Republic of Iraq

Ministry of Higher Education and Scientific Research

University of Babylon

College of Engineering

Civil Engineering Department

An Improving the Concrete Containing High Sulfate by Magnetic Treated Method

A Thesis

Submitted to the College of Engineering at University of Babylon in Partial Fulfillment of the Requirements for the Degree of Master in Engineering / Civil Engineering / Construction Materials

By:

Alaa Abdul kadhim Abdullah

(B.Sc. 2006)

Supervised by:

Prof. Samer Abdul Ameer Almashhadi

Mars / 2023 Shaaban / 1445

بسم الله الرحمن الرحيم

﴿يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ

وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ

وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ﴾

صدق الله العلي العظيم

سورة المجادلة – الآية (11)

Supervisor Certification

We certify that this thesis entitled " **Improving the concrete containing high sulfate by magnetic treated methods**" was presented by **" Alaa Abdul kadhim Abdullah "**, and made under our supervision at The Department of Civil Engineering, College of Engineering, University of Babylon, as a partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering (Construction Materials).

SUPERVISORS:

Signature:

Name: Prof. Samer Abdul Ameer Almashhadi

Date: / /

Dedication

To My dear parents for
their love and care..
To My family for
their love and encouragement..
To All My Real Friends
To All those who support science
intellectually, financially,
and morally.

✍

Alaa K. Abdullah

2023

Acknowledgments

In The Name of Allah, the Most Gracious, the Most Merciful

Praise be to **God**; on his grace is the vast. Writing this dissertation has been wonderful and very rewarding. I would like to thank those who contributed to the final result in so many different ways.

I want to offer this quest to our Almighty God who has given me good health, courage, inspiration, zeal and light to complete this quest. I express my sincere thanks and gratitude to my thesis advisor, ***Prof.*** **"Samer Abdul-Amir Al-Mashhadi"** for his guidance, assistance and professional advice throughout this work, and for the continuous support and valuable suggestions he provided that greatly contributed to the improvement of the dissertation.

I also express my deep gratitude to my **parents** and their prayers always for me, and my family (**my children and my husband**) for their support and help during my studies and their prayers for me, without them I would have been nothing and this message would not have been possible. Thank you all for the strength you give me.

✍

Alaa K. Abdullah

2023

Abstract

The use of electromagnetic field technology to produce magnetized concrete is a new experimental method within the field of renewable and environmentally friendly energy to reduce the problems of sulfate salts in concrete. Building sturdy, long-lasting concrete structures that can withstand weather conditions requires innovative materials and technology. Sulfate salts are one of the biggest problems with concrete in Middle Eastern cities. The cause of the problem of the high rate of salts in the soil, aggregates, and water is due to global warming, which leads to high temperatures and a lack of usable water sources. The internal sulfate attack of concrete is one of the most important problems that deteriorate the strength of concrete; due to the high percentage of "SO_3" in coarse and fine aggregates in particular. Sulfate ($CaSO_4 .2H_2O$) is the least soluble in tap water, as it is found in high quantity on the surface of aggregate granules and within its pores.

The experimental work included manufacturing a magnetic device with an electrical principle that works efficiently and can be used with the pumping device at the work site during concrete pouring. The work of the device is summarized in several stages, the first of which is obtaining magnetized concrete using tap water. The mixture was exposed to three degrees of magnetic intensity (2000, 2500, 3000) Gauss, where the hardened concrete's highest compressive strength was attained with the highest magnetic intensity with an intensity of (3000 Gauss) in (7, 28, 90) days, and this intensity was adopted in the tests of this research. The second stage is the production of magnetized water for the purposes of mixing and curing concrete. The third stage is the production of magnetized concrete using magnetized water. Laboratory experiments proved the efficiency of the device's technology in treating mixtures with the electromagnetic field and

improving the mechanical properties of concrete containing different percentages of sulfate salts.

The results of compressive strength and bending showed a clear improvement of the concrete when exposed to the field of the electromagnetic device; the compressive strength of the magnetized concrete increased by (9.30, 9.31 and 5.32%) for SO_3 =0.15%, (9.32, 9.05, and 5.43%) for SO_3=0.3% and (9.20, 8.46, and 5.27%) for SO_3=0.6% in 7, 28, and 90 days, respectively, just bypassing the concrete mixture through the tube exposed to the electromagnetic field. Several concrete mixtures were prepared before and after treatment with an electromagnetic field, using sand containing (0.15, 0.3) percent of sulfate salts, and failed sand containing (0.6) percent of sulfate. It is noted from the recording of the results of the test that there is a decrease in the compressive and flexural strength at all ages, especially in the later ages due to the influence of salts, where a decrease in the compressive strength was recorded by (4.1, 0.93) at the age of 90 days for concrete mixes (CT**, CTr*) respectively, (CT**:- control mix with tap water, sand with SO_3=0.6, OPC), (CTr*:- control mix with tap water, sand with SO_3=0.6, SRPC), compared to the reference concrete mix (CT, CTr), (CT:- control mix with tap water, sand with SO_3=0.15, OPC), (CTr:- control mix with tap water, sand with SO_3=0.15, SRPC).

The deterioration of the concrete was due to the negative development of salt, and there was a need to use an experimental method to reduce the effect of salt percentages on the properties of concrete through the use of the locally manufactured electromagnetic device. The results of the examination of the magnetized concrete containing different percentages of sulfate salts showed encouraging results, as the percentage of increase in compressive strength (6.17, 3.84); at the age of 28 days for the concrete mixture (TWT**, TWTr*), respectively, (TWT**:- mixture of tap water and electromagnetic treatment, sand with SO_3=0.6, OPC), (TWTr*:- Mixture of tap water and electromagnetic treatment, sand with SO_3=0.6, SRPC), compared with the reference concrete (CT, CTr).

List of Content

List of Figures

List of Tables

List of Plates

List of abbreviations

ACI	**American Concrete Institute**
ASTM	**American Society for Testing and Material**
BS	**British Standard**
EEF	**Early Ettringite Formation**
DEF	**Delayed Ettringite Formation**
IQS	**Iraqi Specification**
MWC	**Magnetic Water Concrete**
OPC	**Ordinary Portland cement**
CT	**Control mix with Tap water, sand with SO_3=0.15, OPC**
TWT	**Mixture of tap water and electromagnetic treatment, sand with SO3=0.15, OPC**
MW	**Mixture with magnetized water**
MWT	**Mixture with magnetized water and electromagnetic Treatment**
CT*	**Control mixture with tap water, sand with SO3=0.3, OPC**
TWT*	**Mixture of tap water and electromagnetic treatment, sand with SO3=0.3**
CT**	**Control mix with Tap water, sand with SO3=0.6, OPC**
TWT**	**Mixture of tap water and electromagnetic treatment, sand with SO3=0.6, OPC**
CTr	**Control mix with Tap water, sand with SO3=0.15, SRPC**
TWTr	**Mixture of tap water and electromagnetic treatment, sand with SO3=0.15, SRPC**
CTr*	**Control mix with Tap water, sand with SO3=0.6, SRPC.**

TWTr* **Mixture of tap water and electromagnetic treatment, sand with SO_3=0.6, SRPC**

SCC **Self Compacted Concrete**

Q **Flow rate**

MFI **Magnetic Field Intensity**

CHAPTER ONE

CHAPTER 1

INTRODUCTION

1.1 Overview

Magnetic treating technology is one of the methods that plays an important role in preparing concrete, as most researchers focused on improving compressive strength and workability by using new philosophies in design methods, perhaps the most important of which is the use of the magnetic field to affect the properties of the water, thus affecting the concrete properties. Due to the importance of water in affecting concrete, the idea of using water exposed to a magnetic field appeared, which proved effective in increasing compressive strength with high workability of the mixture that used magnetized water. The efficiency of magnetized water also increases with the increase in the intensity of the magnetic field to which it is exposed, which leads to low porosity and high density of concrete. **(Ramachandran, 2018), (Mazloom and Miri, 2017).**

When normal water is exposed to a magnetic field, molecules that are contained within a water mass; are reduced from (13 to 5) due to the changes in the physical properties of water, and when testing the concrete models made with magnetic water, the results of the strength to compression, bending and tensile strength were stronger than that of tap water, with the possibility of obtaining superior resistance to the spread of cracks in concrete. It has also been shown that water treated with a magnetic field; increases the bonding strength between steel bars and concrete as well as compressive strength. **(Preethi et al., 2022), (Barham et al., 2021).** All previous experiments conducted to improve the properties of concrete by magnetization method used magnetized water. The current new study involves producing magnetized concrete by using tap water or magnetized water when mixing, then passing the concrete mixture through an electromagnetic field.

1.2 Introduction to Sulfate Attack

Concrete deterioration due to sulfate attack is one of the most important early failure factors. Sulfates in aggregates are oxidized compounds in the presence of oxygen and water. Sulfates are also found within the components of cement, mixing water, or polluting materials for concrete. This is what is called internal sulfate attack **Fig (1-1)**. With the hydration products of cement to the formation of ettringite, which leads to the attack of sulfates, and the last chemical reactions resulting from the attack state causes expansion, increase in permeability, cracking and fragmentation, loss of adhesion between the bonding of the group, gradual loss of strength and thus failure of concrete **(Gorgis et al., 2018), (Campos et al., 2016)**.

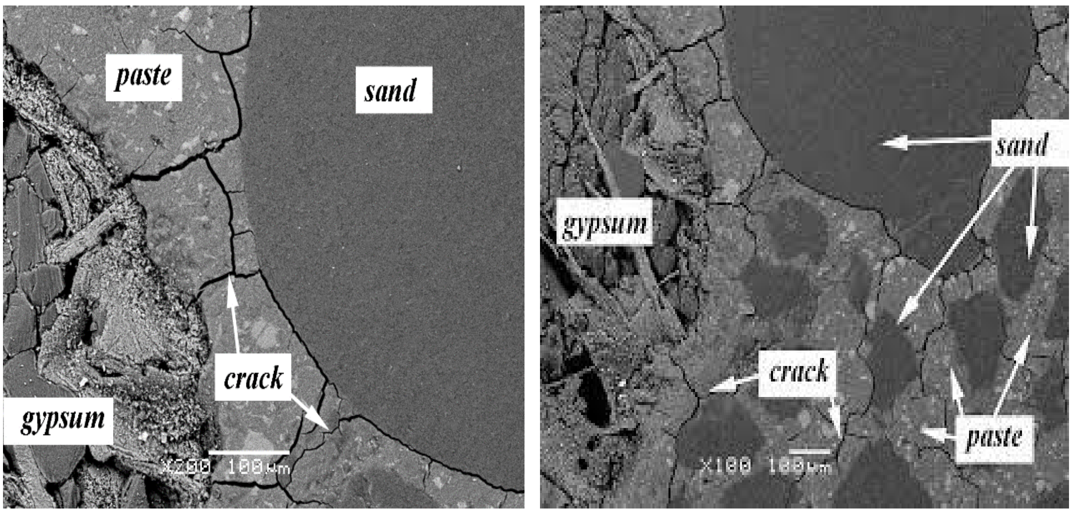
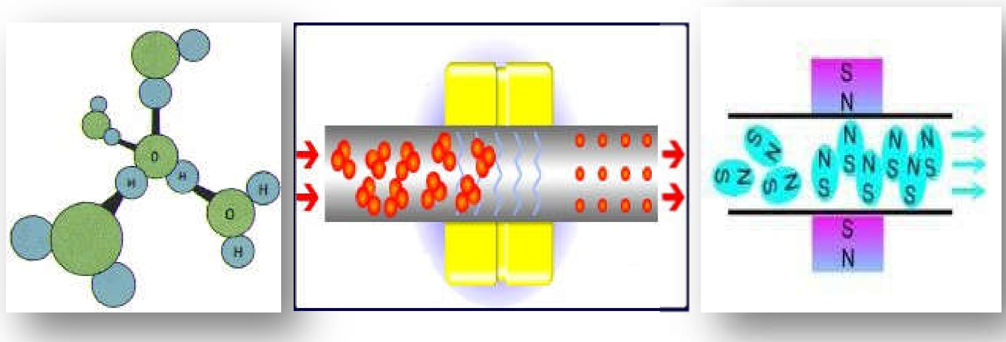


Figure (1-1) Attack by Sulfates inside **(Chen et al., 2020).**

1.3 Description of the Magnetic Water Technology

The use of modern technologies in the design and production of economical concrete with high mechanical properties is a goal that focuses the attention of researchers. The magnetic field treated water technology has been used since the eighties in China and Russia due to the development in the equipment, **Figure (1-2)**. When the tap water flows through the tube exposed to the magnetic field, a change in some physical properties will occur, and the total of water molecules groups decreases from (13 groups to 5 or 6) molecules, which causes the water's surface tension to drop and an increase in the proportion of molecules contributing to the wetting process when it is added to a mixture concrete **(Shynier et al., 2014)**. By utilizing water that has been subjected to a magnetic field, when used in concrete mixing, it can significantly increase the concrete's workability and compressive strength. **(Raouf et al., 2016)**. The value of the PH number increases, the total magnetized water salinity decreases, and the water hardness decreases depending on the intensity of the magnetic field, and time of exposure **(Manjupriya and Malathy, 2016)**.



- A- -B- -C-

Figure (1-2) Water's magnetic mechanism: - **A**: Water Cluster **B:** Cluster Breakage **C:** Orientation **(Manjupriya and Malathy, 2016)**.

Applications of magnetized water can be found across scientific disciplines and industrial sectors, but particularly in environmentally friendly technologies. Using high performance materials with minimal environmental impact and low cost, sustainable development ideas applied to civil engineering will soon allow the production of structures that are compatible with these ideas **(Karkush et al., 2019)**.

The technique of using magnetized water was started by researchers in preparing concrete since the sixties in Russia, and other researches were conducted in China, Japan, and Europe, confirming the improvement of the resistance of concrete by using magnetized water, and thus the amount of cement can be reduced, and it also improves the resistance of concrete to freezing and reduces the phenomenon of Bleeding. A Japanese patent proved that when concrete is exposed to a magnetic field, the cement reaction process tends in the direction along the lines of magnetic direction. The magnetic field can break up the water groups into smaller particles, and a higher activity of the magnetized water occurs, which enables it to penetrate the particles of cement more easily during the cement hydration progression process after adding water to it. The better the efficiency of the hydration process, the greater the greater the concrete resistance. When the magnetized water that carries electric charges surrounds the cement particles, the particles will repel each other, which leads to the dispersion of the cement groups and facilitates the passage of the mixed water trapped between the cement particles **(Su and Wu, 2003)**.

The majority of concrete research efforts have been focused on creating more durable and cost-effective concrete.

