus of rupture)

For bending strength, concrete prisms of (100*100*400) mm were employed. As shown in Figure (4.10), the test was performed according to ASTM C293(2006) using a (TINIUS OLSEN) testing machine, and the bending strength was computed using the formula:

$$Fr = 3PL / 2BD^2 \quad \textbf{(4.3)}$$

where:

Fr: bending strength, (MPa);

P: maximum applied load indicated by tested machine, (N);

L: average length of specimen, (mm);

B: average width of specimen, (mm);

D: average depth of specimen, (mm).

Figure 4.10: Flexural strength test Machine

4.6.3 Split tensile test

The results of the study indicated that there is a relationship between tensile strength (direct and indirect) and compressive strength. When the compressive strength increases, the tensile strength also increases, but to some extent, reaching 1-7% of the compressive strength, and this means that the concrete's resistance to pressure is greater than its tensile resistance, and therefore the relative increase in tensile strength decreases with the increase in the compressive resistance and most cracks are produced in concrete due to weak Tensile strength, there are two types of stretching or (tensile) testing. The first type is direct tension. Tensile strength tests were carried out (ASTM C 496-96), cylindrical formwork aged 28 days, furthest 300 x 150 used. This device distributes compressive strength to small width for the reason of avoiding improper stress concentration and also to compensate in case of surface irregularity.

5. DISCUSSION OF THE FINDINGS

In this chapter, we will discuss the results of the tests conducted in the third chapter, in which different percentages of sulfates (SO) were used to show the effect of those salts on the properties of high-strength concrete that were practically tested (compressive strength, direct and indirect tensile, and bending).

5.1 Concrete Mix

The American Concrete Institute blog was relied on for the amount of water in the concrete mix

(ACI 211.4R-08). Then several experimental mixtures were conducted in the laboratory by changing the water content to obtain a amount of slump of (100mm±5) in order for the mixture to have good workability.

And the same ratio of water to the binder (w/CM) was maintained for all mixtures to maintain the strength. In the mixtures with low operation, an additional amount of plasticizer is added to maintain (Superplasticizers) the slump value by an amount ranging between (75 -100mm) and it varies The added quantity is according to the need of the mixture, and the mixture was re-mixed with the addition of an amount of plasticizer in the mixtures where the amount of subsidence is not available within the specified range.

5.2 Concrete Mixing Steps

Concrete was obtained in the current study by following the following steps

1. Add half the amount of coarse aggregate (gravel) and a small percentage of water to the mixing bowl .
2. Half the amount of fine aggregate and half the amount of cement material (mix cement and silica dust before starting the mixing process) and continue the mixing process for one minute.

3. Half the amount of water and all the amount of superplasticizer is added to the mixer and the mixing continues for two minutes.
4. The remaining materials (half of the coarse aggregate, fine aggregate and half the cement material) are added, then the remaining amount of water is added and the mixing process continues for another three minutes.
5. The workability of all concrete mixes was tested by using the Slump Test on Fresh Concrete after removing it from the mixer.

5.3 Water Reduction

The addition of water-reducing agents to an extreme degree (HRWRA) It imparts positive effects to soft concrete such as increased slump without the need for an additional amount of water, and reducing the ratio of water to the binder (w/cm) to a fixed drop value, improves the workability and facilitates the pumping process of concrete.Table (5.1) and Figure (5.1).

And as it is known that the superplasticizer increases the workability of the mixture in a high way, but this increase does not last for more than (30-60 minutes) . and there are different ways to increase the survival of concrete workable, The method of adding plasticizer was used when pouring concrete (in this research). and By using the trial mixes, we obtained the optimum dosage of HRWRA required to attain maximum water reduction (29) % it is (1.1) % by weight of cement . and the concrete mixes were designed based on adding High-Range Water-Reducing Admixture HRWRA to achieve the required slump (75 - 100 mm) as a selected slump for all mixes. HRWRA can be used in concrete to increase slump and strength by decreasing water demand , According to ACI 211.4R (2008) on mix design

Table 5.1: Quantity on water reduction in concrete mix.

$Quantity\ of\ HRWRA$ $(\%)\ by\ wt.of\ cement$	$W/C\ ratio\ with\ slump\ of\ (75-100)\ mm$	$Water\ reduction\ (\%)$	$slump\ of\ (75-100)\ mm$
1	0.355	22	121
1.2	0.32	27	107
1.1	0.30	29	98
1.15	0.32	26	110
1.25	0.31	28	105
1.3	0.32	23	119
1.03	0.32	25	114
1.05	0.34	24	115

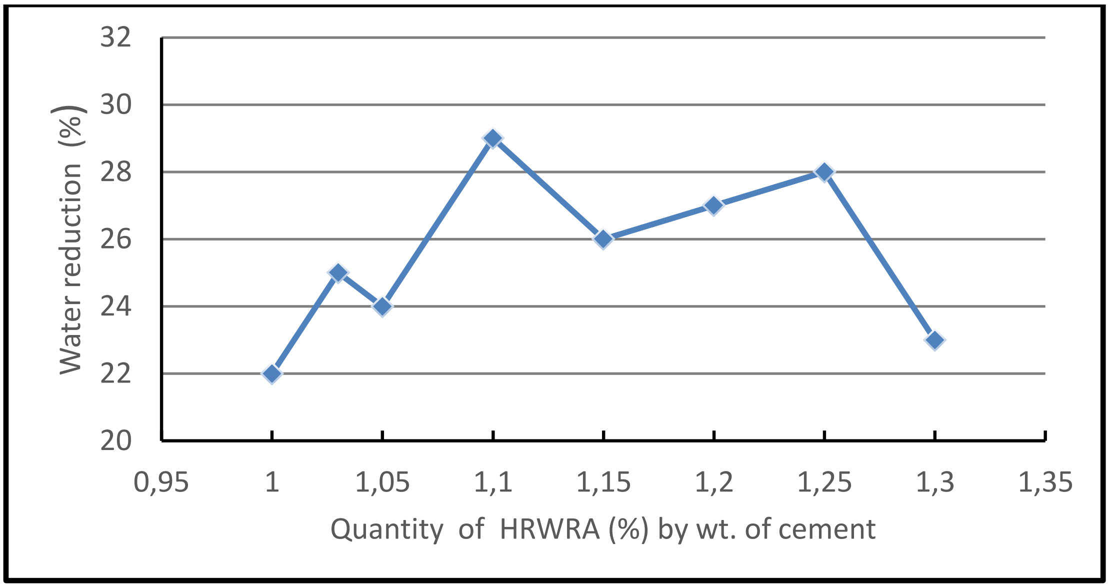


Figure 5.1: Effect of HRWRA dosage on water reduction of consrete

5.4 Casting & Curing

The models were cast using iron molds designated for this purpose and cleaned The molds were well coated and lightly painted with oil before pouring to avoid the hardened concrete adhesion to the inner surface of the molds. All molds are filled with three layers, and each layer is stacked using a metal rod (with a diameter of 22 mm) according to (British Standard Bs 1:881 Part 3:1983), which requires that the thickness of one layer be (50 mm). Then the models are settled and the molds are covered with a layer of nylon for 24 hours to prevent water evaporation, then the molds are opened and the models are placed for 28 days in water in the treatment basins

5.5 Compressive Strength

Table (5.2) displays the compressive strength values for all concrete mixes, which are listed in order of increasing total effective SO_3 percent and decreasing total effective SO_3 percent. Figures (5.2) and (5.3) depict the relationship between total effective SO_3 percent and total SO_3 percent with compressive strength decline as a function of age. The action of sulfate is seen in Figures (5.4) to (5.11).

Murf, MG, MC, MCG, MSM, MSmG, MCSm, MCSmG, MSH, MShG, MCSh, MCShG are among the mixes.

The results show that as the sulfate concentration in cement, sand, and gravel increases with age, the compressive strength falls. For all mixes at all ages of testing, a rise in total SO_3 percent and total effective SO_3 percent corresponds to a modest increase in compressive strength results. The following is how to mix findings can be explained:

The decrease in compressive strength for mix (MG), which contained SO_3 of (1.5,0.4,0.73) percent for cement, sand, and gravel respectively, appears early in the test and continues to the end; the reduction is (5.29,6.05, 8.1) percent at (7,28,90) days compared to the reference mix, which contained SO3 of (1.5,.0.4,0.07) percent.

For the cement mix (MC), which included SO_3 percent (2.77,0.4,0.07), gravel, and sand The drop in compressive strength begins at a young age and continues until the end of the test; the reduction is (7.48, 11.13, 12.2) percent at (7,28,90) days, compared to the reference mix, which contained SO_3 at (1.5, 0.4,0.7) percent. The table shows the other compressive strength reduction values (5.3).

Table 5.2: Compressive Strength Results For All Mixes At Different Ages

item	*Set No.*	*Total SO3% Of Mixes*	*Total effective SO3% of Mixes*	*Compressive strength (MPA)*		
				7 days.	**28 days.**	**90 days.**
1	*MRef*	2.545	2.235	50.44	60.56	70.56
2	*MG*	3.779	2.666	47.2	56.18	64.5
3	*MC*	3.295	2.985	44.52	51.85	60.15
4	*MCG*	4.529	3.416	42.21	49.02	58.17
5	*MSm*	6.577	4.178	40.13	47.89	55.64
6	*MSmG*	7.811	4.611	38.2	45.68	53.08
7	*MCSm*	7.327	4.929	35.97	43.47	50.52
8	*MCSmG*	8.561	5.361	34.5	41.4	48.02
9	*MSh*	9.745	5.776	32.3	38.07	44.27
10	*MShG*	10.979	6.208	30.25	36.28	41.04
11	*MCSh*	10.495	6.526	29.17	34.36	39.55
12	*MCShG*	11.729	6.958	28.03	33.23	38.48

For mix (MG), which contained SO_3 of (1.5,0.4,0.73) % for cement , sand and gravel respectively.

According to Table (5.3), the rise in total effective sulfate content, rather than the total sulfate in the mix, influences the decline in compressive strength of concrete. As the total sulfates in a mix are increased by 11.729 percent, the short and final age concrete strength are reduced by 40% and 42%, respectively, when compared to the reference concrete with a total effective sulfate of 0. (2.24 percent).

Table 5.3: Reduction in compressive strength results for all mixes at different ages

Set No.	*Total SO3% of Mixes*	*Total effective SO3% of Mixes*	***Reduction in compressive strength*** (%)		
			7 days.	***28 days.***	***90 days.***
MG	3.779	2.666	5.29	6.05	8.1
MC	3.295	2.985	7.48	11.13	12.2
MCG	4.529	3.416	12.66	15.93	14.81
MSm	6.577	4.178	14.89	16.63	16.82
MSmG	7.811	4.611	18.57	18.96	20.92
MCSm	7.327	4.929	23.06	23.45	23.90
MCSmG	8.561	5.361	26.12	27.42	28.22
MSh	9.745	5.776	29.88	32.31	32.8
MShG	10.979	6.208	32.78	34.21	36.21
MCSh	10.495	6.526	35.98	38.09	38.98
MCShG	11.729	6.958	40.05	41.36	43.11

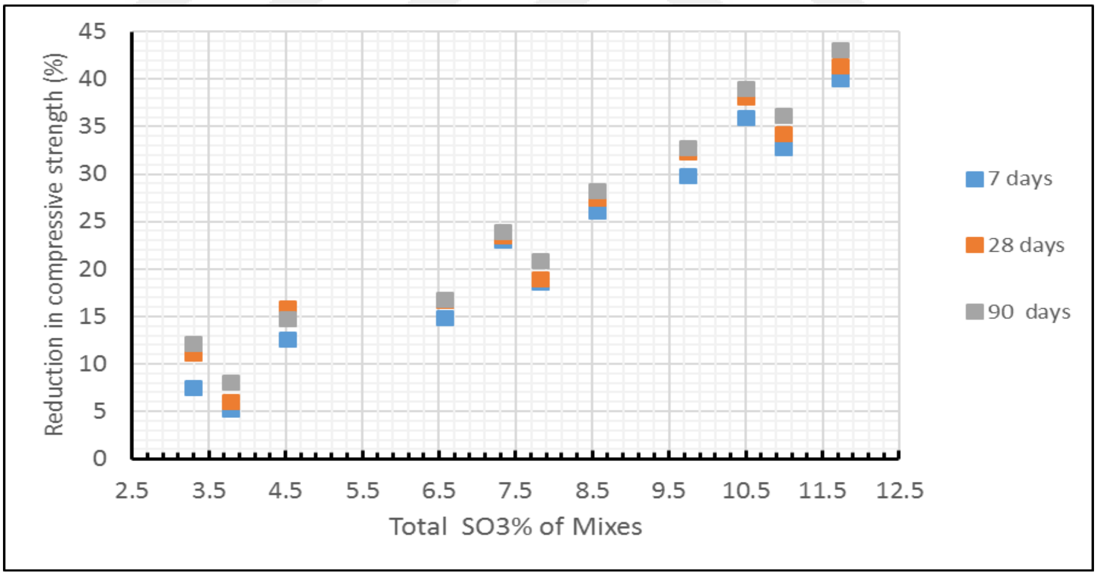


Figure 5.2: Raletion Between Total Effective SO_3 % and Reduction in Compressive Strength at Different Ages