Using a new design philosophy for concrete and modern technologies, such as the use of magnetic field treatment to produce magnetized water. The physical properties of tap water change when exposed to a magnetic field, which leads to a decrease in surface tension and an increase in the percentage of molecules that contribute to the hydration process by reducing the number of molecules in the water groups to 5 or 6 **(Shynier et al., 2014)**.

There are many sectors that benefit from using magnetic water, such as the agriculture, the healthcare sector, the building and construction sector, the dairy industry, and even the oil sector **(Karam and Al-Shamali, 2013)**.

The majority of their academic efforts focus on creating affordable concrete with better mechanical properties using new and developing technologies, and the use of magnetically treated water is an example of practical application, because the costs of these technologies are outweighed by their benefits. The Federal Program (Application of magnetic fields in national economy) has been approved by the Russian Federal Government **(Ahmed, 2009)**.

Making magnetic concrete using magnetic water is a recently well-established method for using electromagnetism to change the properties of concrete. Using the polarity of water molecules as a foundation, Lorenz (1902) initially proposed this technique. The molecules of water enlarge as it travels through a magnetic field. Permeability, temperature, PH, surface tension, specific weight, and solubility are some of the chemical and physical characteristics that alter as a result. The compressive strength and workability of concrete are both improved by (10% to 25%) when using magnetized water. This employing magnetic water makes concrete easier to deal with **(Tarbozagh et al., 2020).**

1.4 Goals and Objectives for the Study

Following is a list of the investigation's most significant goals and objectives:

1) Studying the effect of electromagnetic field intensity in the normal concrete mixture for the production of magnetized concrete.
2) Studying the effect of using different intensities of an electromagnetic field on concrete's mechanical characteristics.
3) Possibility of producing concrete with lower economic cost without using any additives and with better resistance.
4) Production of environmentally friendly concrete that contributes to reducing pollution, and can overcome the problem of high sulfate content in general, especially in Iraq and the Middle East
5) An easy process for treating sulfate salts in fine aggregates in particular, and minimizing their negative impact. The maximum allowable (the sulfate content in sand is no more than 0.5%), the maximum sulfate content in gravel (no more than 0.1%).
6) Magnetic concrete technology is a new technology, and researchers have begun to conduct studies on its application.

1.5 Importance of the Research

The significance of this research in the area of civil engineering lies in a technology that is clean and favorable to the environment to protect the planet from pollution with construction waste (sulfate-contaminated gravel and sand); as well as the carbon emissions resulting from the manufacturing of chemicals such as cement and additives things contribute to make concrete more effective.

Since there is less water available everywhere as a result of global warming, the rate of desertification has accelerated, which has increased sulfate contamination of aggregates, particularly fine aggregates.

Because there aren't enough sources of useable water, a green technique must be developed to treat the concrete containing the contaminated aggregate and increase its efficiency at the same time.

1.6 Structure of the Research

The outlines of this study are as follows:

1) First chapter, introduces sulfate salts attack, magnetized water technology, and in general, concrete. Also gives the primary goals and objectives for this study.
2) Second chapter provides a thorough explanation of the magnetic water and magnetized water techniques as well as their impact on the characteristics of concrete. The magnetized concrete technique is also explained in a new way. The negative impact of sulfate in the aggregates on the characteristics of concrete has been demonstrated. The most significant recent literature on magnetic water technology, magnetized concrete, as well as the impact of sulfates that are harmful in aggregates, is cited in this study.
3) Third chapter, present the materials that are used in the study and their preparation from the site. It also includes the approved proportions of the concrete mixture and the design of the mixtures, in addition to an explanation of how to create concrete samples with the processing procedure based on the permitted specification. Finally, the tests that are carried out on the models using special testing devices in the laboratory includes.
4) Fourth chapter, the findings from testing with tables and figures providing more clarification.
5) The major conclusions and suggestions of this study are made clear in the concluding chapter, chapter five.

CHAPTER TOW

CHAPTER 2

REVIEW OF LITERATURE

2-1 Introduction

According to the modern techniques used in the manufacture of concrete structures, and to keep pace with the development in design, improve the properties, and produce semi-clean, green concrete that is free from environmental pollutants, the current research suggested conducting an experimental study and finding the optimal way to treat the fresh concrete mixture that contains different proportions of sulfate salts using the treating technique Electromagnetism, production of magnetized concrete, and guidance on the use of magnetization in the mix design.

Increasing the durability and strength of concrete is the main challenge of concrete construction. Large amounts of minerals and salts can be found in water, which shortens the longevity of a structure, through their effect on the durability of concrete **(Srinidhi et al., 2019)**.

One of the most important engineering building materials is concrete. Changes in its properties can be made through replacement or addition of special components. In the recent period, many studies have been conducted to improve the long-term performance of concrete and increase its durability because it is considered one of the important aspects of concrete sustainability in addition to the economy and the environment. In order for the world to be free of environmental pollutants and healthy and balanced, at the same time the ingredients must be balanced and healthy **(Kaushik, 2015), (al-Attar, 2018)**.

The specification of a good concrete mix depends largely on the reaction and hydration of the cement in the mix using high - quality water. Most researchers focused on incorporating nanomaterials and pozzolanic into concrete mixtures, in order to achieve a higher level of hydration mechanism of cement, and obtain high-strength concrete. Recently, a brand-new technique that has been implemented, and contributed to the enhancement the qualities of concrete through the use of magnetically treated water **(Ramalingam et al., 2022)**.

Modern technologies are among the requirements of non-traditional and modern construction to produce materials with improved quality. Many studies have recently been conducted to change the properties of the water used in concrete before the mixing process. One of these methods includes treating tap water using different magnet densities and observing the change in the results of compressive strength and mechanical properties, and flow. The magnetic field works to weaken and dismantle the hydrogen bonds inside the water clusters, which leads to the dissolution of the large water aggregates from the molecules into smaller aggregates with stronger hydrogen bonds within the clusters, where the water molecules tend to be attracted as a result of hydrogen bonding naturally **(Ramachandran, 2018)**.

2-2 The Magnetic Water Technology

2-2-1 Overview of the Magnetic Water Technique

The use of magnetized water as mixing water for concrete was initially studied by Wulachoufuski and Alnanina in Russia. Later, it was studied and developed in Japan and Europe. In China, it has been used for airports, docks, military construction, and concrete production for years. Recently, scientific interest in magnetic water technology has increased because it seems that using this technology to produce concrete is better for the environment by reducing costs and pollution because it uses less cement. By allowing ordinary tap water to flow through a certain magnetic field intensity, magnetized water is produced. The data revealed that magnetic water might improve some concrete properties such as workability, strength, bleeding property, thawing, and freezing resistance **(Al-Maliki et al., 2020), (Abdel-Magid et al., 2017).**

Furthermore, the magnetic water technique has been shown to solve the issue of sand with high sulfate concentrations; It is used in the concrete mix **(Al-Hubboubi and Abbas, 2018)**. Additionally, it is feasible to produce affordable concrete with more excellent resistance without including resistance-enhancing chemicals like fly ash **(Halstead, 1995)** and **(Ronne, 1989)**. Moreover, without utilizing any chemical admixtures, such as the high-range water reduction superplasticizer employed by ACI **(Mailvaganam et al., 1999)**.

One of the most recent discoveries to improve the strength characteristics of concrete is the use of magnetized water instead of ordinary "tap water" in the concrete mix. Since the 1980s and 1990s, magnetic water technology has experienced a substantial expansion in an application. This is because of the employment of modern magnetic treatment devices and their beneficial influence on concrete characteristics. The bulk of studies strives to build more efficient, inexpensive concrete with higher strength by incorporating innovative design concepts such as magnetically treated water **(Harsha and Sruthi, 2018)**.

2-2-2 Introduction to Magnetic Water.

Tap water that has been flowed a magnetic field to change and improve all of its qualities is referred to as magnetized water. The typical desired water in this procedure is tap water "drinkable water", which is free of contaminants. By being exposed to a magnetic field, this can be transformed into (magnetic water), as demonstrated in **Figure 2-1**.

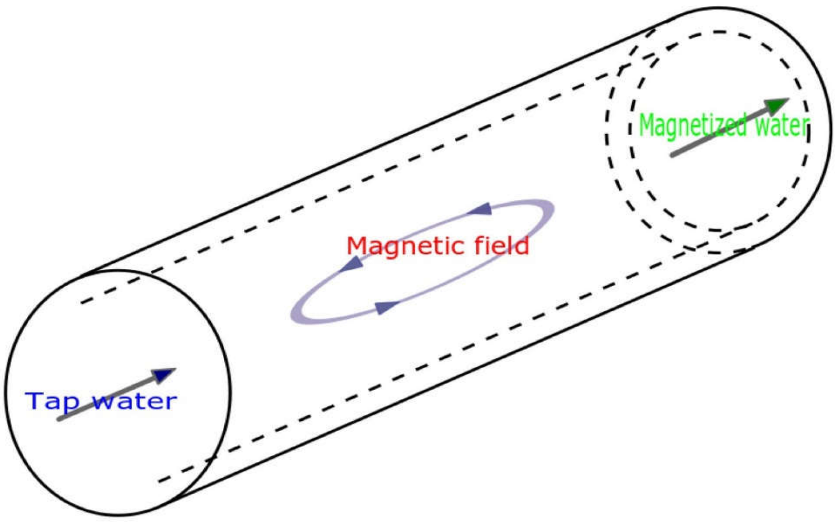


Figure 2-1 Magnetized water technology **(El-Sabrout and El-Hanoun, 2019)**.

Since there is an acute shortage of drinking water in all countries of the world, its importance cannot be emphasized. Therefore, the most efficient use of water during concrete production may be one of the means to support the infrastructure and maintain its sustainability over many years. Water is necessary for the mixing and curing of concrete, starting with the cement hydration process and continuing with the curing process to increase the strength of the concrete. The aggregates are bonded with a paste made by mixing water with cement. The water element hardens the concrete through a process called hydration. The need for water use increases with the increase in the population and the requirements of the human race. About 70% of the water is used in the agricultural sector, compared to only 20% in the industrial production sector. Concrete production consumes nearly one billion tons of water annually **(Ramachandran, 2018)**.

Great efforts are being made to preserve the sustainability of the environment and water, by activating water supply stations in a safe and efficient manner. By using magnetized water with concrete, this approach offers hope for environmental enhancement.

2-2-2-1 Magnetized water's molecular composition.

Figure 2-2 illustrates the structure of the tap water molecule, which is made up of one oxygen atom and two hydrogen atoms connected by a covalent connection at an angle of 104.5°.

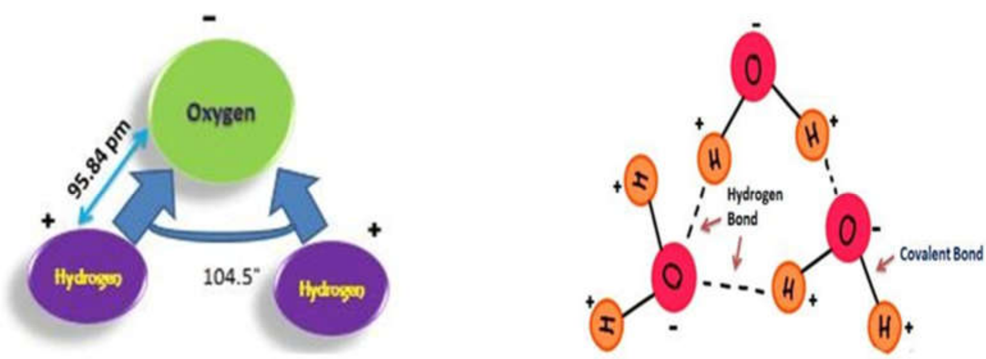


Figure 2-2 Tap water molecules' structure **(Sharma, 2018)**.

The hydrogen bond that binds water molecules together breaks apart when it travels through an area containing a magnetic field, as the level of bonding and union between water molecules decreases because energy absorption. The movement of protons and electrons around their centers of mass, as well as the rotation of electrons around the nucleus results in a magnetic field of water, which arises as a result of the work of the hydrogen atom as a permanent magnetic field. The water molecules will bind to each other in one direction and plane as they pass through a magnetic field, which will reduce their angle of association from 104 to 103 degrees **(Ziyad et al., 2015)** as depicted in **Figure 2-3**.

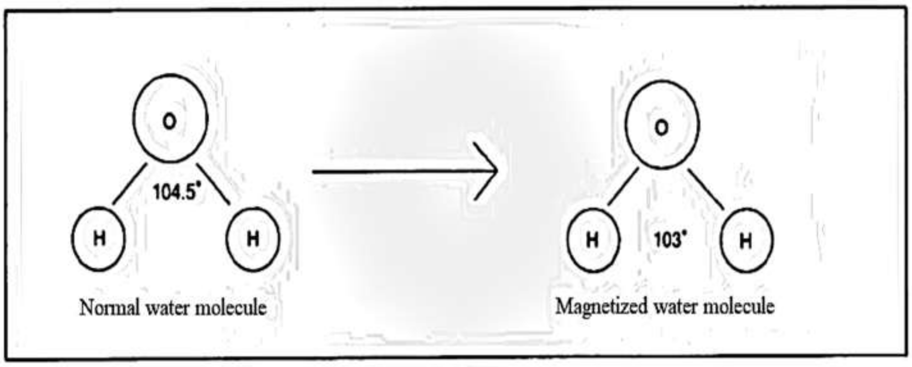


Figure 2-3 Decrease in the degree of the angle that bonds the two hydrogen atoms in the magnetic water molecule **(Venkatesh and Jagannathan, 2020)**.

2-2-2-2 Magnetized water's mechanism.

Scientifically, each group usually consists of 100 water molecules at ambient temperature, and since water is polar, it seeks to attract other molecules through hydrogen bonds, resulting in groups **(Nan and Chea-Fang, 2003)**. Water plays a number of important roles in the mixing and curing stages in the preparation of concrete, starting with process of hydrating the cement and continuing through curing stage to boost the concrete's strength. Drinkable tap water, which is devoid of pollutants, is the normal preferred water for this method. This may be transformed into "magnetic water"; by subjecting it to the magnetic field. Additionally, when bond angles change, molecules' group sizes alter from (13 to roughly five or six molecules), increasing surface area; and viscosity; and accelerating the hydration process. Typically, tap water molecules are oriented randomly, but after "magnetization," they are oriented in a single direction **(Afshin et al., 2010)**.

One oxygen atom and two hydrogen atoms are bound together in water molecules by a single triangle's angle; of approximately (104.5 degrees) by "light spectrum". When exposed to a magnetic field, drops to 103°. As the bond pairs are squeezed to be closer together by the magnetic field, this happens **(Yan MC, 2009)**, **(Shynier et al., 2014)**, as depicted in **Figure 2-4.** An increase in viscosity for water and a drop in surface tension were two changes in the chemical and physical characteristics of water; that the researchers observed when examining magnetic field effects on the formation of hydrogen bonds between molecules of water **(Ahmed, 2009)**.