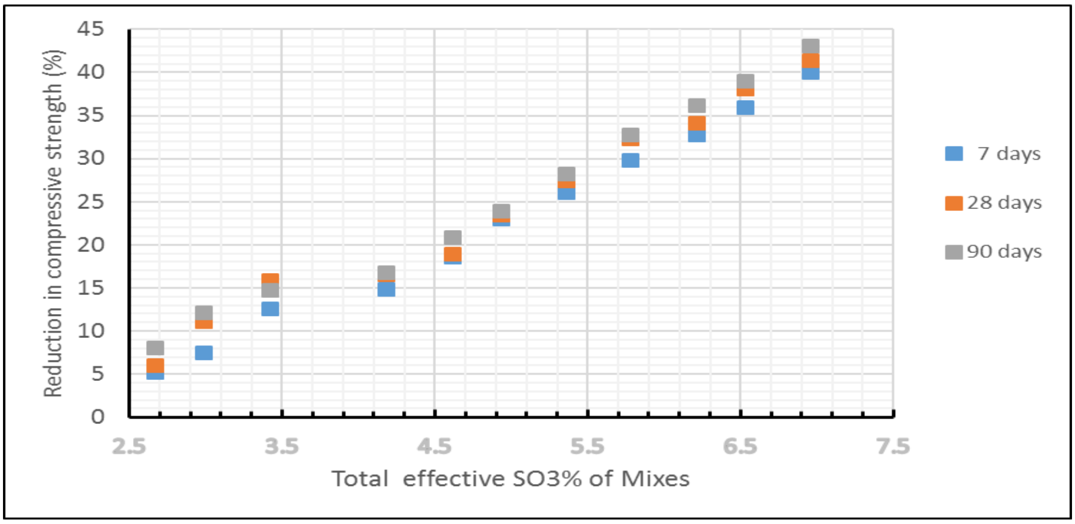


Figure 5.3: Raletion Between Total Effective SO_3 % and Reduction in Compressive Strength at Different Ages

Table 5.4: Effect of Sulphate Content in Cement (%2) on Compressive Strength at Different Ages

item	Set No.	Total SO3% Of Mixes	Total effective SO3% of Mixes	Compressive strength		
				7 days.	28 days.	90 days.
1	*MRef*	2.545	2.235	50.44	60.56	70.56
2	*MG*	3.779	2.666	47.2	56.18	64.5
5	*MSm*	6.577	4.178	40.13	47.89	55.64
6	*MSmG*	7.811	4.611	38.2	45.68	53.08
9	*MSh*	9.745	5.776	32.3	38.07	44.27
10	*MShG*	10.979	6.208	30.25	36.28	41.04

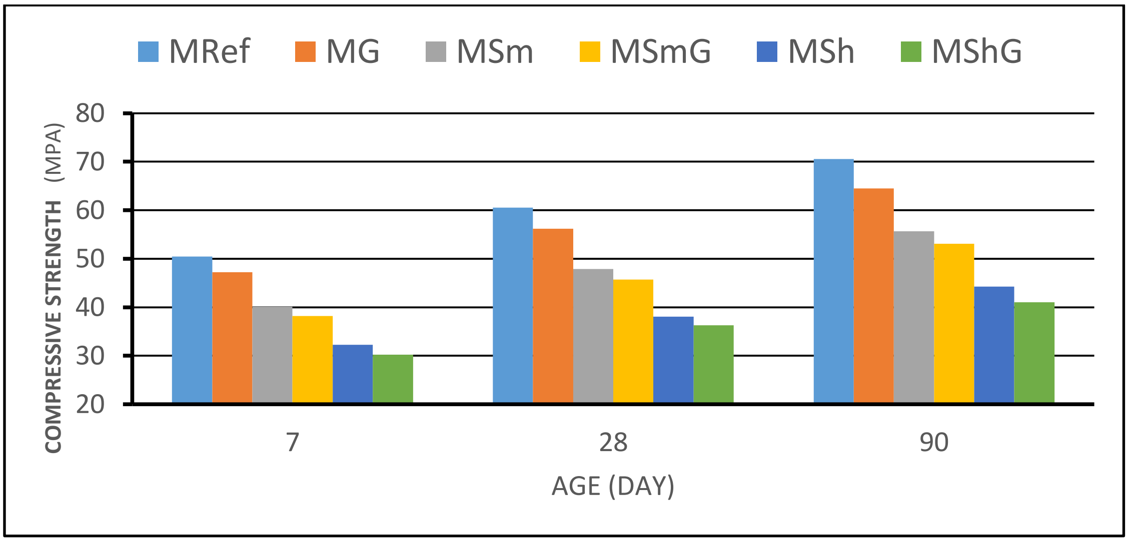


Figure 5.4: Effect of Sulphate Content in Cement (%2) on Compressive Strength at Different Ages

Table 5.5: Effect of Sulphate Content in Cement (2.75 %) on Compressive Strength At Different Ages

item	*Set No.*	*Total SO3% Of Mixes*	*Total effective SO3% of Mixes*	*Compressive strength*		
				7 days.	*28 days.*	*90 days.*
1	*MRef*	2.545	2.235	50.44	60.56	70.56
3	*MC*	3.295	2.985	44.52	51.85	60.15
4	*MCG*	4.529	3.416	42.21	49.02	58.17
7	*MCSm*	7.327	4.929	35.97	43.47	50.52
8	*MCSmG*	8.561	5.361	34.5	41.4	48.02
11	*MCSh*	10.495	6.526	29.17	34.36	39.55
12	*MCShG*	11.729	6.958	28.03	33.23	38.48

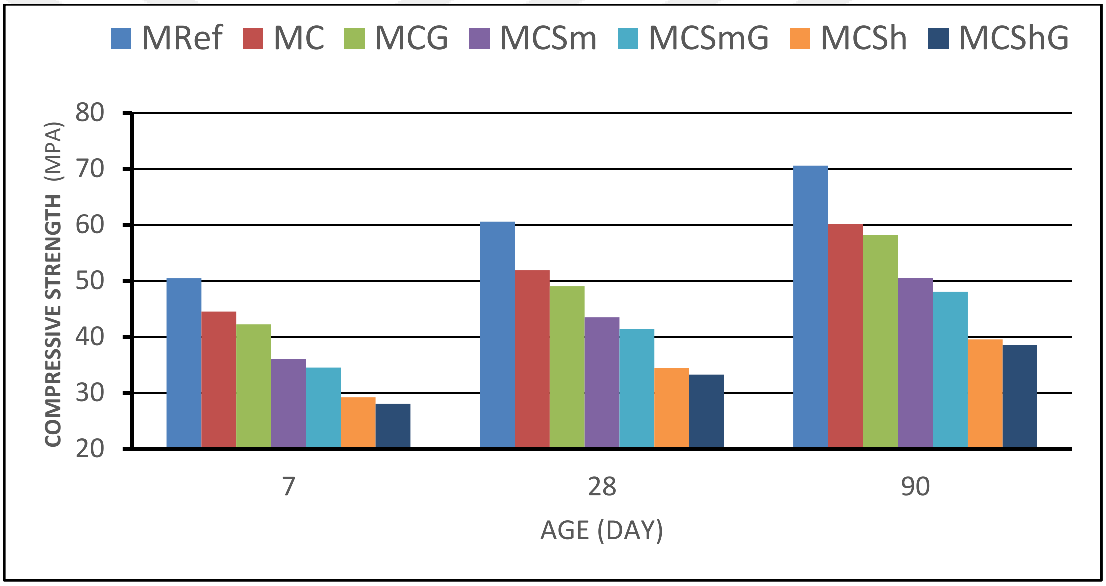


Figure 5.5: Effect of Sulphate Content in Cement (2.75 %) on Compressive Strength At Different Ages

Table 5.6: Effect of Sulphate Content In Fine Aggregate (0.3%) On Compressive Strength At Different Ages

item	**Set No.**	**Total SO3% Of Mixes**	**Total effective SO3% of Mixes**	**Compressive strength**		
				7 days.	**28 days.**	**90 days.**
1	MRef	2.545	2.235	50.44	60.56	70.56
2	MG	3.779	2.666	47.2	56.18	64.5
3	MC	3.295	2.985	44.52	51.85	60.15
4	MCG	4.529	3.416	42.21	49.02	58.17

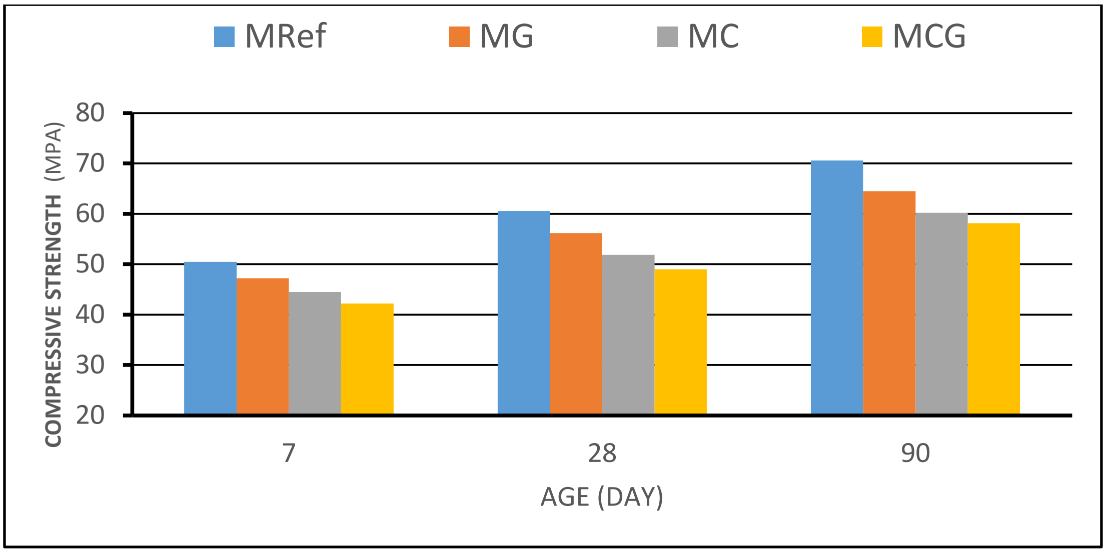


Figure 5.6: Effect of Sulphate Content In Fine Aggregate (0.3%) On Compressive Strength At Different Ages

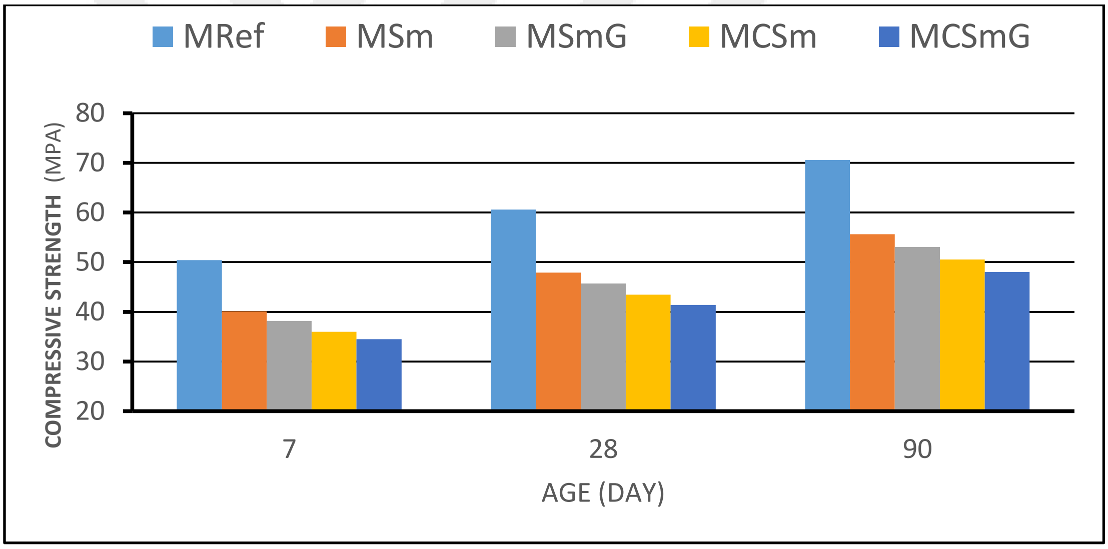


Figure 5.7: Effect of Sulphate Content in Fine Aggregate (3.1%) on Compressive Strength at All Ages