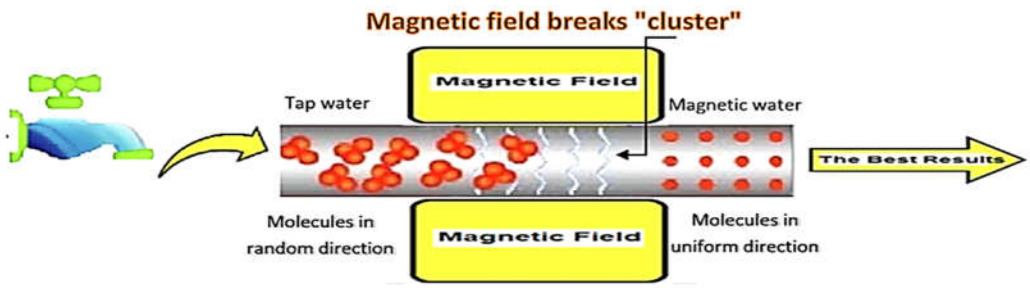


Figure 2-4 Pre- and post-magnetization arrangements of water molecules.

Thus, when traveling through the field of a magnetic, the molecules of water seem to form "clusters" of hydrogen bonds, that break apart and become smaller and more uniform, and less dense. The reduced water requirement for mixing, which has a beneficially impact on the mechanical qualities of concrete, or "the strength," is caused by the magnetized water layer surrounding particles of cement being "thinner than that of tap water" and makes hydration effective; as shown in **Figure 2-5 (Abdel-Magid et al., 2017)**, **(Abbas et al., 2022)**.

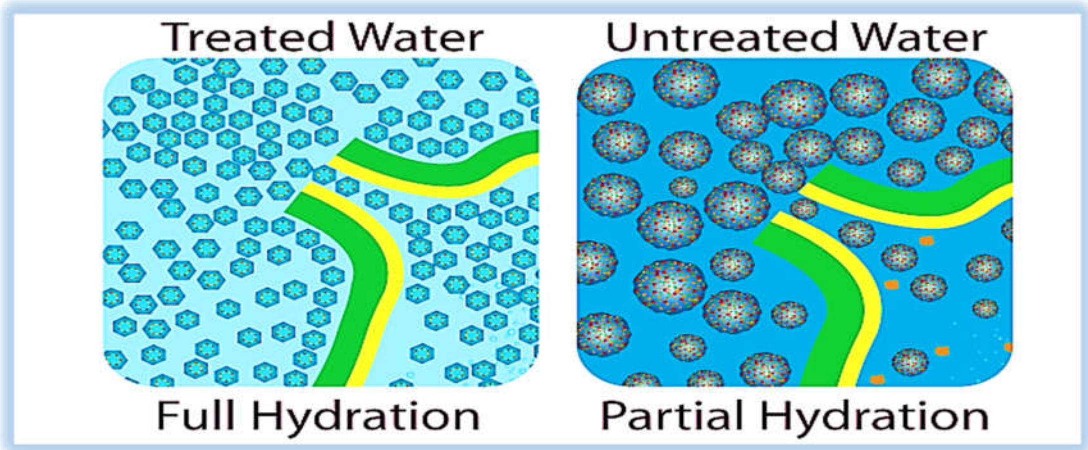


Figure 2-5 Hydration method by (magnetic water) **(Malathy et al., 2017)**.

A visual representation of the process by which the magnetic field modifies the characteristics of tap water to enhance its efficacy was created by" Omni's Magnetic Science" **Figure 2-6**.

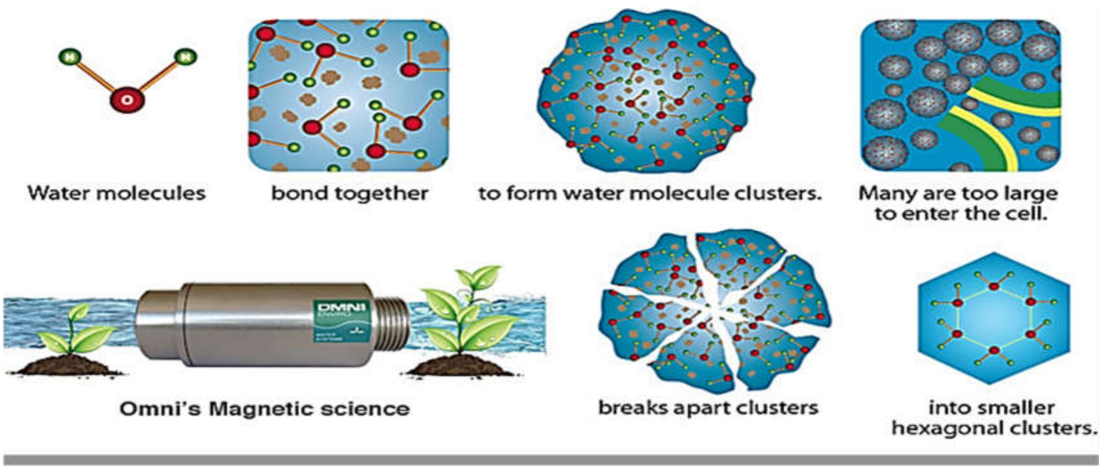


Figure 2-6 An overview of how a magnetic field affects water **(Omni Enviro water system., 2021)**.

2.2.3 A summary of Earlier Studies on the Impact of Magnetized Water, in General and on Concrete, in Particular.

With the use of the sustainable new technology known as "'magnetic water technology,'" the researchers from the following fields conducted intriguing studies. When they employed magnetized water in their work, particularly in the concrete sector, they saw hopeful results:

- **(Reddy et al., 2014)**, used magnetic water instead of tap water improved flexural strength by (25%), compressive strength by (50%). They used magnetized water at an intensity of 985 Gauss. As well as **(Harsha and Sruthi, 2018),** used magnetized water in mixed and cured, the concrete's compressive strength was (50 percent). The flexural strength of concrete that was cured in tap water after being mixed with magnetic water is also 8.5 MPa. While **(Reddy M, 2019),** utilizing magnetized water with a magnetic intensity of "0.6 tussles = 6000 Gauss" in blending concrete mix (water that has been magnetized for 24 hours). Comparing the results to regular concrete, there were 50.2, and 34.5 percent rise in compressive, and flexural. Also **(Narmatha et al., 2021)** there was an improvement of about 64% in the early ages; the magnetized water was used in mixing and curing processes.
- Additionally, they discovered that compressive strength was unaffected by a 75% reduction in cement content or more. Treating concrete with a (magnetic water) frequently provides additional "advantages" in addition to boosting compression resistance. For example, depending on the intensity of a magnetic field to treated tap water, measured in Tesla (1 Tesla = 10,000 Gauss), it boosts durability qualities by reducing water absorption and porosity **(Jain et al., 2017)**.
- In typical circumstances, it has been seen that the (compressive) strengths increase by 9 percent **(Xiao-Feng and Xing-Chun, 2013)**. While in others **(Shynier et al., 2014)** who investigated the impact of employing magnetized water with three distinct magnetic intensities , about (4.000, 6.000, and 9.250) Gauss, on concrete qualities, they discovered a 10 to 22. percent improvement in compressive strength.

While **(Karam and Al-Shamali, 2013)**, Compared the use of magnetized water to tap water as concrete's compressive strength increased by 10 to 15%. Additionally, other mechanical characteristics increased, including (flexural and splitting tensile) strength, by (7 to 28%). Comparing two-unit weights of concrete mixes prepared with ordinary water, the unit weight of the mixes made with MW without additive increased by 2.0%, and the unit weight of the mixes made with admixture increased by 6.0%. According to **Plate 2-1**, an increase in a slump of 10% to 35% is feasible when MW used.

A. Concrete prepared using normal water. **B. Concrete prepared using magnetized water.**

Plate 2-1 Fresh concrete's plasticity level "slump" varying **(Karam and Al-Shamali, 2013)**.

- **(Divya, 2020),** Based on a 22% improvement in compressive strength and up to 12% less cement, magnetic water concrete was found to have advantages over tap water concrete. Additionally, magnetized water concrete [MWC] was more workable than normal water concrete [NWC] due to its higher slump value. While **(Ramalingam et al., 2022)** work centered on assessing the microstructural behavior, fresh, and concrete's hardening behavior when made with magnetized water with a density of (0.9) Tesla. The results proved that the positive effect of magnets on the properties of the treated water showed an encouraging improvement in the properties of concrete, and this increases with increasing the period of exposure to the magnetic field. The values of increase were 25.6% for workability and 24.1% for compressive strength. Aa well as, the researcher **(Ziyad et al., 2015),** used magnetic water with a strength of 9000 Gauss to produce the best results, with increases in flexural, and compressive strength about 22, and 23.3 percent, respectively, at the age of (28) days. Moreover, compared to the reference concrete mix, there was a slight increase in the density of concrete was revealed. While **(Raouf et al., 2016)**

Found that employing replacing tap water with magnetic water for various types of reactive powder concrete; led to percentage improvements in flexural, and compressive strength of up to 18, and 24 percent at twenty-eight days, respectively.

- **(Al-Maliki et al., 2020)**, found a marginal improvement in terms of workability. When using magnetic water as an alternative to regular water to create concrete. The maximum improvement in concrete strength was achieved at 1.3 Tesla magnetic mixing water, about 17%, as well as a decrease in cement content of roughly 7.5 percent. Three different magnetic treatment water intensities (0.9, 1.1, and 1.3) Tesla were used in the study.
- **(Chibowski and Szcześ, 2018)**, pointed out that the gradient of the magnetic field is considerably more critical for the effects to occur than the strength of the magnetic field itself.
- An investigation by **(Karthik et al., 2019)**, Showed magnetized water undergoes structural changes as its exposed surface area increases in a magnetic field, and when used in concrete in place of regular water,

a noticeable increase in compressive resistance appears. This additional resistance makes it possible to reduce the cement content in concrete while still achieving the desired strength of the material.

- **(Hassan, 2008)** examined the impact of magnetized water on the characteristics of cement mortars with different water/cement ratios at the ages of 1 and 7 days, including (initial and final) setting time, consistency of concrete, and compressive strength. The results of this study revealed that using 2 different types of mixed water (Tap water and magnetized water). The Compressive strengths varied between (5.5 to 32.5) MPa, beginning setting periods were between (4 and 32) minutes, and the setting time, final was between (303 and 546) minutes.
- According to **(Srinidhi et al., 2019)** research's, recirculation time is demonstrated to rise when the value pH of magnetized water rises to 7.87 from 6.68 over the course of about an hour. When the water - to -cement ratio is 0.30 and water that has been magnetized has a 50 mm slump value, concrete becomes more workable. Compared to tap water, compressive strength has increased by 37.41% on average.
- **(Malathy et al., 2017).** The result of the research on the impact of adding "magnetic water" to concrete mix with improving workability and compressive strength of concrete. It was found that when magnetized water (MW) was used, the cement content could be reduced to 10.25 percent without affecting the strength of the concrete.
- **(Kaushik, 2015)** examined the effects of magnetic water with varying exposure times to the magnetic field. The examination included the measurement of flexural and compressive strength. The results of this investigation show that adding magnetic water to concrete mixes enhances the overall mix properties.

- **(Ahmed, 2009)** proved in his study that the use of magnetic water technology improves workability of the fresh concrete mix, and the compressive strength increases from 10-20% compared to samples prepared with ordinary tap water. The magnetic intensity used was "1.2 Tesla", the treatment time was "4.5 sec/l", and the water flow velocity was 0.71 m/s. **Table 2-1** shows the improvement results.

Table 2-1 The specimens' test results **(Ahmed, 2009)**.

specimen	The slump {mm}	At 7, 28 days, the average compressive strength is MPa.	Percent growth, at 7, 28-day.
"NA"	(20)	"27.10 , 47.3"	21%, 13%
"MA"	(65)	"32.80 , 53.4"	
"NB"	(75)	"21.10 , 36.1"	13%, 10%
"MB"	(115)	"23.90, 39.7"	
"NC"	(10)	"28.7, 48.6"	16%, 14%
"MC"	(35)	"33.4, 55.5"	

Similar research was done by **(Nwofor and Azubuike, 2020)** to determine the best duration for the use of a magnetic field to expose water and examine the impact of magnetized water on concrete's compressive strength and workability. When compared to regular concrete, the compressive strength when used water that had been subjected to magnetic fields of "336 mT"; for periods of (12, 18, 24, 36, and 96) hours increased significantly by 6.5 percent after seven days and by 17 percent at 28 days at the magnetization level of 12 to 24 hours.

- **(Jouzdani and Reisi, 2020).** They examined the effects of varying magnetic field strengths MFI= 0.6, 0.9, 1.2, and 1.5 teslas as well as varying water flow rates in various electromagnetic fields Q = (9, 18, and 27) L/min with respect to the parameters of SCC. As a starting point for the tests, tap or magnetic water was used to create four fundamental mixtures with W/C values of 0.35, 0.40, 0.45, and 0.50. The findings illustrated that utilizing magnetic water in place of tap water improved the workability of concrete and enhanced the mechanical characteristics of SCCs. MFI = (1.2 T) and Q = (9 L/min) were shown to have the strongest positive effects of magnetic water, which led to a 34.1 percent reduction in the use of superplasticizers under these circumstances. The concrete's compressive, and flexural strengths could each be improved by up to 34.1 percent, and 52.4 percent. Due to the use of magnetized water in SCC, it has been found that hydrated SCC products are denser and have less porosity than typical concrete products, as shown in **Plate 2-2**.