Table 5.7: Effect of Sulphate Content in Fine Aggregate (3.1%) on Compressive Strength at All Ages

item	Set No.	Total SO3% Of Mixes	Total effective SO3% of Mixes	Compressive strength		
				7 days.	28 days.	90 days.
1	MRef	2.545	2.235	50.44	60.56	70.56
5	MSm	6.577	4.178	40.13	47.89	55.64
6	MSmG	7.811	4.611	38.2	45.68	53.08
7	MCSm	7.327	4.929	35.97	43.47	50.52
8	MCSmG	8.561	5.361	34.5	41.4	48.02

Table 5 8: Effect of Sulphate Content In Fine Aggregate (5.3%) On Compressive Strength All Ages

item	***Set No.***	***Total SO3% Of Mixes***	***Total effective SO3% of Mixes***	***Compressive strength***		
				7 days.	***28 days.***	***90 days.***
1	*MRef*	2.545	2.235	50.44	60.56	70.56
9	*MSh*	9.745	5.776	32.3	38.07	44.27
10	*MShG*	10.979	6.208	30.25	36.28	41.04
11	*MCSh*	10.495	6.526	29.17	34.36	39.55
12	*MCShG*	11.729	6.958	28.03	33.23	38.48

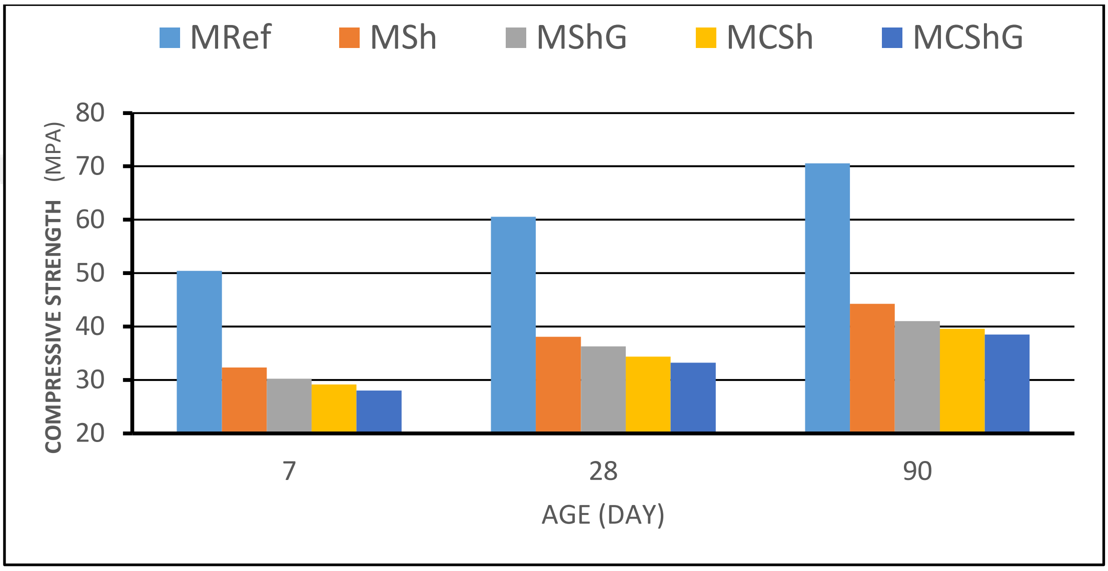


Figure 5.8: Effect of Sulphate Content In Fine Aggregate (5.3%) On Compressive Strength All Ages

Table 5.9: : Effect of Sulphate Content In Fine Aggregate (0.06%) On Compressive Strength All Ages

item	***Set No.***	***Total SO3% Of Mixes***	***Total effective SO3% of Mixes***	***Compressive strength***		
				7 days.	***28 days.***	***90 days.***
1	*MRef*	2.545	2.235	50.44	60.56	70.56
3	*MC*	3.295	2.985	44.52	51.85	60.15
5	*MSm*	6.577	4.178	40.13	47.89	55.64
7	*MCSm*	7.327	4.929	35.97	43.47	50.52
9	*MSh*	9.745	5.776	32.3	38.07	44.27
11	*MCSh*	10.495	6.526	29.17	34.36	39.55

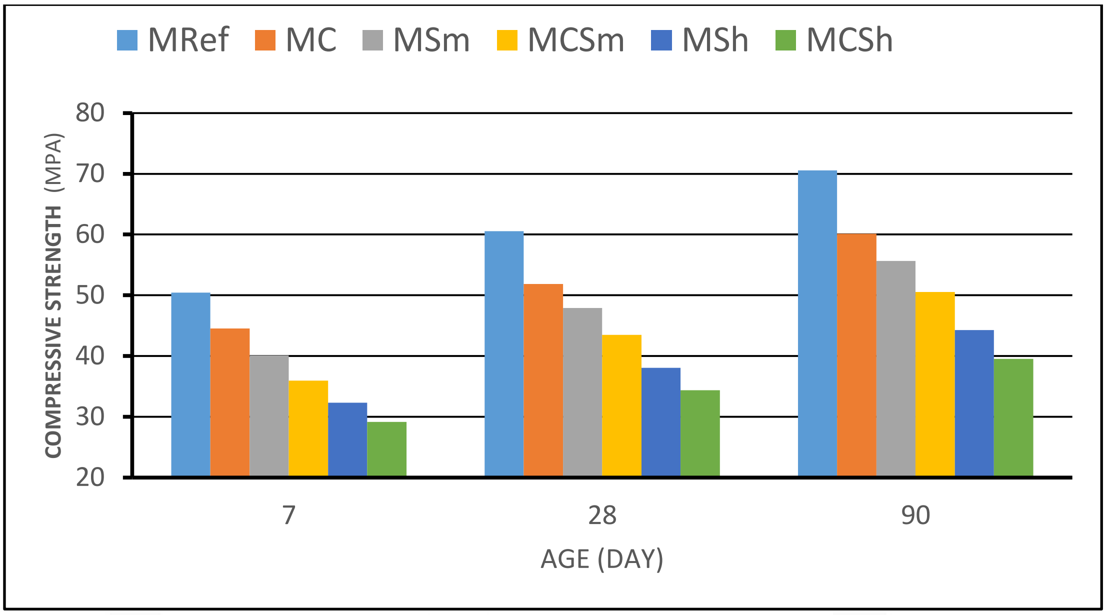


Figure 5.9: Effect of Sulphate Content In Fine Aggregate (0.06%) On Compressive Strength All Ages

Table 5.10: Effect of Sulfate Content in Coarse Aggregate (0.72%) on Compressive Strength At Different Age

item	*Set No.*	*Total SO3% Of Mixes*	*Total effective SO3% of Mixes*	*Compressive strength*		
				7 days.	*28 days.*	*90 days.*
1	*MRef*	2.545	2.235	50.44	60.56	70.56
2	*MG*	3.779	2.666	47.2	56.18	64.5
4	*MCG*	4.529	3.416	42.21	49.02	58.17
6	*MSmG*	7.811	4.611	38.2	45.68	53.08
8	*MCSmG*	8.561	5.361	34.5	41.4	48.02
10	*MShG*	10.979	6.208	30.25	36.28	41.04
12	*MCShG*	11.729	6.958	28.03	33.23	38.48

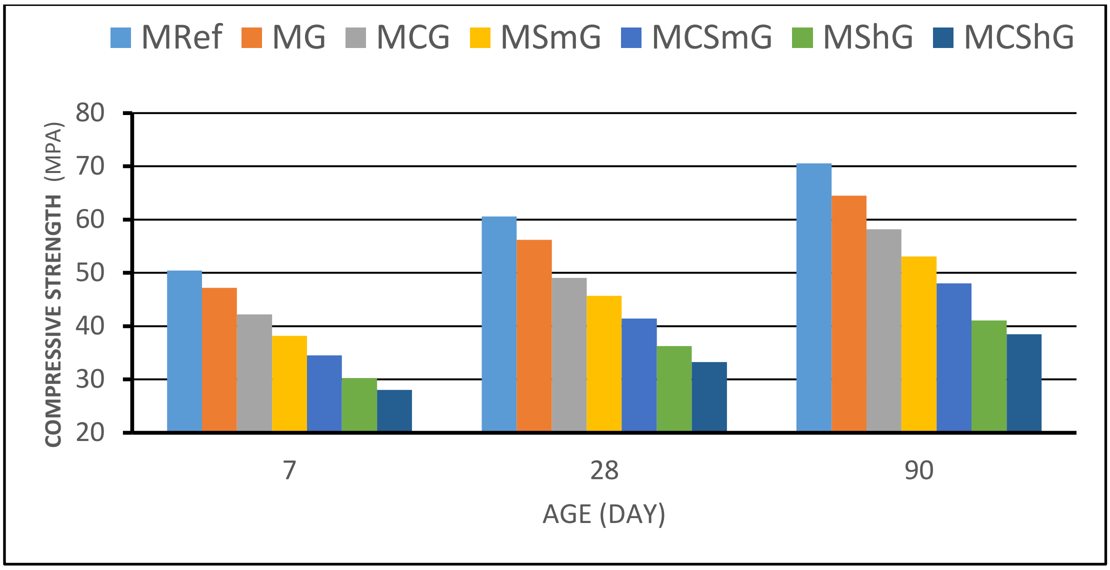


Figure 5.10: Effect of Sulfate Content in Coarse Aggregate (0.72%) on Compressive Strength At Different Age

Table 5.11: Effect of Total Effective SO_3% Sulphate Content On Compressive Strength At Different Ages

item	Set No.	Total SO3% Of Mixes	Total effective SO3% of Mixes	Compressive strength		
				7 days.	28 days.	90 days.
1	*MRef*	2.545	2.235	50.44	60.56	70.56
2	*MG*	3.779	2.666	47.2	56.18	64.5
3	*MC*	3.295	2.985	44.52	51.85	60.15
4	*MCG*	4.529	3.416	42.21	49.02	58.17
5	*MSm*	6.577	4.178	40.13	47.89	55.64
6	*MSmG*	7.811	4.611	38.2	45.68	53.08
7	*MCSm*	7.327	4.929	35.97	43.47	50.52
8	*MCSmG*	8.561	5.361	34.5	41.4	48.02
9	*MSh*	9.745	5.776	32.3	38.07	44.27
10	*MShG*	10.979	6.208	30.25	36.28	41.04
11	*MCSh*	10.495	6.526	29.17	34.36	39.55
12	*MCShG*	11.729	6.958	28.03	33.23	38.48

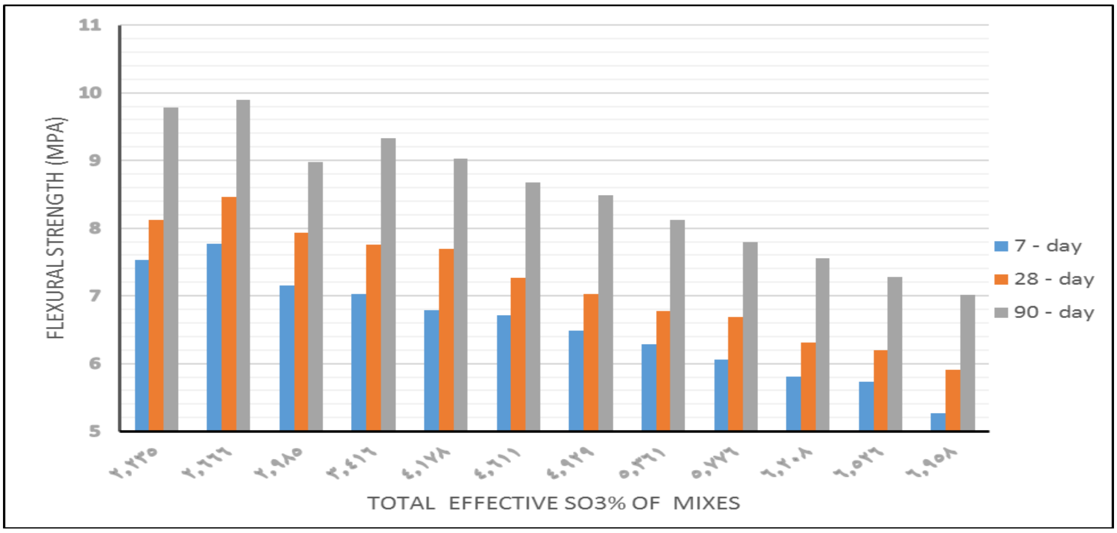


Figure 5.11: Effect of Total Effective SO_3% Sulphate Content On Compressive Strength At Different Ages

5.6 Flexural Strength

The results shown in Table (4.4) and Figures (4.12) and (4.13) indicate a decrease in the flexural strength with an increase in the total sulfate content SO_3 % and total effective sulfate SO_3 % in cement, sand and gravel for all mixtures at all ages of the test. Figures (4.14) to (4.21) also show the effect of the presence of sulfate in the concrete mix on the flexural strength. The results of the mixtures for different ages are explained as follows:

- The decrease in the flexural strength of the mixture (MG), which contains SO_3% (2,0.3,0.72) for cement, sand and gravel respectively, appears at an early age and continues until the final test life, and the decrease is at a rate of (3.21,4.01, 5.65%) for ages (7,28,90) days in a row compared to the reference mixture containing SO_3 (2,0.3,0.06)%.
- The decrease in bending resistance appears at an early age and continues until the final test life of the mixture (MC), which contains SO_3% (2.75,0.3,0.06) for cement, sand and gravel, respectively, and the decrease is at a rate of (4.55, 7.32, 7.99)% for ages (7,28,90) days in a row compared to the reference mixture containing SO_3 (2,0.3,0.06)%.
- Results of the examination results for the flexural strength shown in Table (4.5) indicate that the decrease in the early ages of concrete ranges from (3%) to (28%) as for as The total effective sulfate content gives good behavior with low bending strength other than the total sulfate content, and the reason for

this is due to the effect of sulfate which is related to the size of the gypsum particles in the concrete components, when the grain size increases, the effectiveness decreases due to the increase in the fineness modulus of the particles. This is evident from the figures below.

We can conclude that the effect of sulfate on flexural strength is the same as its effect on compressive strength due to active sulfate, which weakens the bond between aggregate and paste and thus causes concrete failure.

Table 5.12: Flexural Strength Results For All Mixes At Different Ages

Set No.	*Total SO3% of Mixes*	*Total effective SO3% of Mixes*	*Flexural strength (Mpa)*		
			7 days.	*28 days.*	*90 days.*
MRef	2.545	2.235	7.53	8.12	9.78
MG	3.779	2.666	7.77	8.46	9.89
MC	3.295	2.985	7.15	7.93	8.97
MCG	4.529	3.416	7.03	7.76	9.33
MSm	6.577	4.178	6.79	7.69	9.03
MSmG	7.811	4.611	6.71	7.27	8.68
MCSm	7.327	4.929	6.49	7.03	8.49
MCSmG	8.561	5.361	6.29	6.77	8.12
MSh	9.745	5.776	6.06	6.69	7.79
MShG	10.979	6.208	5.81	6.31	7.55
MCSh	10.495	6.526	5.73	6.2	7.28
MCShG	11.729	6.958	5.27	5.91	7.01

Table 5.13: Reduction in Flexural Strength Results For All Mixes At Different Ages

Set No.	*Total SO3% o Mixes*	*Total effecti SO3% of Mixes*	*Reduction in l strength (%)*		
			7 days.	*28 days.*	*ys.*
MG	3.779	2.666	3.23	4.02	5.67
MC	3.295	2.985	4.58	7.36	7.98
MCG	4.529	3.416	6.04	8.19	9.18
MSm	6.577	4.178	7.78	9.36	12.08
MSmG	7.811	4.611	9.93	14.31	15.51
MCSm	7.327	4.929	13.1	17.14	17.47
MCSmG	8.561	5.361	15.41	19.97	20.98
MSh	9.745	5.776	19.03	21.86	24.19
MShG	10.979	6.208	21.72	25.77	26.63
MCSh	10.495	6.526	23.72	27.05	29.26
MCShG	11.729	6.958	28.41	24.76	31.61

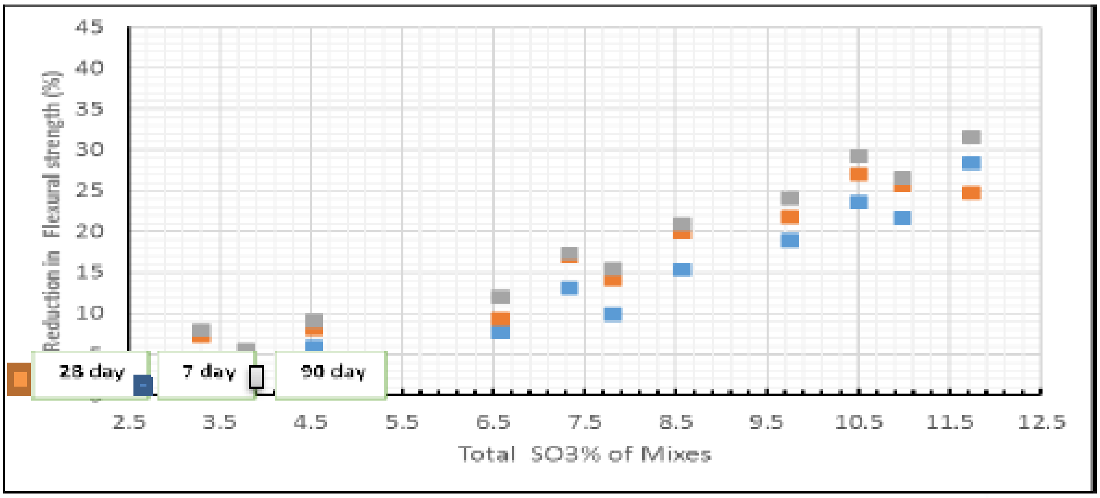


Figure 5.12: Realtion Between Total Effective SO_3% and Reduction In Flexural Strength at Different Ages

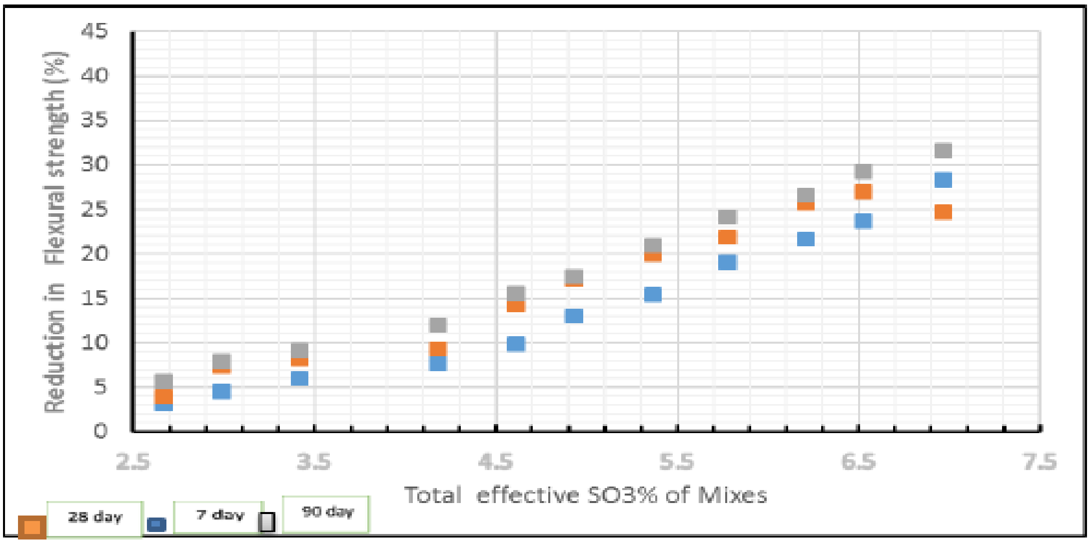


Figure 5.13: Realtion Between Total Effective SO_3% and Reduction In Flexural Strength at Different Ages

Table 5.14: Effect of Sulphate Content in Cement (2%) on Flexural Strength At Different Ages

itm	*Set No.*	*Total SO3% of Mixes*	*Total effective SO3% of Mixes*	*Flexural strength (Mpa)*		
				7 days.	*28 days.*	*90 days.*
1	*MRef*	2.545	2.235	7.53	8.12	9.78
2	*MG*	3.779	2.666	7.77	8.46	9.89
5	*MSm*	6.577	4.178	6.79	7.69	9.03
6	*MSmG*	7.811	4.611	6.71	7.27	8.68
9	*MSh*	9.745	5.776	6.06	6.69	7.79
10	*MShG*	10.979	6.208	5.81	6.31	7.55

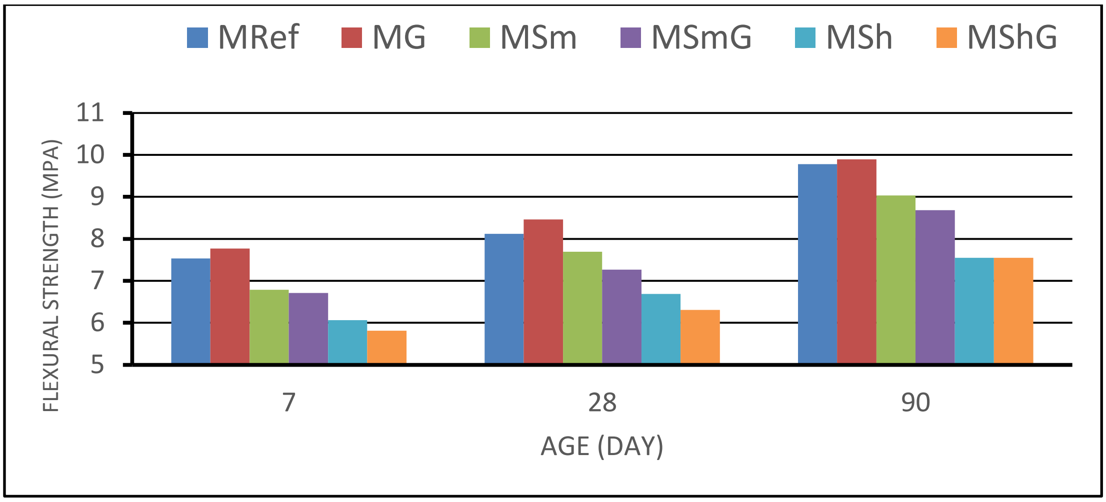


Figure 5.14: Effect of Sulphate Content in Cement (2%) on Flexural Strength At Different Ages

Table 5.15: Effect of Sulphate Content in Cement (2.75%) on Flexural Strength At Different Ages

itm	Set No.	Total SO3% of Mixes	Total effective SO3% of Mixes	Flexural strength (Mpa)		
				7 days.	28 days.	90 days.
1	MRef	2.545	2.235	7.53	8.12	9.78
3	MC	3.295	2.985	7.15	7.93	8.97
4	MCG	4.529	3.416	7.03	7.76	9.33
7	MCSm	7.327	4.929	6.49	7.03	8.49
8	MCSmG	8.561	5.361	6.29	6.77	8.12
11	MCSh	10.495	6.526	5.73	6.2	7.28
12	MCShG	11.729	6.958	5.27	5.91	7.01