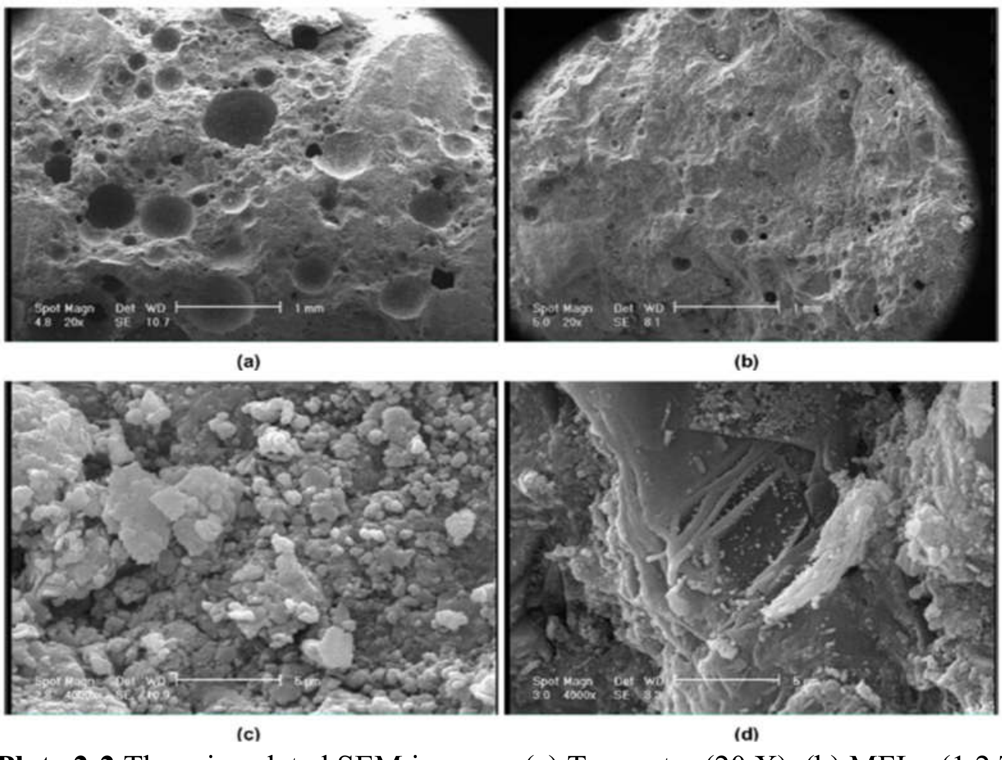


Plate 2-2 The mix-related SEM image: - (a) Tap water (20 X), (b) MFI = (1.2 T, Q = 9 L/min for MW (20 X), (c) tap water (4000 X), (d) MFI = 1.2 T, Q= 9 L/min for MW (4000 X) **(Jouzdani and Reisi, 2020)**.

- **(ELShami et al., 2022)** Conducted a study to enhance the mechanical characteristics of SCC concrete and microstructure using (MW). A group of mixtures was prepared using SF (silica fume), the weight of the cement was replaced by 5% and 10%, and the magnetic intensity that was used to treat the mixing water using permanent magnets with an intensity of "1.4 T" and the duration of the cycle (50, 100 and 50). The results of the verification proved that the mixtures prepared with magnetized water are denser and contain a high percentage of (C-S-H), and ideal results for compressive strength were obtained when using 150 MW cycles with a replacement ratio of 5% silica fume.

- **(Hashim et al., 2019)** The impact of magnetic water treatment on the rate of corrosion in pipes was investigated. They used three distinct flow rates and three different magnetic intensities, in a continuous treatment process. Before and after magnetic treatment, the rate of corrosion of samples was assessed every (60 minutes) for two hours. When the data obtained before and after the magnetized treatment were compared, it was observed that the magnetic intensity "5000 Gauss", and flow rate "0.025 l/s" changed the most, with the highest reduction in corrosion rate (88.9%). They concluded that as the frequency of exposure to the magnetic field grew and the magnetic intensity increased, so did the effect of magnetic water treatment on reducing corrosion rate in pipes.
- **(Ghorbani et al., 2021)**. Using magnetized water and granite waste dust GWD used by partial replacement with PRC cement, the mechanical properties of concrete and the toughness of samples exposed to the environment of two solutions of NaCl and H_2SO_4 were investigated. The test results illustrated that the use of MW improved the durability and mechanical properties of concrete, without taking into account the percentage inclusion of GWD.
- **(Sevim et al., 2023)**, the effects of MW on the properties of composites comprised of fly ash, blast furnace slag, and cement are examined in this article. Total of twenty-two different mixture

combinations of "FA/BFS" (0, 5, 10, 15, 20, 25%); by cement weight were made utilizing tap water "TW and MW". The solid-state characteristics of the cementitious composites "compressive strength, water absorption traits, and fast chloride ion permeability test", as well as the soft-state characteristics, were examined (initial and final setting time and consistency). The progression of wetting products was investigated utilizing "scanning electron microscopy SEM", and mercury infiltration porosimetry "MIP" testing. The findings demonstrated that the cementitious composite samples created with MW had significantly superior qualities in both their fresh and hardened states. The use of up to 25 percent (FA/BFS) in cementitious compositions made with MW is advised.

- **(Mazloom and Miri, 2017)** Studied concrete's characteristics mixed with Mw, which contains "silica fume SF", and a "superplasticizer SP", in both fresh and hardened states. The findings of this investigation revealed that (MW) improved workability and compressive strength of concrete. The positive influence on both workability and compressive strength was improved by increasing the intensity of a magnetic field utilized to produce MW. All of the fresh concrete mixes made with magnetic water (MW) had a workability that was around 35% higher than those made with tap water. The applied magnetic fields for creating magnetic water in this study were (0.09 and 0.12) Tesla. The effect of MW on improving the workability of the mixtures was also increased by increasing the magnetic field. The use of MW with superplasticizer (polycarboxylate SP), containing samples by about 15%, could increase the compressive strength. The effect of MW on boosting compressive strength was improved by increasing the magnetic field. When comparing the 28-day test results to the 90-day test results, the positive impacts of MW on enhancing compressive strength diminished. It means that MW has a smaller impact on the long-term mechanical properties of concrete than on short-term ones.

- On soil columns in the city of Basra, Iraq, tests were conducted, **(Hamza, 2019),** to estimate the rate salt removal and to calculate the amount of filter water needed in order to reduce salinity. In the samples, magnetized water (MW) with magnetic domains (1, 3, 5, 7, and 9). Various exposure times and constant flow velocities were also used. The results for reference soil columns filtered with non-magnetic water "NMW" were compared with the measurements obtained, and it was found that the percolation times for (MW) with magnetic fields (9, 7, 5, 3, and 1) were, respectively, (17.3%, 10.8%, 8.9%,7.6%, and 3.9%) faster. In addition, when the magnetic field was 9, less MW was needed for filtering.
- The study conducted by **(Karkush et al., 2019)** looked at the rapid increase in the use of magnetized water in a number of scientific fields as well as the effects of levels of different magnet strengths; on the electrical and chemical characteristic of tap water; that has undergone reverse osmosis treatment. The project examined the use of magnetized water in several scientific fields, particularly in enhancing the chemical and geotechnical properties of soil and water treatment. Investigations have also been made into how different magnetic field strengths affect the electrical and chemical properties of water that has undergone reverse osmosis and ozone treatment. The use of this water can enhance the geotechnical properties of the swollen soil.
- **(Ahmed and Manar, 2021)** carried out an experimental research to determine the best technique for magnetic treating of mixtures and developed guidelines for its usage in the formulation of concrete mixtures. it looked at six magnetic intensities: 25, 50, 100, 200, 400,

and 500 mT. The pilot program took into account more than 180 samples. Each experiment divided the fresh mixture into 2 portions. The first portion is unprocessed, while the second portion is subjected to a magnetic field. Checks were made on the workability and mechanical characteristics. The compressive strength of concrete mixes increased significantly by up to 16%, according to experimental results. A processing flow density of 400 m T resulted in the largest gains in workability, which ranged from 7% to 26%. When fresh mixes were magnetically cured, the flexural and tensile strength also increased. The study results showed that when performing magnetic treating of mixes, it is possible to use the potential for water reduction and recombination while keeping equivalent workability.

2.2.4 Sulfate of Aggregate, and Magnetic Water Technology.

2.2.4.1 Attack by Sulfates "an Internal Sulfate Attack"

Salinity in aggregate, soil, and water is an issue in the Middle East, especially Iraq, as well as other nations, as a result of rising temperatures brought on by global warming and a lack of water supplies that can be used to irrigate crops, which has accelerated desertification. The internal attack of sulfate salts in the aggregate generally is one of the major issues that endanger the strength and durability of concrete. In pores and aggregate surfaces, tap water contains a significant amount of low-soluble sulfate salts, the most significant of which is calcium sulfate.

About 95% of the sulfate salt in aggregate in Iraq is calcium sulfate, with the remainder being sodium, potassium, and magnesium sulfate. Due to the addition of gypsum to cement during the grinding stage, to regulate the speed of hydration and the time of cement paste and assist the grinding process, calcium sulfate (gypsum) is more significant for this type of attack **(Al-galawi and Hassooni, 2016)**.

The source of sulfates in concrete is one of the factors that lead to the attack of internal sulfates. The source of these sulfates comes from the incorporation of water and sulfates present in the aggregate, as well as gypsum that is added to cement during the grinding process to regulate the setting time, as well as external environmental factors **(Campos et al., 2016)**. **Plate 2-3** illustrates the concrete damage brought on by internal sulfate attack.

Plate 2-3 Internal sulfate attack causes damage to concrete **(Eng-Tips.com., 2019)**.

2.2.4.2 Ettringite Formation and Degradation Caused by Delayed Ettringite.

The sulfates inside the concrete are attacked by the reaction between the sulfate of aggregate and (C_3A- Tricalcium aluminate), which are cement hydration products, which results in " $3CaO.Al_2O_3.3CaSO4.31H_2O$ " which is the compound ettringite **(Zhang and Li, 2016)**.

Due to the volume increase and significant internal stresses, this compound produces, concrete's durability is decreased, and its mechanical qualities are negatively impacted **(De Souza et al., 2020, Al-Hubboubi and Abbas, ,2018, al-Attar, 2018, Al-Obaidy, 2017, Horkoss et al., 2016)**.

Ettringite production is to blame for the majority of concrete structure expansion and deterioration **(Kharchenco and Alekseev, 2019), (Merida and Kharchi, 2015)** according to **Plate 2-4**.

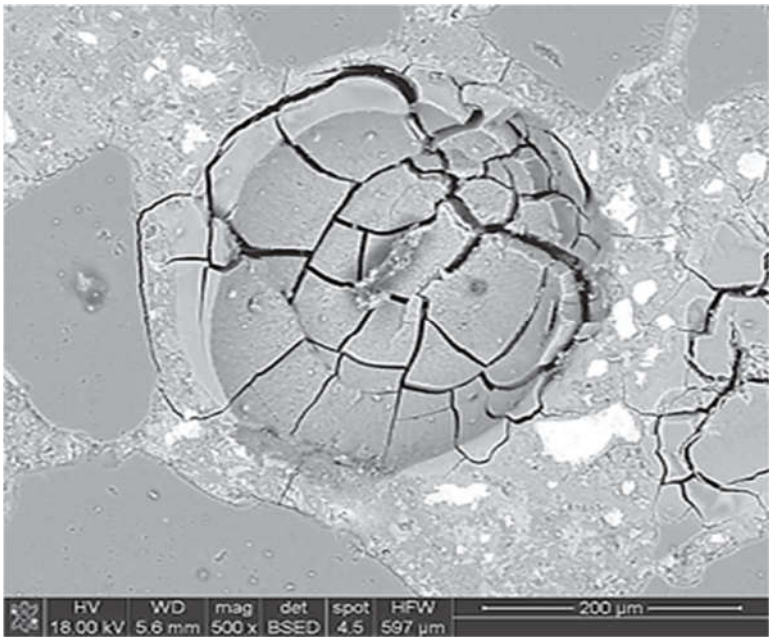


Plate 2-4 Concrete destruction brought on by the production of ettringite **(Owsiak, 2010).**

Ettringite compound is formed in two phases, the first of which is known as "early elevation formation" (EEF), which occurs directly within the first hours after mixing and pouring the concrete components and is safe for concrete, as shown in the following reaction.

$C_3A + 3(CaSO_4.2H_2O) + 26H_2O \rightarrow C_3A.3CS.H32$

After several months or even years of pouring concrete, a so-called "secondary ettringite" stage known as "Delayed Ettringite Formation" DEF occurs and causes the cracking of concrete structures as a result of excessive heat-treatment temperatures **(Kadhim et al., 2020)**.

According to **Figure 2-7**, the expansion mechanism can be considered as including the following elements: increase in solid volumes; expansion in overhead chemical reactions; directed crystal growth; crystallization stresses, the onset of the bulge; osmotic pressure; and local reversal of dehydration.

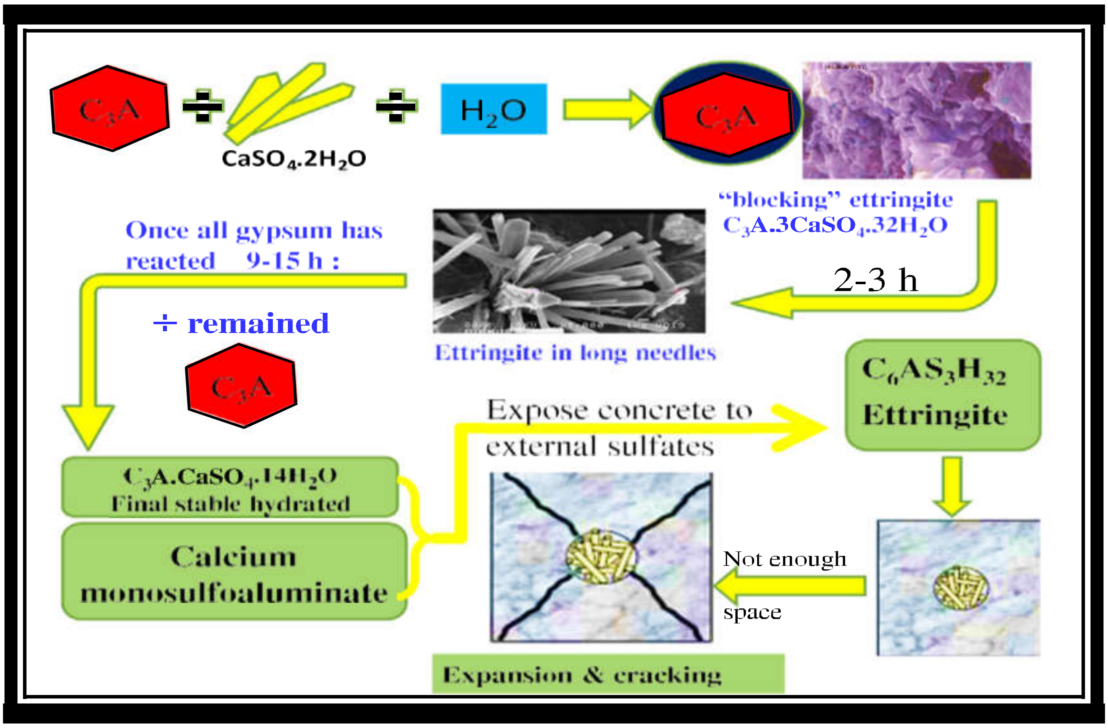


Figure 2-7 The mechanism illustrates the attack of sulfates and ettringite **(Hodhod and Salama, 2013).**

<u>2.2.4.3 Earlier Investigations on how Sulfate Affects the Characteristics of Concrete.</u>

The change in the performance of cement concrete under different climatic circumstances reflects its vulnerability to external/internal chemical attacks, particularly sulfate attacks **(Nadir and Ahmed, 2022)**.