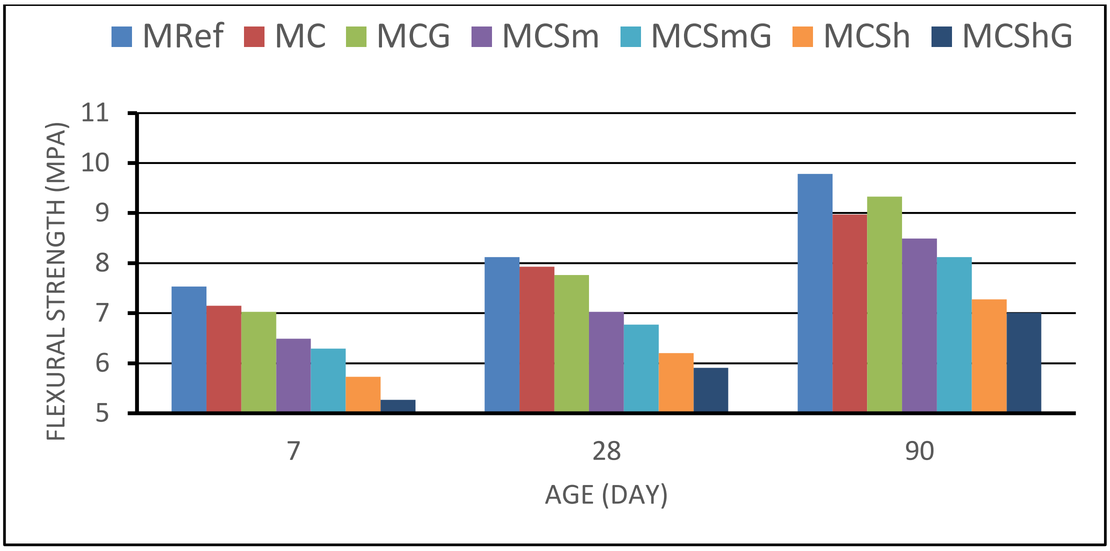


Figure 5.15: Effect of Sulphate Content in Cement (2.75%) on Flexural Strength At Different Ages

Table 5.16: Effect of Sulfte Content In Fine Aggregate (0.3 %) On Flexural Strength At All Agess

itm	*Set No.*	*Total SO3% Of Mixes*	*Total effective SO3% of Mixes*	*Flexural strength (Mpa)*		
				7 days.	*28 days.*	*90 days.*
1	*MRef*	2.545	2.235	7.53	8.12	9.78
2	*MG*	3.779	2.666	7.77	8.46	9.89
3	*MC*	3.295	2.985	7.15	7.93	8.97
4	*MCG*	4.529	3.416	7.03	7.76	9.33

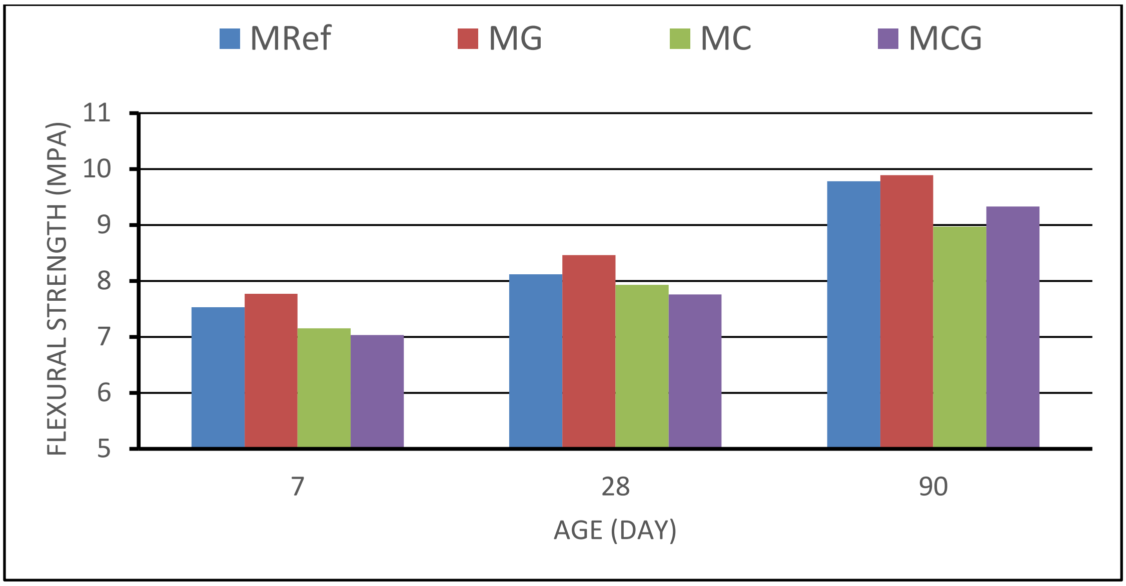


Figure 5.16: Effect of Sulfte Content In Fine Aggregate (0.3 %) On Flexural Strength At All Agess

Table 5.17: Effect of sulfte content in fine aggregate (3.1 %) on flexural strength at all agess

Itm	*Set No.*	*Total SO3% of Mixes*	*Total effective SO3% of Mixes*	*Flexural strength (Mpa)*		
				7 days.	*28 days.*	*90 days.*
1	*MRef*	2.545	2.235	7.53	8.12	9.78
5	*MSm*	6.577	4.178	6.79	7.69	9.03
6	*MSmG*	7.811	4.611	6.71	7.27	8.68
7	*MCSm*	7.327	4.929	6.49	7.03	8.49
8	*MCSmG*	8.561	5.361	6.29	6.77	8.12

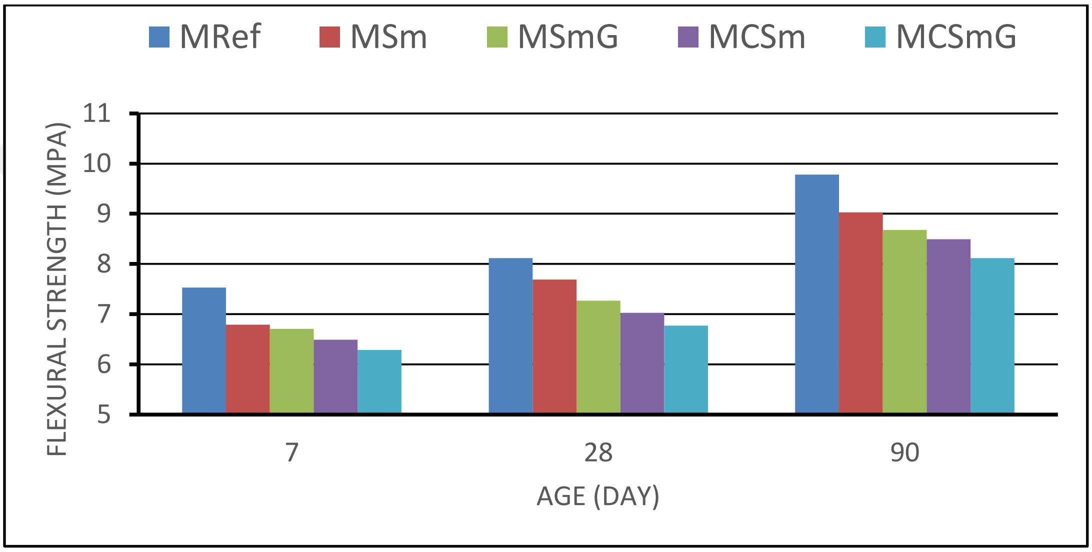


Figure 5.17: Effect of sulfte content in fine aggregate (3.1 %) on flexural strength at all agess

Table 5.18: Effect of Sulfte Content in Fine Aggregate (5.3 %) on Flexural Strength at All Agess

itm	*Set No.*	*Total SO3% of Mixes*	*Total effective SO3% of Mixes*	*Flexural strength (Mpa)*		
				7 days.	*28 days.*	*90 days.*
1	*MRef*	2.545	2.235	7.53	8.12	9.78
9	*MSh*	9.745	5.776	6.06	6.69	7.79
10	*MShG*	10.979	6.208	5.81	6.31	7.55
11	*MCSh*	10.495	6.526	5.73	6.2	7.28
12	*MCShG*	11.729	6.958	5.27	5.91	7.01

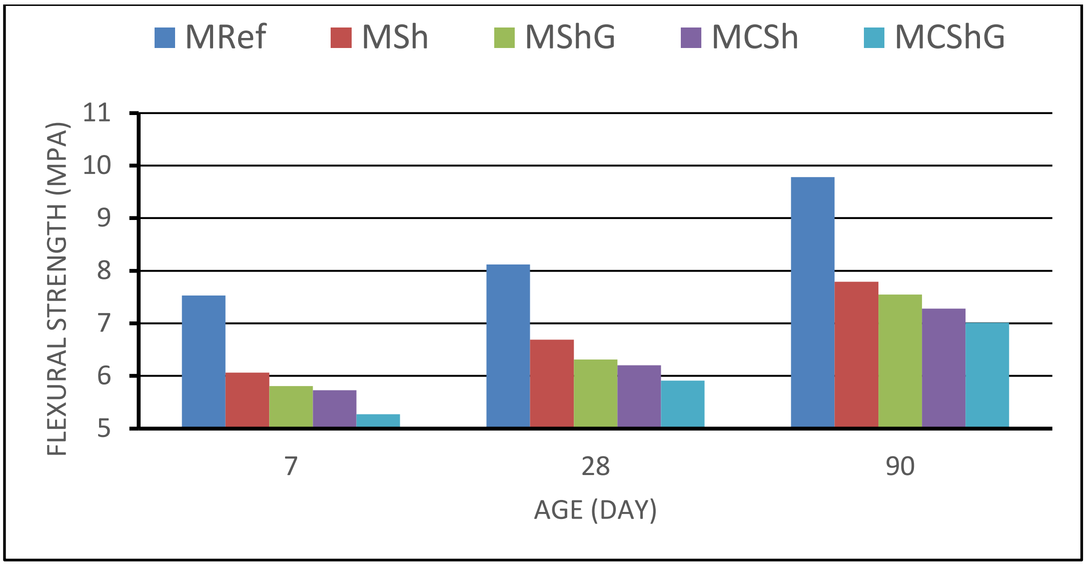


Figure 5.18: Effect of Sulfte Content in Fine Aggregate (5.3 %) on Flexural Strength at All Agess

Table 5.19: Effect of Sulfte Content In Coarse Aggregated (0.06 %) On Flexural Strength At All Agess

itm	Set No.	TotalSO3% Of Mixes	Total effective SO3% of Mixes	Flexural strength (Mpa)		
				7 days.	28 days.	90 days.
1	MRef	2.545	2.235	7.53	8.12	9.78
3	MC	3.295	2.985	7.15	7.93	8.97
5	MSm	6.577	4.178	6.79	7.69	9.03
7	MCSm	7.327	4.929	6.49	7.03	8.49
9	MSh	9.745	5.776	6.06	6.69	7.79
11	MCSh	10.495	6.526	5.73	6.2	7.28

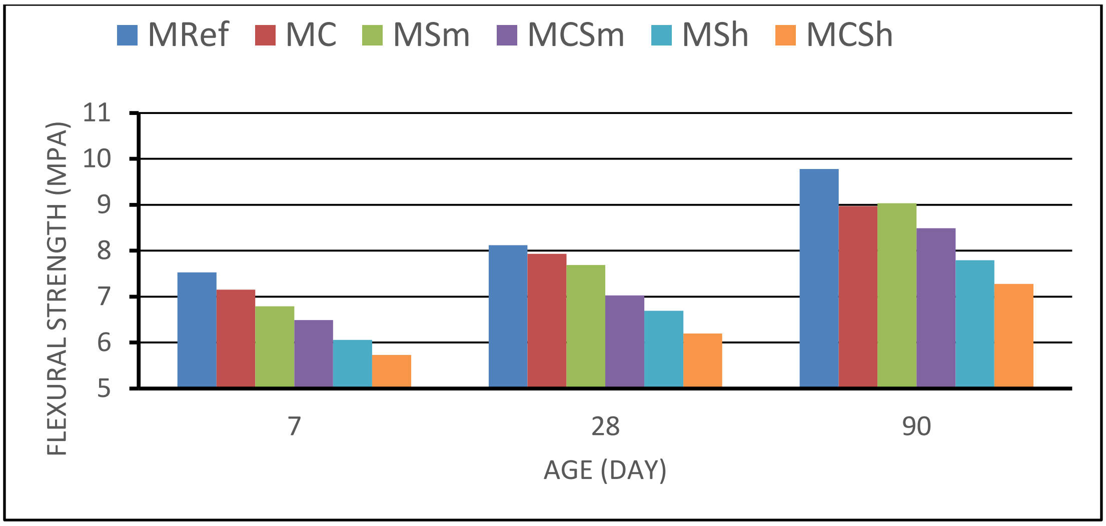


Figure 5.19: Effect of Sulfte Content In Coarse Aggregated (0.06 %) On Flexural Strength At All Agess

Table 5.20: Effect of Sulfte Content in Coarse Aggregated (0.72 %) on Flexural Strength at All Agess

	Set No.	*Total SO3% of Mixes*	*Total effective SO3% of Mixes*	*Flexural strength (Mp*		
				7 days.	*28 days.*	*90 days.*
1	*MRef*	2.545	2.235	7.53	8.12	9.78
2	*MG*	3.779	2.666	7.77	8.46	9.89
4	*MCG*	4.529	3.416	7.03	7.76	9.33
6	*MSmG*	7.811	4.611	6.71	7.27	8.68
8	*MCSmG*	8.561	5.361	6.29	6.77	8.12
10	*MShG*	10.979	6.208	5.81	6.31	7.55
12	*MCShG*	11.729	6.958	5.27	5.91	7.01

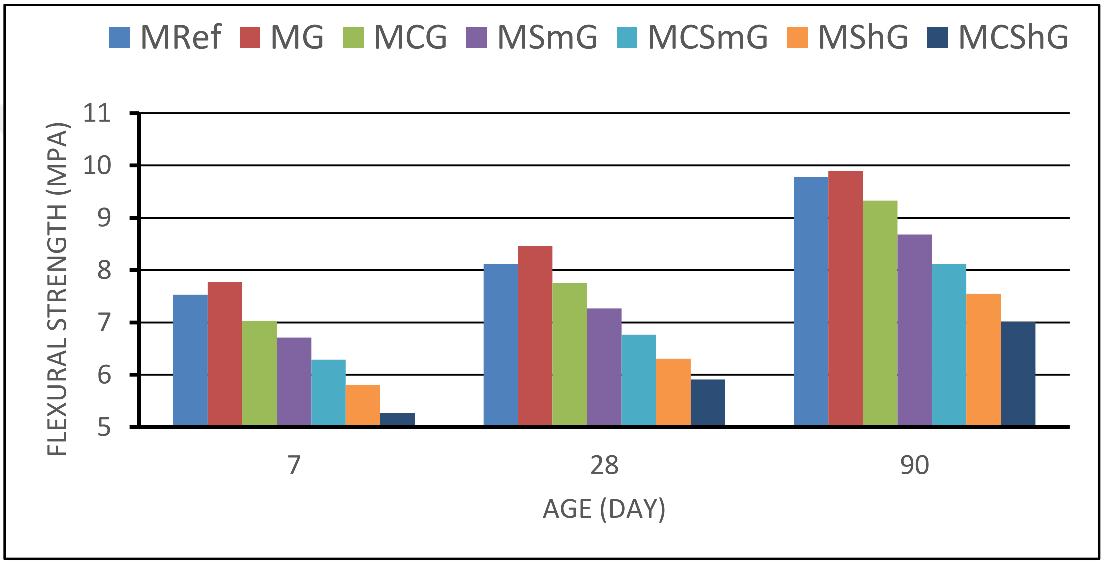


Figure 5.20: Effect of Sulfte Content in Coarse Aggregated (0.72 %) on Flexural Strength at All Agess

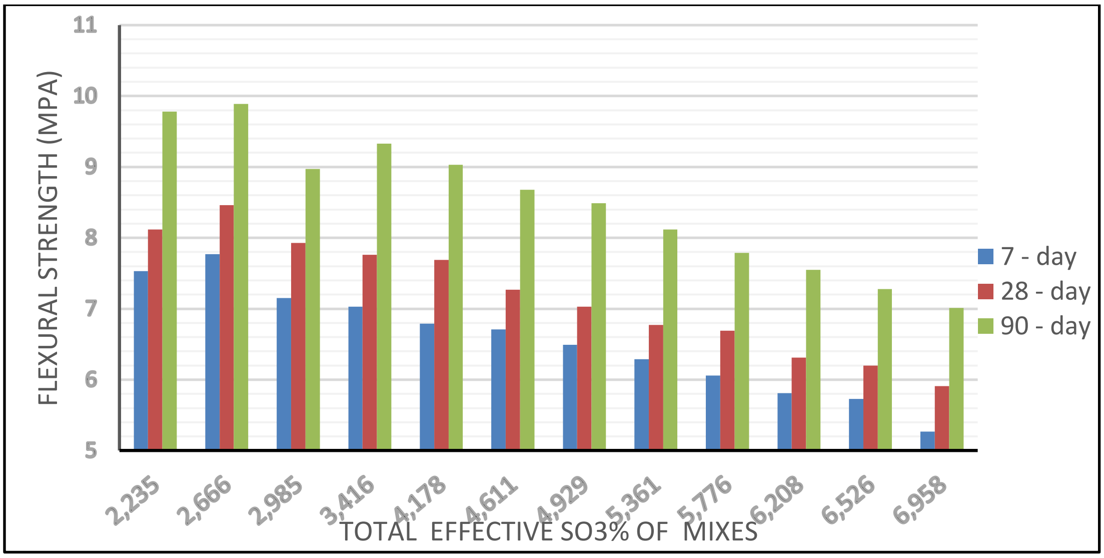


Figure 5. 21: Effect of Total Effective SO_3% Sulfate Content on Flexural Strength at Different Ages

6. STATISTICAL QUALITY CONTROL

6.1 Application of the DMAIC Methodology

In order to control the quality in the project, the research sample will be resorting to the DMAIC methodology, which works to improve the compressibility by detecting errors and their causes, as well as improving some chemical properties of the concrete mixture, as this methodology consists of five stages and in each stage some tools will be used And quality control techniques based on data, field visits and personal interviews to know the reality of the project's work, conduct analyzes and make improvements. Figure (6.1) illustrates the working mechanism of the DMAIC methodology and the process of its application in the research sample project.

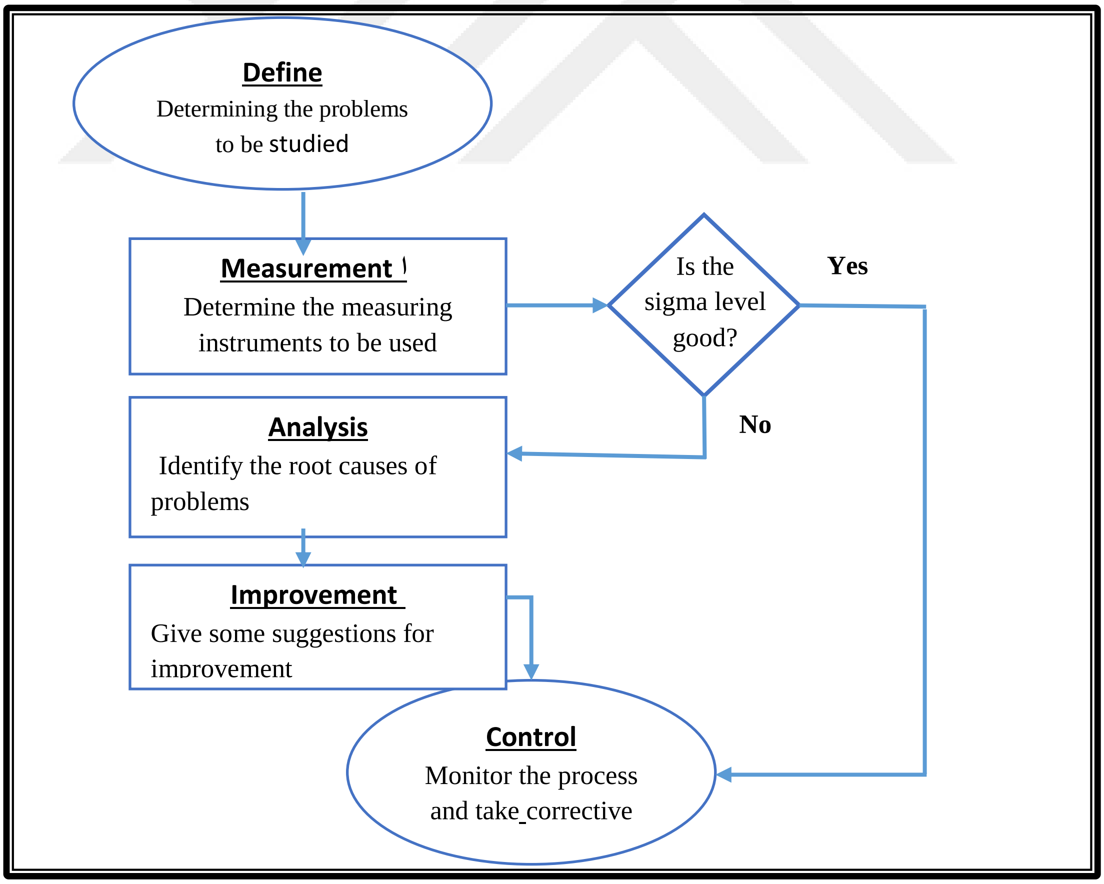


Figure 6.1: The Mechanism of Action of the DMAIC Methodology

Source: (Prepared by the researcher through the use of flowchart)

6.1.1 Define stage

Studying the process by which the components of the concrete mix are mixed and their need for improvement and identifying the problems that occur during pouring. The project to be improved in order to provide and allocate the necessary resources and funds for its implementation.

Table 6.1: Project Charter Tool

Project Title	Application of the methodology DMAIC in Project
Description of the problem	The presence of some problems in the concrete mix due to the presence of sulfate salts in some components of the mix, which negatively affects the performance of high-resistance concrete, as its resistance decreases somewhat.
Location	Iraq - Salah al-Din.
Project duration	3 year
Project application location	Sports stadium in Salah al-Din.
Nature of the project	Studying the reality of the company and trying to improve some of its construction operations.
The objective of applying the DMAIC methodology	Improving the properties of high-resistance concrete, as well as identifying the main and most influential causes of some of the existing problems.
Tools and techniques used	Project Charter ،quality control charts ،process capability ، sigma level ،Brainstorming مخطط ،cause and effect ،pareto chart.

***Source:** (Prepared by the researcher)

After conducting a study of the reality of a number of construction projects in Salah al-Din Governorate, the Saladin Stadium project and its hotel were selected as a project under implementation and of special importance to the Ministry of Sports and Youth and to the governorate. In the project, the focus was on the attack of sulfate salts on the concrete mixtures, which results in side effects that are reflected in some of the properties of the concrete.

In order to study the problem correctly, collect information about it and arrange it according to the most important, the brainstorming method will be used, which is a tool to identify problems that affect operations and give a number of ideas and opinions that caused them (i.e. trying to determine their causes) based on a number of steps, including the following:

Formation of a team to discuss the problem: A team was formed consisting of (the official of the quality department, the official of the laboratory and quality control department, supervisors from the resident engineer department). By raising and codifying a number of reasons.

The problem was studied and diagnosed by conducting personal interviews and frequent field visits to the project and looking at it closely.

A number of reasons have been put forward that lead to the appearance of these defects in the concrete mix . All ideas and proposed causes (types of defects) were also recorded and arranged according to importance by reviewing the records and knowing the extent of their recurrence and identified their main causes (the soil of the project, the type of materials constituting the concrete mixture, the method of mixing,)

6.1.2 Measurement stage

Information was collected and compressive strength was measured at three ages (7, 28, 90 days) where (quality control panels, production process capacity and its indicators, sigma level measurement, Pareto chart) were used.

The percentages of the presence of sulfate salts in the components of high-strength concrete in different periods and ages have been studied for the purpose of showing the effect of these percentages on the compressive strength of concrete mainly. This test has been focused on its utmost importance and its direct impact on the performance of high-strength concrete. It is possible Perform the same steps for the rest of the tests used in the research. The mean panel was used for standard deviation, which is one of the important variables panels and is used when dealing with products that affect human life and when the sample size is large and characterized by the accuracy of the results of its analysis. Where (the arithmetic mean and the upper and lower limits of control were extracted and compared with the limits of the technical specification, standard deviation, and range) and the results were analyzed.