Many researchers have examined the exterior and internal effects of sulfate in concrete on the characteristics of concrete, and they have found that the strength of concrete significantly decreases with time, especially as it ages **(Kadhim et al., 2020), (Gorgis et al., 2018), (Saleh, 2017)**.

The researchers **(Fawzi et al., 2015)** Looked into how much SO_3 was present in various materials, including sand, cement, and gravel, as well as the difference between total and total effective SO_3 content. In the investigation, 2 groups of SO_3 in cement, 3 groups in the sand, and 2 groups in gravel were used. According to the findings, it is preferable to examine the total effective SO_3 content as opposed to the total SO_3 content because, depending on the granular size, SO3 will have a different effect on each component of concrete. The compressive strength data after 90 days show that a reduction in compressive strength of (7.53, 11.44, 14.59) percent is caused by the total effective content of SO_3 (2.647, 2.992, 3.244) percent, which is equal to the total SO_3 (3.778, 3.294, 4.528) percent.

(Jihad, 2009) the properties of concrete made of fine aggregates with a concentration of SO_3 (2.33%) higher than the Iraqi standard limits of 0.5% were investigated. While it was determined that the total SO_3 level of the mixture was within specifications (IQS NO.45/1984), the tensile, compressive, and flexural strengths were not less than (94, 80, 84) percent when compared to the 180-day-old control mixture.

(Kadhim et al., 2020) By substituting type I cement with 20% silica fume for some of the regular cement, researchers looked at how internal sulfate attack "ISA" affected some properties of lightweight concrete "LWC" and regular concrete "NC". Another one resists the internal effects of SO_3; 3 and 6 percent by using (SRPC) rather than class I. The ages of 28, 60, and 90 days, respectively, the presence of 3% SO_3 in "NC" reduces compressive strength by 7%, 33.5, and 43.8% percent. The compressive strength of NC drops by 3.6, 38.3, and 49.3 percent at ages 28, 60, and 90, respectively, when the SO_3 percentage is raised to 6%. The tensile and compressive strength at later ages was reduced for both (NC and LWC) when the SO_3 percentage was increased by up to 6%. "28 days and more".

(Chen et al., 2020), the initial compressive strength of concrete was found to be 25% lower when the sand included 0.5–1.5 percent SO_3. Additionally, the initial compressive strength of samples with sand concentrations of 3-7% SO_3 decreased by 38%.

The effect of internal and external concrete effects of SO_3 on high-performance and normal concrete was studied **(Saleh, 2017)**. This experiment aims to investigate the effects of a highly concentrated external SO_3 solution on the compressive strength of a concrete mixture with two different internal concentrations of SO_3. The researcher used locally available sand with a normal SO_3 content of 0.2% and a non-standard SO_3 content of 1.13%. According to the results, the compressive strength growth increases continuously in the samples immersed in tap water; however, the development rate of concrete decreases with the decrease of the water/cement ratio.

In a 360-day study, **(Touma, 2008),** examined the impact of internal and external SO_3; on the Compressive strength of high-performance concrete and plain silica fume concrete. When calcium sulfate is added to the concrete mixtures in the ratio of (3%, 5%, and 7%) by weight of sand, respectively, after 28 days of curing, the compressive strength of the concrete decreases by (50.9%, 65.5%, and 66.73%). The data also indicated that the percentage of cement content increased by 3%, 9%, and 11% in concrete mixtures containing calcium sulfate by sand weight by 3%, 5%, and 7%.

A study of concrete mixes using sand with sulfate contents of (1.5 and 3)%, **(Al-Obaidi, 2014)** found that the compressive strength increased early on and then degreased as the concrete aged.

(Colman et al., 2020) Internal sulfate attack may result from some recycled materials such as fine aggregate containing gypsum residue "FRA". In this case, gypsum contamination of the aggregate provides sulfate rather than the well-known external sulfate attack or delayed ettringite formation "DEF". In order to identify the variables that affected the sulfate attack reaction, a set of different environments was applied to treat cement slurry prepared with contaminated FRA. The mechanical properties and microstructure of concrete were investigated. According to the results, gypsum content, porosity, temperature, and alkalinity all have an influence on sulfate attack effects. On the other hand, the type of cement and the size distribution of gypsum was not.

2.2.4.4 Using the Magnetic Water Technique, Aggregate Sulfate (from sand and crushed gravel) was Treated in conjunction with earlier research.

In the realm of green energy, a novel technique used to solve a significant issue in Iraq and other nations is the use of magnetized water to exclude sulfate salts from aggregates (crushed gravel and sand).

Washing the aggregates with tap water did not assist remove the sulfate since the standards for measuring the proportion of SO_3 sulfates in aggregates used in concrete works call for dissolving the aggregates in hydraulic acid.

(Ibrahim and Abbas, 2021a) A study was carried out to find out the possibility of using magnetic water and its ability to eliminate the high percentage of sulfate SO_3 by washing sand with magnetic water. The laboratory work included two stages: in the first stage, magnetic water was produced in the laboratory using a magnet strength of 9000 Gausses, while the second stage included the manufacture of a highly efficient device for the purpose of washing the sand used in the concrete. Two percentages of the sulfate content of the fine aggregate were used with the reference mixes, (0.2%) with the 1st concrete mix; and 2.1 percent with the 2nd mix. The laboratory results demonstrated an improvement in the mechanical properties of concrete using treated sand compared to the reference mixtures that used untreated sand, as well as the efficiency of the technique used to reduce the percentage of sulfate salts in the sand.

High sulfate content in the sand is a problem that has been successfully solved using magnetic water technology. A patent was secured by the researchers **(Al-Hubboubi and Abbas, 2018)** for their simple and inexpensive magnetic water approach for washing and cleaning sand that solely contains sulfate salts. However, in addition to the fact that the technique has not been tested on coarse aggregates, they were unable to develop a device that can wash huge quantities at a rapid rate. They washed numerous samples of sand with different "SO_3" levels of (0.3, 0.8, and 3 percent) with magnetic water about (12, 8, 4, and 2) a liter, requiring one liter for every kilogram of sand; with intensity (9000 and 5000) Gauss. One kilogram of sand containing three percent SO_3 requires eight liters of magnetic water with a "9000 Gauss" intensity, and the amount of magnetized water needed reduces as the percentage of SO_3 in the sand lowers.

The issue of high sulfate salts (3.54) percent in the fine aggregate "sand" used in reactive powder concrete was addressed by the researchers **(Khreef and Abbas, 2021a)** Who have done on experiment with various treatment approaches. It was discovered that the compressive and flexural strength of magnetized water was higher than tap water when used to wash sulfate salts.

Using the magnetized water approach with a magnet intensity "1500 Gauss" for the leaching of soil salts, the experimental investigation was conducted by **(AL- Juthery et al., 2013)**, and the results indicated a significant decrease in the concentration of soil salts when utilizing magnetic water in the washing process instead of "tap water".

In order to remove scaling salts (sulfate salts, carbonate, and chloride of Ca_2+, Mg_2+, Fe_3+ cations +, and Fe_2) from power heat-exchanger devices and pipelines, this review article **(Mosin and Ignatov, 2015)** provides an overview of current trends and modern methods for implementing magnetic water treatment. The type of physical and chemical dissolution and crystallization processes are affected by magnetic water treatment, as well as the water, mechanical impurities, scale-forming salts, and ions.

2.2.4.5 Improving Concrete Properties Using Magnetic Treating Technique with the Previous Study

The technology of magnetic treatment of sulfate salts present in the sand within the concrete mixture is one of the modern methods that falls within the field of clean and green environmentally friendly energy, and works to address the problem of salts, where are more dangerous to concrete in Iraq.

The process in this research included two phases: the phase of manufacturing a local device to work efficiently when used in treating fresh concrete and the phase of testing three magnetic intensities to choose the highest strength of hardened concrete. The results of laboratory tests proved the efficiency and success of this technique in limiting and minimizing the negative impact of high sulfate levels in the sand, especially those that exceed the permissible limit in the specific Iraqi specification (No. 45 of 1984), which stipulates that it is not more than 0.5% in the sand.

How to use this device and the possibility of linking it to the concrete pumping machine when pouring at the work site were discussed and studied. There is an urgent need to sulfate treatment in fresh concrete using modern technology, as magnetic field treatment technology is one of the most recent methods. Magnetic technology devices cause a strong concentration of magnetic field that penetrates the wall of the concrete pipe passing through it. The strong magnetic field reaches and affects the concrete mixture and works to bring about a change in the chemical and physical properties of the mixture of water and the constituent materials of the concrete because of its effect on the hydrogen bond that connects the water molecules. The disintegration of the bonds between the water molecules causes an increase in the movement of the salts, which makes them more capable of solubility.

Much of the experimental study that was previously conducted focused on the magnetization of water only for use in concrete mixtures through the use of the magnetic field. Recently, a study was conducted by **(Ahmed and Manar, 2021)** to provide magnetic treatment of different intensities on the wet concrete sample after placing it in the mold, and the treatment is on a sample concrete in one direction, the principle of operation in this way is quite similar to the MRI scanner. In the experiment, magnetic intensities of 25, 50, 100, 200, 400, and 500 mT were used to treat the concrete sample. The fresh concrete mixture was divided into 2 groups, the first group was untreated, and the second group was placed in a mold and exposed to the magnetic field. The results showed a clear improvement in the compressive strength of 16%, and the best workability was recorded when treating (400 mT). In addition, the study recommended the possibility of water reduction while maintaining the same workability when treating.

There haven't been any studies conducted on the application of magnetic treatment for fresh concrete mixtures, including various ratios of sulfate salts in the sand, to limit and reduce its detrimental influence on the properties of concrete after hardening, either internationally or locally.

2-3 The System's Working Principle

The system's working principle is mainly based on using electromagnets to process concrete prepared using fine aggregate with different percentages of sulfate salts in the sand, including the portion that does not match the IQS. Thus, the possibility of reducing the negative impact of sulfates on concrete after hardening to obtain compressive and bending resistance within the acceptable and standard limits of the specified specifications. AC direct current was used to generate the electromagnetic field used in the treatment.

The device is locally made and consists of four pieces of magnets which are copper coils wrapped around a wrought iron core and completely insulated by a clip insulator to provide safety and reduce heat when the device is used in the laboratory and is connected in series. Attached to the device is the operating box, which includes the main circuit breaker and the secondary circuit breaker number 3, for three stages of magnetic intensity. It also contains heat reducers and side fans to reduce high temperatures when working for long periods. **Plate 2-5** shows the details of the magnet piece during the winding of the wire and the final shape and shows the parts of the operation box. The device was fed with direct electric current (220 volts). The device can also be powered by a generator or batteries. The box attached to the device includes the main operating switches (the main circuit breaker), whose work is in a closed circuit, where one of the lines is connected to the magnets in a row, and the second line is connected to the heat reducer. It also includes three secondary circuit breakers to raise the magnetic field strength in three phases. During the work, three different magnet intensity values were obtained, measured, and verified by a magnetic field measuring device (Tesla meter), where the readings were (2000, 2500, 3000) Gauss.

Plate 2-5 - Details of the electromagnet device.

2-4 The Most Important Characteristic of Magnetic Treating Technology for Fresh Concrete in the Current Work.

1. The device used in the current work generates magnetic fields with different magnetic intensities (2000, 2500, 3000) Gauss, and performs two operations at the same time:

- Production of magnetized water using the maximum magnetic intensity (3000) Gauss.
- Treating the concrete mixture and improving the mechanical properties.

2- The device can be used at the work site with the concrete pump during the pouring process by connecting it from a direct energy source or through the battery.

3 - It can provide an effective economic return by reducing the use of additives to improve the fresh and hardened properties through the new technology used to improve the properties of concrete.

4 - This technology is renewable, clean, and green energy.

5 - The principle of this technique depends on the electromagnet, which is characterized by its low manufacturing cost compared to the encouraging results in improving the compressive strength, in addition to the long operational life of the magnet devices.

CHAPTER THREE

CHAPTER 3

Experimental Works and Materials

3.1 Introduction

This chapter includes information on the ingredients, treatment method, mixes, mixing procedure, casting, and curing. The investigation used a variety of testing techniques.

The primary goal is to investigate the use of an electromagnetic field technique to create magnetized concrete by allowing the concrete mixture to flow through a tube of a device that is exposed to the electromagnetic field, hence improving the mechanical characteristics of hardened concrete. Considering that the gypsum salts in the aggregates are poorly soluble and cannot be easily removed by washing with tap water, it is also necessary to solve the issue of sulfate in aggregates (sand) by using a new technique.

The tests performed on the samples of concrete utilized in this research are described in detail, including:

1) Fresh concrete tests "slump flow test."

2) Compressive Strength.

3) Flexural Strength.

Concrete is a composite material comprised of sand, gravel , water, and cement, thus knowing its qualities is crucial.

These materials have traits like (water content, specific gravity, unit weight, and gradation).

The materials' origins, chemical compositions, and physical qualities were tested at the "University of Babylon's College of Engineering," Civil Engineering Department laboratories.

3.2 Diagram of the Research Process

Two phases make up the experimental effort for this study. The initial stage involved the selection, preparation, and assessment of the raw materials' physical and chemical qualities. In order to choose best-combining weight proportions and concrete type, this phase also includes trail mixtures. The chosen materials were then combined using the best mixing ratio, and cast samples were then cured for the necessary amounts of time (7, 28, and 90 days). Samples were looked in the second step. The flowchart shown in **Figure (3-1)** illustrates the overall experimental inquiry.

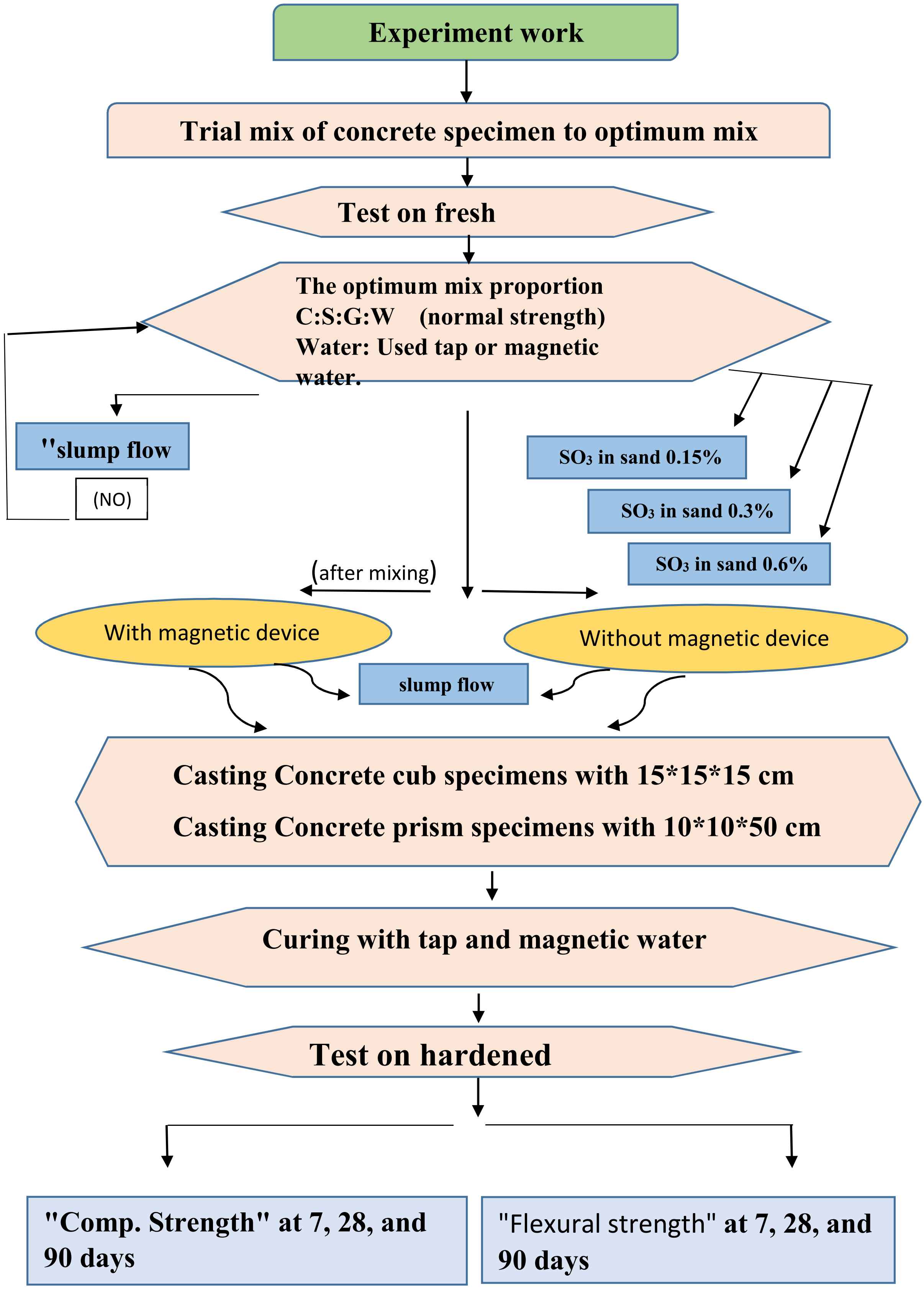


Figure (3-1): The research plan's flow chart.

3.3 Materials

3.3.1 Blended Cement

The types of cement used in this work were ordinary Portland cement and sulfate resistance cement (OPC, RPC) which is commercially known as **"Mass."**

It was manufactured in Sulaimanya city, and it was taken from local markets. According to Iraqi Specification 5, the cement was classified as regular Portland cement **(Iraqi standard specification no.5., 2019)**, with high early strength class 42.5 R (IQS 5 - CEM I 42.5 R). It was kept in a dry place to shield it from exposure to different atmospheric conditions.

Chemical evaluation; and physical characteristics, that are within the **Iraqi Spesification 5, 2019. Tables (3-1)** and **(3-2)** contain descriptions of the used cement, respectively.

Table (3- 1): OPC's chemical composition and main compounds.

Test name	Contents (by weight %)	Limits of Iraqi Specification NO.5/2019 (42.5 R)
"Lime –CaO"	60.60	---
"ilica -SiO_2 "	19.80	---
"Alumina - Al_2O_3 "	4.80	---
"Iron oxide - Fe_2O_3 "	3.00	---
"Magnesia – MgO "	3.50	≤ 5.0%
"Sulfate - SO_3 "	2.22	≤ 2.8% **if** C_3A > 3.5%
"Loss on Ignition - L.O.I. "	3.10	≤ 4.0%
"Insoluble residue - I.R. "	0.70	≤ 1.5%
(OPC' main compounds" Bogue's Eq.")		
[C_3S] - "Tricalcium silicate"	59.63	
[C_2S] - "Dicalcium silicate"	11.78	
[C_3A] - "Tricalcium aluminate "	7.64	
[C_4AF] - "Tetracalcium alumino-ferrite"	9.12	

Table 3 - 2: (Physical characteristics of OPC).

testing name	"Results"	Limitations of (Iraqi Specification) No. 5/2019 (42.5 R)
Fineness (Blaine method), (m^2/kg)	320	≥ 280
Setting time (Vicat's method), Initial setting time (min.) Final setting time (hr.)	90 5	≥ 45 ≤ 10
Compressive strength (MPa), Early strength (2 days) Standard strength (28 days)	24 42.63	≥ 20 ≥ 42.5

Tables (3-3) and (3-4) provide information on portland cement's chemical and physical properties resistant to sulfates, in accordance with Iraqi Standard Specification **(Iraqi standard specification no.5., 2019)**.

Table 3.3: SRPC's main chemical components and composition.

Test name	(Contents by weight %)	Limits of Iraqi Specification NO.5/2019 (42.5 R)
"Lime – CaO"	62.10	---
"Silica - SiO_2 "	20.30	---
"Alumina - Al_2O_3 "	4.07	---
"Iron oxide - Fe_2O_3 "	5.17	---
"Magnesia - MgO"	1.75	≤5.0 %
"Sulfate - SO_3 "	2.33	≤ 2.5% if C_3A ≤ 3.5%
"Loss on Ignition L.O.I. "	3.61	≤4.0 %
"Insoluble residue- I.R. "	0.55	≤1.5 %
(OPC main compounds" Bogue's Eq.")		
[C_3S] Tricalcium silicate	63.73	---
[C_2S] Dicalcium silicate	10.27	---
[C_3A] Tricalcium aluminate	2.04	≤3.5%
[C_4AF] Tetracalcium alumino-ferrite	15.74	---

Table 3. 4: Physical properties of SRPC.

testing name	Results	Limits of (Iraqi Specification NO.5/2019 (42.5 R)
Fineness "Blaine method, m^2/kg"	335	≥ 300
Time setting " Vicat's method" **time of initial setting "hr.: min"** **time of Final setting "hr. : min"**	2:23 3:10	≥ 45 ≤ 10
Compressive strength (MPa), **Early strength (2 days)** **Standard strength (28 days)**	25.4 44.30	≥ 20 ≥ 42.5

3.3.2 Aggregate Fines (Sand)

For this project's concrete mixes, a fine aggregate, natural sand from the AL-Nabaei region, was used. Aggregates were used for concrete mix under saturated and surface-dry conditions. Testing the aggregate samples physically and chemically were checked with the **Iraqi Spesification 45,** as shown in **Table (3-5);** different SO_3 contents were chosen to investigate the efficiency of the magnetized concrete technique **(Iraqi standard specificationNo.45., 1984)**. The grading of the three samples which are used in the mix design lies in zone **(2),** according to **Table (3-6)**. In the Building Materials and health Laboratories, tests were established in the department of civil engineering at the university of Babylon, as shown in **Figure (3-1)**. **Plate (3-1)** Shows the process of checking the percentage of sulfates in the sand**.**

Table (3- 5): Aggregates' physical and chemical characteristics.

Test name	Sample 1	Sample 2	Sample 3	Limits of Iraqi specification NO.45/1984
Sulfate content,%	0.15	0.3	0.6	≤ 0.50%
Specific gravity	2.58	2.57	2.58	-
Fineness modulus	2.61	2.70	2.58	-
Absorption , %	0.78	0.82	0.80	-

Table (3- 6) The fine aggregate's grade.

Sieve Size (mm)	Cum. Passing% for sample 1	Cum. Passing% for sample 2	Cum. Passing% for sample 3	Limits of the Iraqi specification NO.45/1984 zone (2)
10	100	100	100	100
4.75	93.3	100	94	90-100
2.36	77.7	80.96	83	75-100
1.18	64.6	67.29	73	55-90
0.60	54.4	54.22	59	35-59
0.30	26.3	22.89	27	8-30
0.15	3.1	4.22	6	0-10

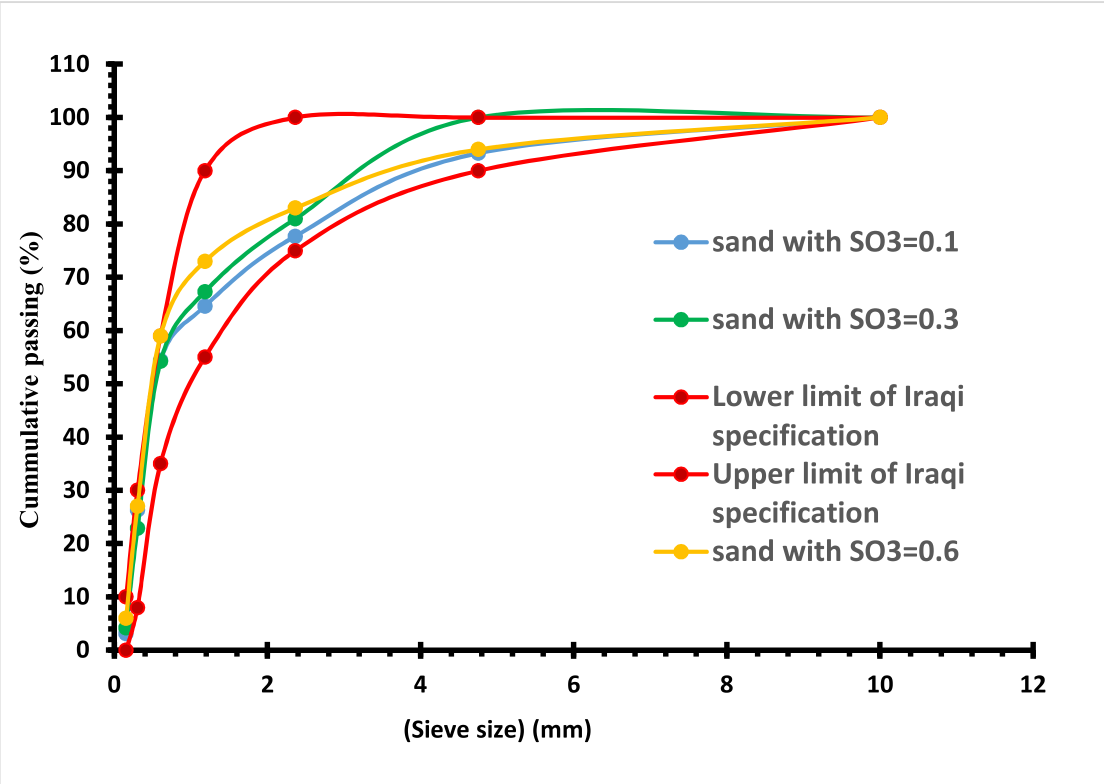


Figure (3-1) Grading of fine aggregates for samples 1, 2 and 3

Plate (3-1) Sand sulfate content measurement.

3.3.3 Crushed Coarse Aggregate.

In the AL-Nibaai region in Iraq, the (coarse aggregate) was employed as a crushed gravel with an approximate maximum size of 20 millimeters. Before use, the gravel is washed, exposed to air to dry its surface, and stored in containers on a moist, dry surface. As stated in **Table (3-7)**, physical and chemical examinations of the aggregate sample were performed using the Iraqi Specification **(Iraqi standard specificationNo.45., 1984); Table (3-8)** and **Figure (3-2)** show how it was graded. In the Civil Engineering Department's building materials lab at the University of Babylon, tests were set up.

Table (3- 7) Crushed coarse aggregate's physical and chemical characteristics.

properties	Results of the Sample's test	Limit of the Iraqi specification(NO.45/1984) (5-20) mm
(Specific gravity)	2.7	-
(Sulfate content) , SO_3 %	0.03	≤ 0.1 %
(Dry rodded density), kg/m³	1650	
(Absorption%)	0.52	-

Table (3- 8) Crushed coarse aggregate size distribution.

Sieve Size (mm)	Cumulative Passing% for sample	Limits of the Iraqi specification NO.45/1984 of (5-20)mm
37.5	100	100
20	97.14	95-100
10	33.46	30-60
4.75	0.12	0-10

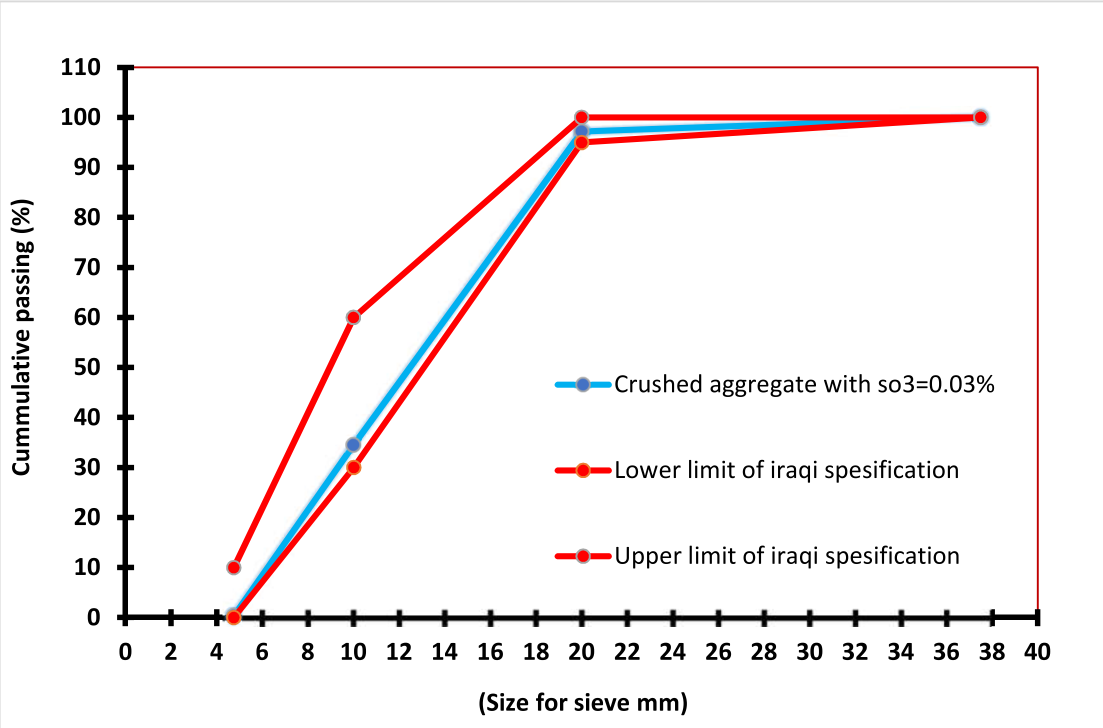


Figure (3-2), crushed aggregate grading.