The (compressive strength) was measured for a number of mixtures at different times and for three ages (7, 28 and 90). These readings were recorded using the laziness program and their equations, the following was calculated:

- Arithmetic mean standard deviation
- Limitations of Statistical Adjustment Through Equations

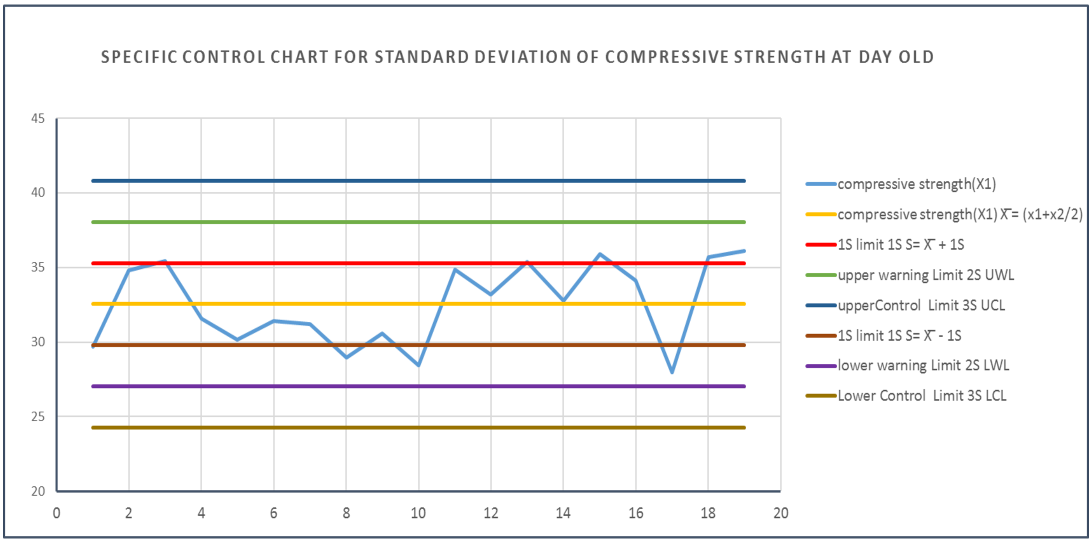


Figure 6.2: Statistical analysis of the mean panel for the standart deviation at different ages

The two panels of the mean and the standard deviation of Figure (6.2) show that the process is statistically disciplined because the samples fall within the limits of control, and there is also fluctuation around the central line that draws attention and work to keep the samples close to the central mean.

Although the process is statistically controlled, (the limits of statistical control) fall outside (the limits of the technical specifications set in which the company operates, and this indicates the low ability of the process. Figure (6.3) indicates that the limits of statistical control of the compression strength are outside the limits of the technical specifications

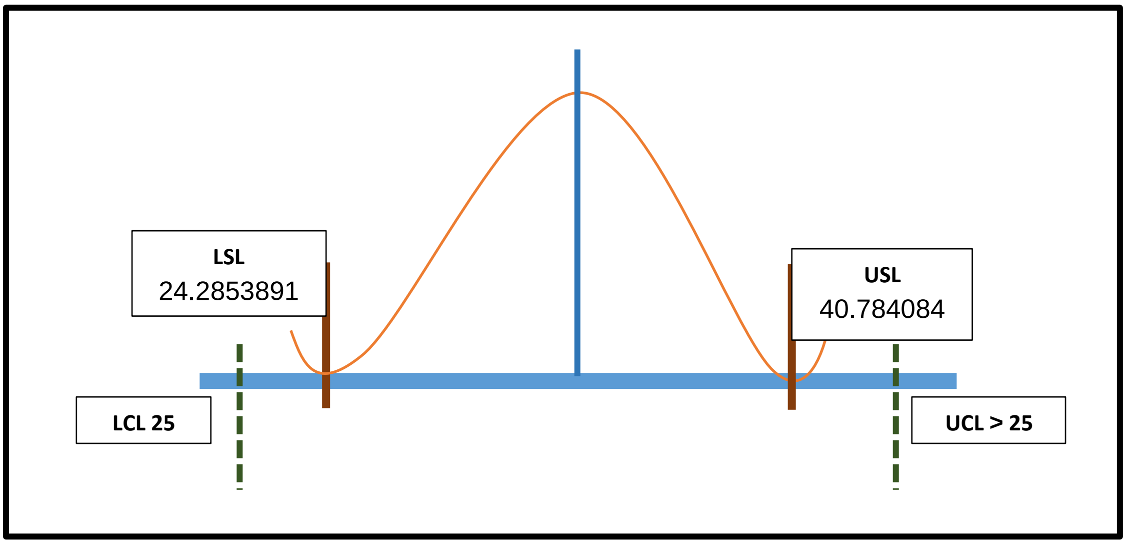


Figure 6.3: Limits For Adjusting The Compressive Strength

Source: (Prepared by the researcher)

6.1.3 Analysis stage

In this stage, data about potential problems are collected in order to convert them into information, as well as identify the main and most influential causes of these problems, depending on many tools, the most important of which is the "Ishikawa Cause and Effect Diagram".

The causes of the problem were identified using the cause and effect diagram, as this diagram is one of the best tools that work on studying the problem in depth and identifying its root causes.

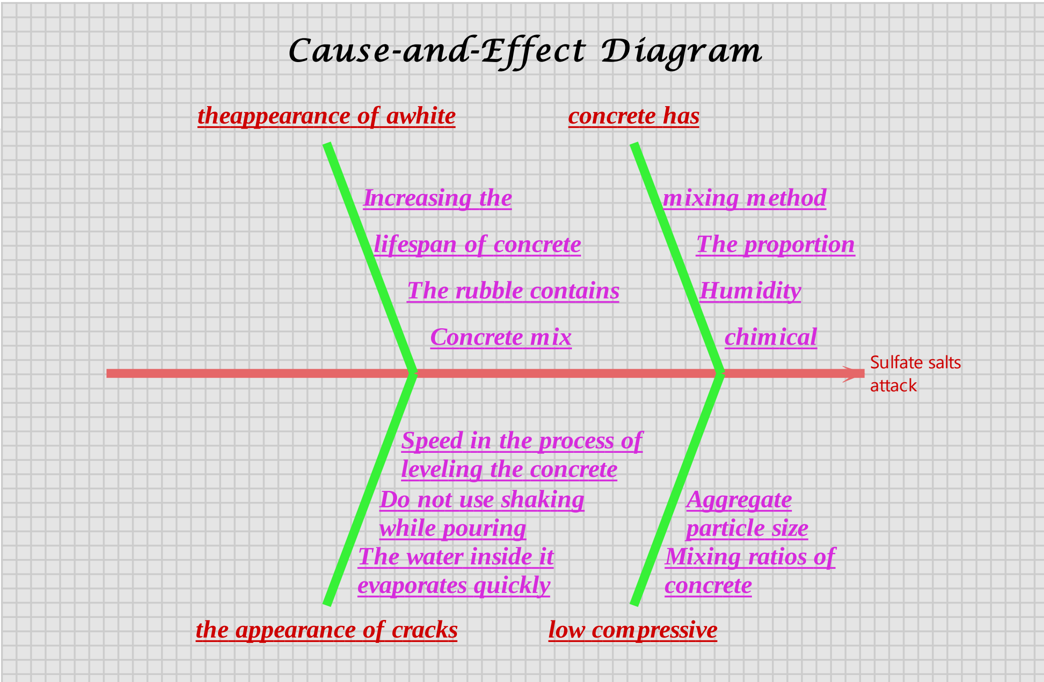


Figure 6.4: Fishbone to improve the properties of high strength concrete

6.1.4 Improvement stage

This stage is based on making improvements and modifications to address the problems identified by developing solutions and proposals as follows:

Increasing the amount of cement inside the mixture leads to an increase in hydration products inside the concrete body, which reduces the internal voids in the concrete body and thus leads to improving the compressive strength of the concrete and compensating for the lack of resistance due to the presence of these salts.

Use of additives for concrete mix to improve concrete performance

Conducting a number of experimental laboratory tests during the process of mixing the ingredients. It is possible to delay the process of sampling during the first hour in order to reach the appropriate mixture.

Using quality control tools such as (Pareto chart, cause and effect chart “Ishikawa” and quality control panels) which are very important to determine the causes of defect and defect since the company has sufficient data.

Establishing specialized training courses and programs to work and trying to involve all workers in them, in order to raise their creativity and level of efficiency and reduce errors (because training workers is an essential element within the prevention costs of quality, and prevention costs are the funds that are spent to prevent defects and deviations in the construction process, that is, it is the stage The first in the process of error prevention and quality control

6.1.5 Control stage

At this stage, operations are monitored, performance is measured, and corrective actions are taken. The improvement process should be in stages, because making total improvements at the company level will raise total costs. The project management must follow scientific methods and use modern programs to reach better results.

6.1.6. The most important results of applying the DMAIC methodology in the research sample company

• Improving the efficiency of project performance in general.

• Raising the capacity of project operations.

• Increasing the sigma level of the project due to the improvement of quality.

• Reducing dispersion and deviation in the production process.

• The ability of the DMAIC to deal with more than one problem at the same time.

• Accurately diagnose problems and give them realistic solutions that fit the nature of the project's work.

• There is still an opportunity to make more improvements within the project, but this needs more time, work and awareness to spread the culture of graceful hexagons and its application mechanism

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The effect of the chemical composition of cement depends on the proportions of its four main components, namely: Dicalcium Silicate C2S, Tricalcium Silicate C3S, Calcium Trialuminate C3A, Calcium Ferric Tetra aluminate C4AF

Cement with a high content of C2S acquires strength faster than cement with a high percentage of C3S since C2S is the compound responsible for the early strength of the cement.

Active SO3 shares positive results for all tests conducted in the study in comparison to SO3 results non-active.

It is possible to increase the sulfate levels in the aggregate used in concrete if the SO3 content in the cement is reduced.

The compressive strength of the concrete mix containing effective SO3 decreased by less than its decrease in the concrete mix containing SO3 at the age of 90 days.

The importance and impact of sulfate content in aggregates is less than its importance and impact on cement

The use of fine aggregates containing 3%, 5%, 7% of sulfate salts leads to a deficiency. In the compressive strength of concrete at age 28 due to the attack of sulfate salts that attack weak compounds in cement, namely tricalcium aluminate (C3A) and quaternary calcium aluminate (C4AF).

The results showed a great effectiveness of using the DMAIC methodology in improving the performance of the concrete mixture, especially at the measurement stage and when using quality control panels to identify samples that deviated from the measurements.

The DMAIC method showed an effective response in the analysis phase and using the Ishikawa diagram to determine the causes of deviations and problems experienced by the concrete mixture.

The higher the quality level at the beginning of the project, the greater the positive impact on the quality of the future stages of the project, and this shows the importance of applying the DMAIC methodology in improving the quality of the project by dividing the project and verifying the quality of its stages

7.2 Recommendations

Revise the Iraqi Standard (IQS) No. 45/1984 for the sulfate content of all types of cement. Effective SO3% and compare it with international standards such as American or British to choose the best ratio.

Relying on the DAMAC work team for the purpose of continuing to follow up on quality according to its different stages and giving him the time necessary for that for his high ability to diagnose and treat deviations

The use of sulfate-strength cement, a type of Portland cement, where the amount of tri-calcium aluminate is limited to less than 5% and the oxides of calcium, silicon and various minerals are less than 25%, which reduces the formation of sulfate salts, at which time the possibility of sulfate attack on concrete is reduced.

REFERENCES

Abbas S. Al-Ameeri, Rawaa H. Issa (April 2013). "Effect of Sulfate on The Properties of Self Compacting Concrete Reinforced By Steel Fiber" International journal of civil engineering and technology volume 4, issue 2, March-,pp.270-287,University of Babylon

Abla M.Zayed, (2004). "Effect of SO3 Content on Concrete Structures Using Florida Materials" ,Ph.D thesis University of south Florida ,Florida department of transportation.

ACI Committee (2008). 211.4R, "Guide for Selecting Proportions for High Strength Concrete With Portland Cement"

ACI Committee 212, (2009). "Guide for The Use of High Range Water Reducing Admixtures (Superplasticizers) in Concrete"

Aitcin, P.-C., (2004). "(Modern Concrete Technology 5) High-Performance Concrete", Taylor and Francis e-library.

Al-Amoudi, O. S. B., (2002), "Attack on plain and blended cement exposed to aggressive sulfate environment", *Cement and Concrete Composites*, Vol. 24, No. 3, pp. 305-316

Al-Janabi, T.H., (2007). "Behavior of High Performance Concrete Exposed to Internal Sulfate Attack", M.Sc. Thesis, University of Technology.

Al-Khalaf, Muayyad Nouri, (1983). "The Effect of Salts in Sand on Some Properties of Concrete", National Center for Construction Laboratories - Ministry of Housing and Construction, Arab Concrete Technology Course.