3.3.4. Blending Water.

Water from the tap, from Babel City's IQS 1703/1992-compliant water supply system **(Iraqi Specification. , 1992)** was used to blend and cure cases of magnetic and tap water. The magnetic water apparatus utilized here generates electromagnetic waves. To get magnetized water, the tap water valve was opened, and the 3000 Gauss electromagnet was utilized to magnetize the water. The magnetic field intensity was measured using a Tesla meter. As illustrated in **Plate (3-2) (a, b)**, To prevent losing its quality, magnetic water should be Collected in an empty container; and used as quickly as Possible. Magnetic water used in curing was replaced every three days to preserve its beneficial attributes.

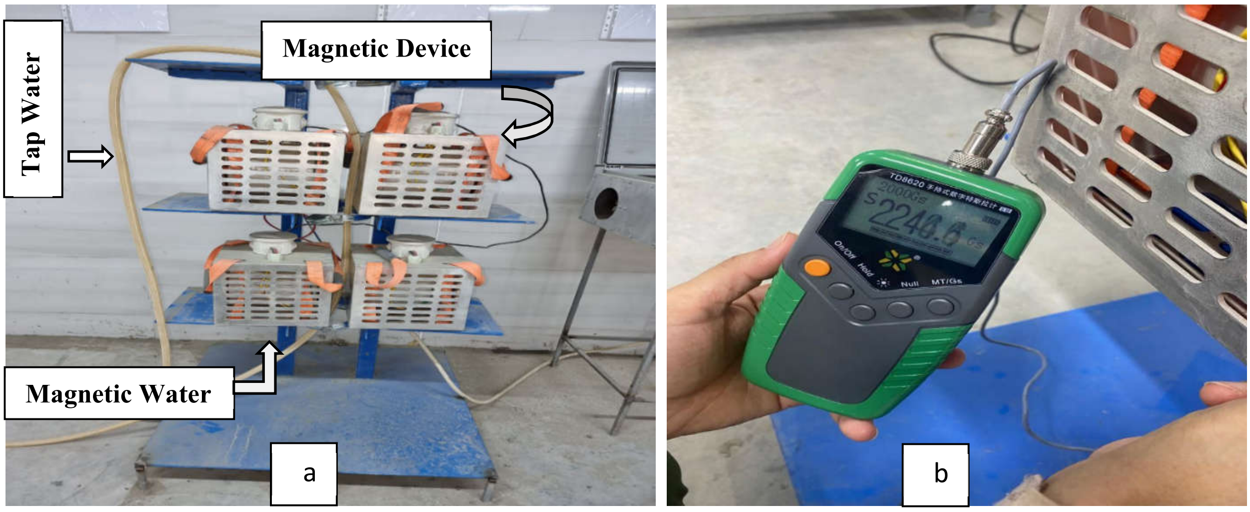


Plate (3-2) (a) The apparatus for preparing electromagnetic water and (b) the tesla meter for measuring the magnet's intensity.

3.4 Design Mix.

A reference mix with the necessary cylinder compressive strength (30 MPa) was made using the American mixed-method design ACI (ACI 211.1-91, 1991), which at twenty-eight days of age produced a cube compressive strength of 37.5 MPa. All the mixtures ranged in a slump from 75 to 100 mm and contained 1.024 kg/m^3 of crushed aggregate, 699 kg/m^3 of fine aggregate, 417.52 kg/m^3 of cement, and 205 kg/m^3 of water, with a water/cement ratio of 0.43, as shown in **Table (3-9)** and 1:1.7:2.45 for the ratios of cement, sand, and crushed aggregate.

Table (3-9) Materials used to make concrete that complies with ACI 211.1-2002.

stated compressive strength of the cylinder (MPa)	content of cement kg/m^3	content of Sand kg/m^3	content of Gravel kg/m^3	content of water kg/m^3
30	417.52	699	1024	205

3.5 Laboratory Procedures for Concrete Test Specimen Manufacturing and Curing.

In accordance with **(ASTM C192., 2016)**, standard operating procedures for the selection of materials, mixing of concrete, manufacture and curing of concrete, and test samples were developed.

3.5.1 Material Preparation

Before mixing, the concrete materials should be brought to room temperature, which is between 20 and 30 degrees Celsius. The cement must be kept in a dry place, and aggregates must be both wet and dry on the surface when they are used.

3.5.2 Concrete Mixing

Just before the mixer started rotating, gravel and a small amount of mixing water were added, as shown in the **Plate (3-3)**. Sand, cement, and mixing water should be added while the mixer is running until the mixture is consistent. Mix the concrete for 3 minutes after all the ingredients have been added to the mixer, then wait three minutes before blending it again (2 minutes). When the device is at rest, cover the open end or top of the mixer to stop evaporation.

Plate (3-3): used concrete mixer

3.5.3 Exposing the Concrete Mixture to Electromagnetic Field.

The principle of the system's work is based on the use of an electromagnetic wave device to produce magnetized concrete by passing it through the device tube with a diameter of 4 inches. Three different proportions of sulfate salts were used in the sand used for concrete mixes (0.15, 0.3, 0.6%), where each concrete mix was compared with a specific proportion of sulfate and treated with the electromagnetic wave device with its untreated reference mix with the same percentage of sulfate salts.

Thus, a clear improvement was obtained in the mechanical properties of magnetic concrete and exposed to electromagnetic waves. The work of the entire system of the electromagnetic device is shown in **Plate (3-4)**.

The device contains from:

- Four pieces of an electromagnet,
- Which is an iron core wrapped around a copper wire,
- Through which a tube with a diameter of 4 inches passes.
- The device joins the operating box that includes the main operating switch (a main circuit breaker), and it also includes three secondary

operating switches (a secondary circuit breaker); each operating switch generates an electromagnetic field intensity,

- The electromagnetic field intensity of the first, second, and third cycle circuit breaker is about (2000, 2500, 3000) Gaus, respectively.
- The intensity of the electromagnetic field was measured laboratory; using a Tesla meter, as shown in the **Plate (3-5)**.

Plate (3-4): The complete system of electromagnetic apparatus used.

Plate (3-5): Using a Tesla meter to measure the intensity of the electromagnetic field in the laboratory

To produce magnetized concrete, the electromagnetic device used was a new technology and method. The stages of organization for the production of magnetized concrete were clarified, as shown in **Plate (3-6)**.

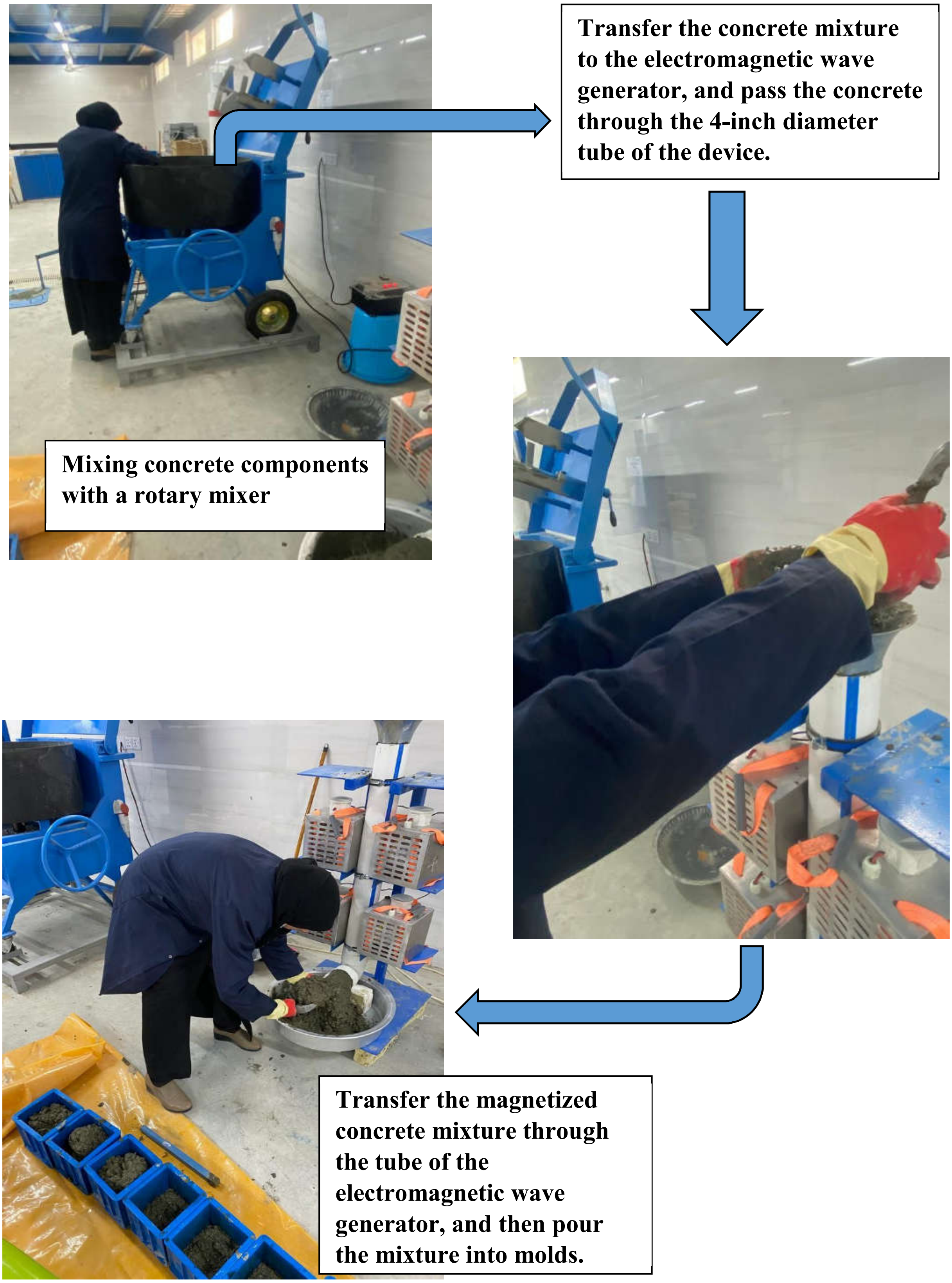


Plate (3-6): A magnetic concrete production process diagram.

The process of producing magnetized concrete is explained below:

- Preparing the concrete mix. The concrete components (gravel, sand, cement, water) are mixed in the rotary mixer.
- Transfer the mixture to an electromagnetic wave generator. The concrete mix is transferred immediately after mixing through the device tube with a diameter of 4 inches, where the mix is exposed to electromagnetic waves as it passes through the tube.
- Mixing assembly. The concrete mixture is collected after leaving the device tube in a container at the bottom of the tube, and then directly concrete is poured into molds.

3.5.4 The Preparation of Specimens

Freshly mixed concrete was poured, after the mixing process was complete, into plastic mold samples in the shape of cubic (150 mm); it served as the compressive strength measure, and steel prism molds (100 x 100 x 500 mm); were employed to measure flexural strength, They were all thoroughly cleaned and organized, before being lubricated with mineral oil to prevent adhesion with concrete during the hardening process, Compaction was achieved through the compacting bar, with 35 strokes per layer for 150 mm cubes; Cube compression was performed in three levels by hand in accordance **with (BS 1881: part 108: , 1983)**. The placement of prisms complied with **(ASTM C192., 2016),** There were two layers of compressed prisms, and 28 strokes were used to hand stack each layer. The specimen surfaces were evened out and given just 24 hours. To prevent segregation during the casting of the samples, use a spatula to fully mix the mixture in the mixing bowl before transferring it to molds. To ensure that the mixture is dispersed evenly and to prevent pebbles from settling in one area of the mold over another, the spatula should be pushed over the top border of the mold.

3.5.5 Specimen Curing

After completing the preparation of the samples, they are placed inside the laboratory to maintain moisture and prevent evaporation for a period of (24 ± 8 hours), then they are opened from molds. The untreated concrete samples of the device are placed in the tap water tank, and the treated concrete samples passing through the device tube; are placed at a temperature of (23 ± 2 ° C) in the tank of magnetized water for curing. The sample's age was tested at (7, 28, and 90) days.

3.6 The Tests

3.6.1 Fresh Concrete Testing

The slump of the concrete mixture is assessed using the slump test method, whether on - site or in the laboratory, as shown in **Plate (3-7)**. In the current study, it is based on the use of **(ASTM C 143. , 2015)** as a design factor.

Plate (3-7): The slump test in the laboratory**.**

3.6.2 Concrete Testing After Hardening

3.6.2.1 Test of Compressive Strength

Using a digital testing machine with a capacity of (1900 KN), the compressive strength of concrete was measured at a loading rate (of 0.3 MPa/s), as illustrated in **Plate (3-8)**. The test was done based on **(BS EN 12390-3., 2001)**. For each cube, the force at which it broke was written down. The compressive strength was then found by dividing the force at which the cube broke by the area where the force was applied. For each exposure time, an average of three cubes were used. When the samples of concrete were looked at, they were 7, 28, and 90 days old. To figure out the compressive strength of concrete samples, the following law is used:

$$\left(fc = \frac{F}{Ac}\right) \quad \text{...} \quad \textbf{(3-1)}$$

Where: ……………..

(fc) : Compression strength MPa ;

(F): The maximum applied load for the tested machine at failure is indicated by (N);

(Ac) : Area of a cube's cross-section (mm^2).

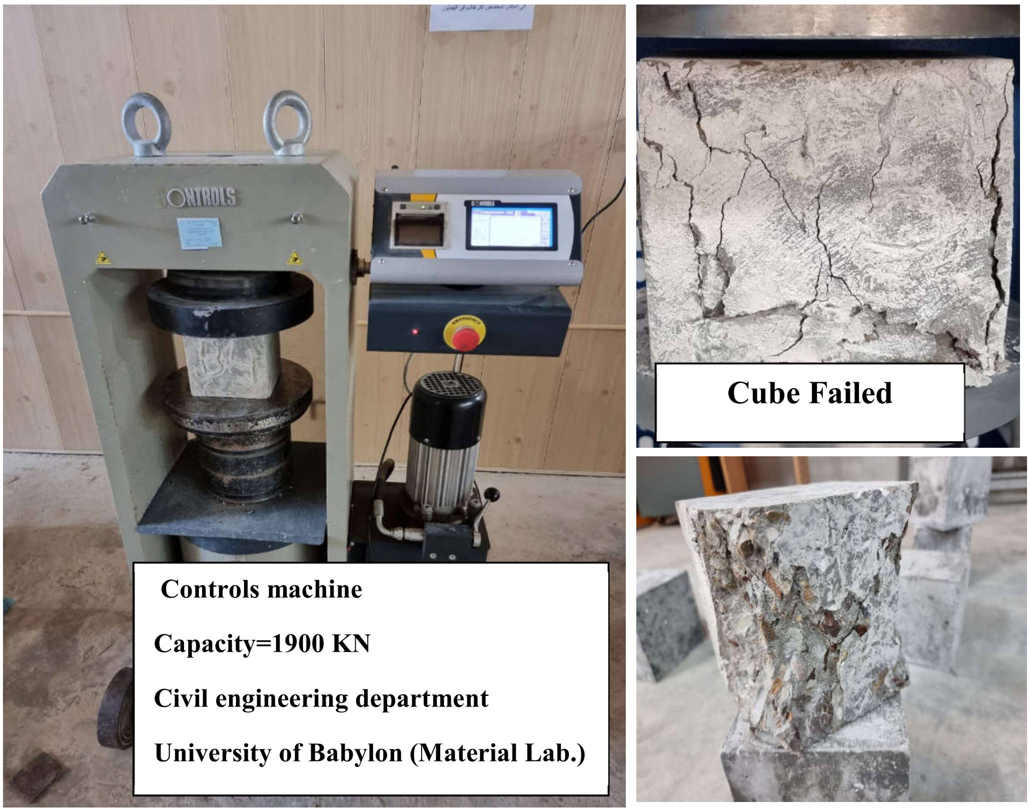


Plate (3-8): Machine for compressive strength testing and cube failure.