Al-Qazzaz, **Ismail Ibrahim and Al-Hadithi, Rami Hekmat and Corel, Adel Abdel Malik,** (2009), "Six Sigma and other modern methods in total quality management", Dar Al-Maysara for Publishing, Distribution and Printing, 1st Edition, Amman.

Al-Robayi, A.H., (2005). "Resistance of High Performance Concrete Exposed to External and Internal Sulfate Attack", M.Sc. Thesis, University of Technology.

ASTM C1157M (2006). "Standard Performance Specification for Blended Hydraulic Cement" ASTM, Philadelphia, PA.

ASTM C150 (2006). ASTM "Standard Specification for Cement".

ASTM C642, (2006). "Standard Test Method for Density, Absorption, and Voids in Hardened Concrete".

Balsam J. M. F., (2008).،"Properties and testing of concrete material"،Training Course، engineering collage ، university of Altahdee in Libya ،July from 7/6 to7/16 in.

Diah, A.B.M., **and Boon, K.H**., (2008). "High Performance Concrete: Towards Durable Construction", University Teknikal, Malaysia Melaka, ICCBT, PP.(31-44).

Essam Melhem, Bassam H., (2008). "Concrete's stress resistance and its effect on acidic media" Journal of Damascus University for Engineering Sciences - Volume Twenty-four - Number One.

Ferraris, C. F., Stutzman, P.E., and Snyder, K. A., (2006)." Sulfate resistance of concrete: A new approach", R&D Serial No. 2486, Portland Cement Association, Skokie, Illinois, USA, 93 pages

Flatt, R. J., (2002). “Salt damage in porous materials: how high supersaturations are generated”, *Journal of Crystal Growth,* Vol. 242, No. 3-4, pp. 435-454.

Geffen, Frank van & Niks, **Rudi** (2013) "Accelerate DMAIC using process mining" In: Proceedings of 3rd BPI Challenge BPIC’13, Beijing, CEUR-WS.org,

Geffen, Frank van & Niks, Rudi (2013). "Accelerate DMAIC using process mining" In: Proceedings of 3rd BPI Challenge BPIC’13, Beijing, CEUR-WS.org,

Getting Started With High-Strength Concrete (1993). "The Concrete Producer", November

Habeeb G. M., (November, 2000)."Residual Mechanical Properties of High Strength Concrete Subjected to Elevated Temperatures", A thesis submitted to the Civil Department, College of Engineering, Al-Mostansiriya University

Hassan, K.E., Cabrera, J.G., and Maliehe, R.S., (2000). "The Effect of Mineral Admixtures on The Properties of High Performance Concrete", Cement and Concrete Composites, Vol.22, No.4, PP.(267-271).

Heinz, D. and Ludwig, U., (1987). "Mechanism of Secondary Ettringite Formation in Mortars and Concretes Subjected to Heat Treatment", Concrete Durability - Katharine and Bryant Mather International Symposium, SP-100, ACI, Detroit, Mich., pp. 2059-2071.

Heizer, Jay & Render, Barry & **Munson, Chuck** (2017). Operations Management: Sustainability And Supply Chain Management, 12th Edition, Pearson education, Inc., USA

Hooton RD., (1993). "Influence of Silica Fume Replacement of Cement on Physical Properties and Resistance to Sulfate Attack, Freezing and Thawing, and Alkalisilica Reactivity". ACI Mater J. 90(2):143–51

International Organization for Standardization, (2008), “*ISO 9000 - Quality Management*”, www.iso.org

Iraqi Standards (1984). “Aggregate from Natural Sources for Concrete and Construction”, Ministry of Housing and Construction, No.45, Baghdad.

Irassar, E. F., Di Maio, A., and Batic, O. R., (1995), “Sulfate attack on concrete withnmineral admixtures”, *Cement and Concrete Research*, Vol. 26, No. 1, pp. 113- 123.

Jan Skalny, Jacques Marchand and Ivan Odler (2002). “Sulfate Attack on Concrete”.

Kai Yang (nd.)."Design for Six Sigma: A Roadmap for Product Development 2nd Edition

Khudair J. A. and Faleh S. Kh., (2013). ‘‘Sulphate Resistance of Concrete Containing Silica – Fume’’, Proceedings of the First Basrah International Civil Engineering Conference (BICCE-01), PP.109-117, Iraq.

Lee Krajewski, **Manoj Malhotra,** (Jan 4, 2018). "Operations Management: Processes and Supply Chains "

Lee Krajewski, Manoj Malhotra, (Jan 4, 2018). Operations Management: Strategy and Analysis (6th Edition) 6th Edition

M. Santhanam, M.D. Cohen, J. Olek, "Mechanism of Sulfate Attack: A Fresh Look": Part 1: Summary of experimental results, Cem. Concr. Res. 32 (6) (2002) 915–921.

Naaman, A.E. (2000). HPFRCCs: "Properties and Applications in Repair and Rehabilitation". ACI SP182, 1–16.

Naik NN. (2003). "Sulfate Attack on Portland Cement-Based Materials: Mechanisms of Damage and Long-Term Performance", PhD thesis, Georgia Institute of Technology, Georgia.

Naik, N.N., Jupe, A.C., Stock, S.R., Wilkinson, A.P., Lee, P.L., and Kurtis, K.E., (2006). "Sulfate Attack Monitored By Micro CT And EDXRD: Influence of Cement Type, Water to Cement Ratio, and Aggregate", Cement and Concrete Research, Vol.36, No.1, PP.(144-159).

Natalya G. (2003). Shanahan "Influence of C3S Content of Cement on Concrete Sulfate Durability" University of South Florida.

Neville, A. M., (2000). "Properties of Concrete" Five, and final Edition, Wiley, New York and Longman, London.

Neville, A.M., (2010). "Properties of Concrete", Longman Group, 4th and Final Edition, PP.(18-87), (508-677).

Nyrén, Gustav, (2007), “Product Development According to Six Sigma and the DMAIC Improvement Cycle”, MSc Thesis Submitted to the Department of Business Administration and Social Sciences, Industrial Business Administration, Leleå University of Technology.

Pande, Pete and Holpp, Larry, (2002), “What is Six Sigma”, McGraw-Hill company, Inc., USA.

Park, Sung, H., (2003), “Six Sigma for Quality and Productivity Promotion”, Asian Productivity Organization APO, Tokyo, Japan.

Parker, Harry, (1986), “Simplified Design of Reinforced Concrete”, Third Edition, John Wiely & Sons, Inc.

Patel, Nilesh, K.; Suhagia, Bhanubhai, N.; Marolia, Bhavin, P.; Mishra, Ashish, D.; and Shah, Dinesh, R., (2007), “Six Sigma: A Measure of Goodness in Quality Management System”, Available at (www.Pharmainfo.net) e-journal, Vol. 5, Issue. 1.

Pepper, M.P.J. and Spedding, T.A., (2010), "The Evolution of Lean Six Sigma", International Journal of Quality & Reliability Management (IJQRM), Vol. 27, No. 2, pp. 138-155, Emerald Group Publishing Limited

Peurifoy, Robert L. and Oberlender, Garold D., (1996), "Formwork for Concrete Structures", Third Edition, McGraw-Hill company, Inc.

Pheng, Low, Sui., **and Hui, Mok, Sze,** (2004), "Implementing and Applying Six Sigma in Construction", Journal of Construction Engineering and Management, Vol. 130. No. 4, pp. 482-489, ASCE.

Pierre-Claude Aitcin (1998). "How to Produce High Strength Concrete", Professor,Department Of Civil Engineering University Of Sherbrooke.

Prassad, P.V.S., and Jha, K., (2005). "High Performance Concrete", Dy. CE/ Rly, Professional Course (Bridges & General), PP.(2-4)

Pyzdek, Thomas, (2003). "The Six Sigma Handbook: A Complete Guide for Green Belts, Black Belts, and Managers at All Levels", First Edition, McGraw-Hill Companies, Inc., New York..

Racine, John, (2005), "The Evolution of Six Sigma", MSc Thesis Submitted to the Business Administration Department, the Faculity of Strayer University, Virginia, USA

Researchers in Construction Management, (nd.). Cardiff, UK, White Rose Research Online, University of Leeds, Sheffield and York, pp. 267-276.

Saco, Z. and Rassam, D., (1989). "The Effect of Gypsum Coatings on Coarse Aggregates Upon The Properties of Concrete " , 5th Edition , Conferee of SRC , Vol.4 , part 1 , Baghdad.

Saito, H. and Deguchi, A. (2000). "Leaching Tests on Different Mortars Using Accelerated Electrochemical Method", Cement and Concrete Research 30: 1815–1825.

Samaa Ali (2010). "The Effect of Cement and Admixture Types On The Resistance of High performance Concrete to Internal Sulfate Attack" M. Sc. thesis University of Baghdad, Baghdad.

Samarai, M.A., (1976). "The Disintegration of Concrete Containing Sulfate-Contaminated Aggregates", Magazine of Concrete Research 28: 130–142.

Santhanam, M., Cohen, M. D., Olek, J., (2001), "Sulfate attack research – whither now?" *Cement and Concrete Research*, Vol. 31, No. 6, pp. 845-51.

Sayed Horkoss, **Roger Lteif, and Toufic Rizk** (2011). "Influence of The Clinker SO3 On The Cement Characteristics" Cement and Concrete Research.

Schroeder, R., (2008), "Operation Management: Contemporary Concepts and Cases", Third Edition, McGraw-Hill company, Inc

Silva; Batalha; Filho; Ceccarelli; Anjos; and Fesz, (2009). "Integrated Product and Process System with Continuous Improvement in the Auto Parts Industry", Journal of Achievements in

Sokovic; Pavletic; and Fakin, (2005), "Application of Six Sigma Methodology for Process Design", Journal of Materials Processing Technology, Vol. 162, No. 163, pp. 777-783, Elsevier publishing.

Srinivasu, Rallabandi; Reddy, Satyanarayana; Asarao, Vuda; and Rikkula, Srikanth, (2010). "The Contribution of TQM and Six Sigma in the Organizations to Achieve the Success in Terms of Quality", International Journal of Reviews in Computing, Vol. 4, No. 2, pp. 8-19.

Stamatis, Dean H., (2004), "Six Sigma Fundamentals: A Complete Guide to the System, Methods and Tools", New York Productivity Press. p. 1, a Division of Kraus Productivity Organization, Ltd. New York, USA.

Stevenson, William J., (2005), "Operation Management", Eighth Edition, McGraw-Hill Irwin companies Inc., NY, USA

Tehrani, Maryam, Dabbaghi, (2010), "Performance Improvement in Construction Project based on Six Sigma Principles", MSc Thesis Submitted to the Department of Quality and Environmental Management, Industrial Engineering, University of Borås, Sweden

The American Society for Quality, (1998). "ASQ D1-9000-1: Advanced Quality System Tools", USA.

The Steel Construction Institute SCI, (2007), "The Inspection of Surface Preparation and Coating Treatments", Guidance Note, No. 8.06

Tutesigensi, A.; and Pleim, V., (2008), "Why Small and Medium Construction Enterprises Do not Employ Six Sigma", Proceedings of 24th

Wiele, A van der; **Williams, A.R.T.; and Dale, B.G**., (2000), "ISO 9000 Series Registration to Business Excellence: the Migratory Path", Business Process Management Journal, Vol. 6, No. 5, pp. 417-427, MCB University Press. Annual ARCOM Conference, Association of.

Wiele, A.; Dale, B. **and Williams, A.,** (1997), "ISO 9000 Series Registration to TQM: the Transformation Journey", International Journal of Quality Science, Vol. 2, No. 4, pp. 236-252, MCB University Press

Yuniarto, Hari, **and Elhagm, Taha,** (2008), "Enhancing Six Sigma with Systems Dynamic", Proceedings of the World Congress on Engineering, London, UK. ISBN: 978-988-17012-3-7.

RESUME

EDUCATION:

- Bachelor's degree in Civil Engineering
- Isra University College Department of Civil Engineering

WORK EXPERIENCE:

- Work experience
- Trainee engineer in the Tikrit stadium project

PERSONAL INFORMATION:

- Degree: Bachelor's degree in Civil Engineering
- Name: Mais Ahmed Majid Hamid Al-Jumaili
- Date and place of birth: Baghdad / 1996
- Marital status Single
- Nationality: Iraqi
- Nationality: Arab

SKILLS:

- Management and teamwork
- Decision making and problem solving
- Leading and Negotiating
- Planning and working under pressure