3.6.2.2 Test of Flexural Strength

In this test, prisms of concrete measuring (100*100*500 mm) were employed as seen in **Plate (3-9),** and utilizing a basic beam with fourth - point loading at a rate of 3 MPa/min, flexural strength tests were carried out. Testing was done in accordance with **(ASTM C 78. , 2016)**. Since our crack began at the surface tension and was located in the length's middle third, it is possible to calculate the rupture modulus; by using the "following formula":

$$(\mathbf{R}=\frac{\mathrm{PL}}{\mathrm{bd2}}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \mathbf{(3\text{-}2)}$$

Where): -

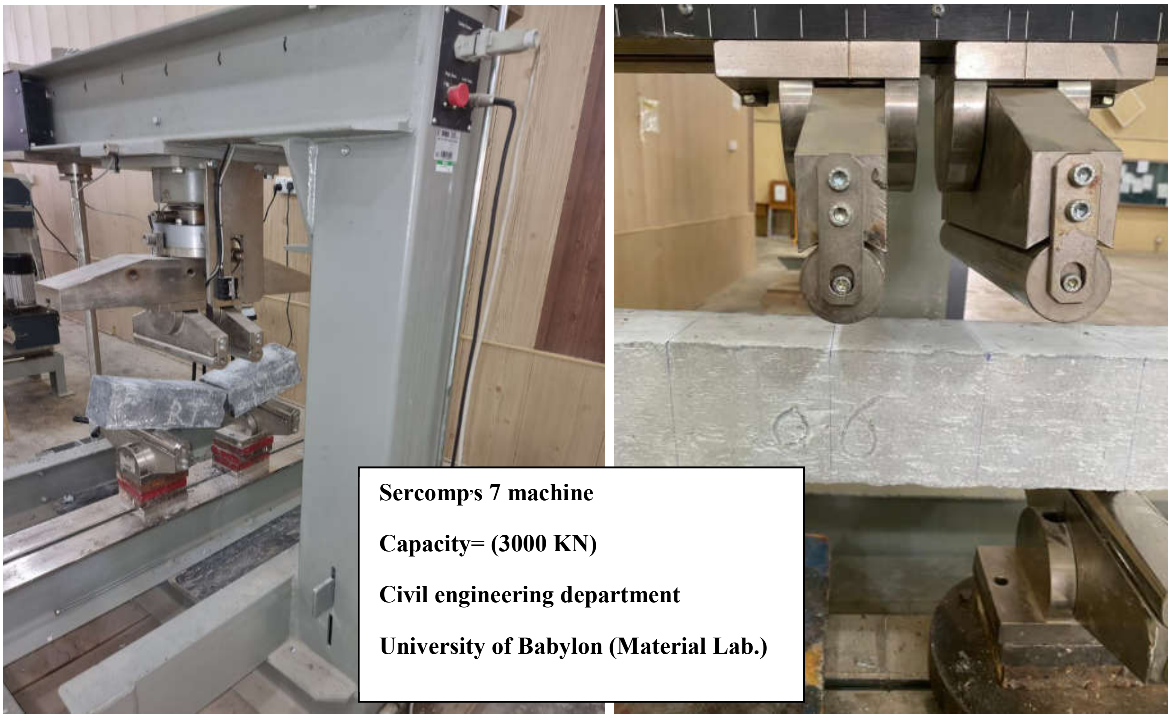
(R): Rupture modulus (MPa).

(P): Maximum load that a machine under test has revealed (N);

(L): Span length (mm) of the specimen;

b): At the fracture, the average specimen width (mm);

d): Average depth at the fracture of the specimen (mm).



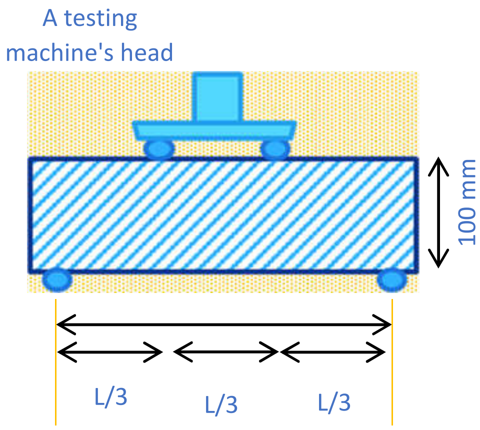


Plate (3-9): Equipment for testing flexural strength and prism failure, with a sketch.

CHAPTER FOUR

CHAPTER 4

Testing Findings and Discussion

4.1 Introduction

The main objective of this study is to experimentally investigate the behavior of ordinary concrete exposed to electromagnetic field and compare it with reference concrete that is not exposed to electromagnetic field, using different percentages of sulfate salts.

Several tests (compressive strength and flexural strength test) were carried out using tap water and magnetized water for both mixtures: the untreated reference mixture; and the magnet treated mixture, then the curing of concrete samples containing different proportions of sulfate salts in fine aggregate (sand); In tap water and magnetized water basins. This chapter presents the experimental results from the test program. The studied experimental variables were the type of cement used (normal, sulfate resistant), the percentage of sulfates in the sand (0.15, 0.3, 0.6), the type of water used (tap water, magnetized water) for the concrete mixture and curing, electromagnetic field intensity exposed to concrete (2000,2500,3000) Guess.

4.2 Using Different Values of Electromagnetic Field Intensity and Their Effect on The Compressive Strength of Concrete

To study magnetic concrete technology, three levels of electromagnetic field strength were used with intensity (2000, 2500, 3000) Gauss, and the mixtures were subsequently treated using maximum intensity.

Table (4-1) and **Figure (4-1)** show the results of the mechanical characteristics of compressive strength, where the mixture that was prepared using ordinary tap water showed an improvement in the compressive strength after exposing the fresh concrete mixture to the waves of the electromagnetic device, by passing the mixture through the device tube 4 inches in diameter. **Table (4-2)** shows the percentage of increase in compressive strength up to (6.8, 6.9, 6.7) %, (14.12,14.22,15.3) % for the second and third magnetic intensities compared to the first, the compressive strength test was used for hardened concrete aged (7, 28, 90) days.

Table (4-1) Result of the treated concrete's compressive strength with each electromagnetic intensity (MPa).

Magnetic intensity (Gauss)	Age of test (days)		
	7	28	90
First intensity (2000)	34	40.8	45
Second intensity (2500)	36.3	43.6	48
Third intensity (3000)	38.8	46.6	51.87

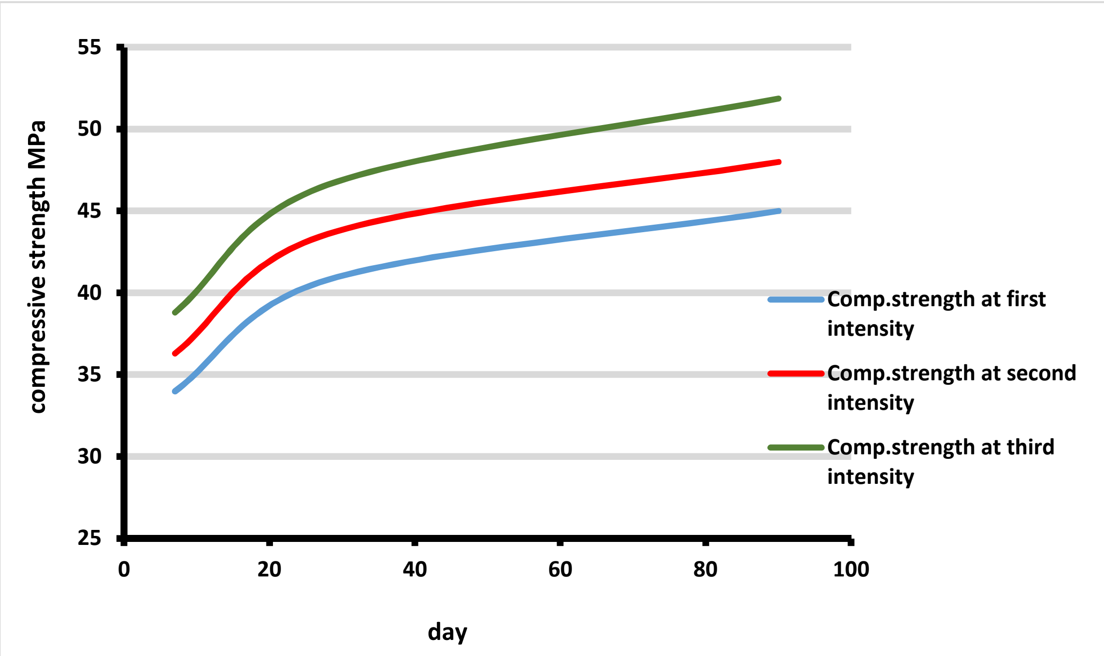


Figure (4-1) Comparison results of compressive strength of treated concrete with each Intensity.

Table (4-2) Compressive strength increase in percentage.

the description	Age of test (days)		
	7	28	90
Ratio of increase in compressive strength at second intensity	6.8 %	6.9 %	6.7 %
Ratio of increase in compressive strength at third intensity	14.12 %	14.22 %	15.3 %

The highest compressive strength was obtained at the highest magnetic intensity (3000) Gauss, which was adopted in the research tests currently being conducted.

4.3 Influence of Magnetized Water on Concrete Compressive Strength.

The most typical test for hardened concrete is the compressive strength test. It is employed to calculate the concrete's potential strength. Concrete is categorized according to its compressive strength in international and national codes. Compressive strength is 'similarly' the most crucial aspect of treated concrete.

Table (4-3) and **Figure (4-2)** demonstrate the compressive strengths of the two mixes, CT (control mixture with tap water), and MW (mixture with magnetized water). The second mixture MW, prepared with magnetized water at a magnetic intensity of 3000 Gauss, showed an improvement in compressive strength, compared to the reference mixture CT, prepared with tap water. **Table (4-4)** and **Figure (4-3)** show the percentage improvements in compressive strength up to (3.1, 2.8, and 2.7%), respectively, at 7, 28, and 90 days. The reason for the increase in compressive strength is due to the effect of the an electromagnetic treatment of the water used in mixing and curing, where the magnetic field breaks down the hydrogen bonds of the water groups into smaller groups and increases the number of molecules that contribute to the hydration process **(Shynier et al., 2014)**.

A reasonable agreement was reached with researchers **(Karam and Al-Shamali, 2013)** who used a magnetic intensity of (12000 Gauss) to reach an increase in compressive strength of (10% to 15%) at the age of (28) days when using magnetic water to mix concrete.

An increase in strength was observed when using magnetized water in the mixture instead of the normal tap water, where the magnetized water proved its effectiveness in improving the strength of concrete. This is consistent with previous studies that discovered the better effect of magnetically treated water on untreated tap water, and this is due "in fact" to the resulting water masses are smaller in size after the magnetization process, as the surface area of water increases and the particles disperse evenly, thus increasing the amount of hydration water that can be Reaching it, and thus the hydration of the number of cement particles increases, which leads to an increase in density and an improvement in quality.

Table (4-3) Compressive strengths for (CT) and (MW) concrete mixtures .

Mix ID	Description	Test (MPa)	Age at testing (day)		
			7 day	28 day	90 day
CT	Tap water	Compressive strength	35.5	42.63	49.25
MW	Magnetized water	Compressive strength	36.6	43.8	50.57

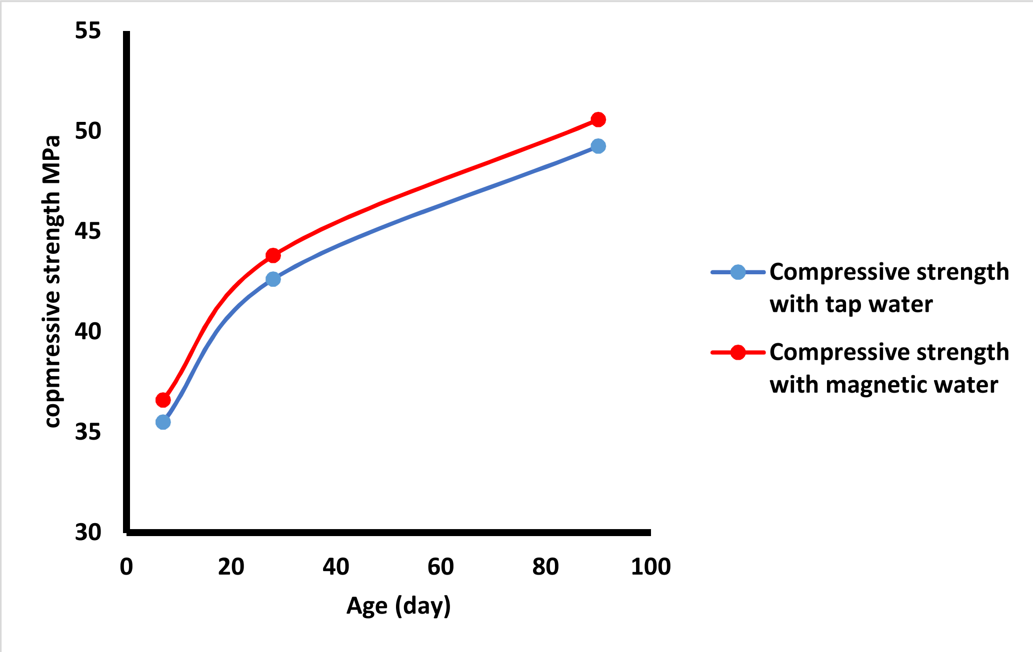


Figure (4-2) Results for compressive strength for reference mix (CT) and (MW) mixtures.

Table (4-4) Comparing the (MW) mix to the (CT) mix, the percentage increase (%).

Test %	Age at testing (day)		
	7 day	28 day	90 day
Compressive strength	3.1	2.8	2.7

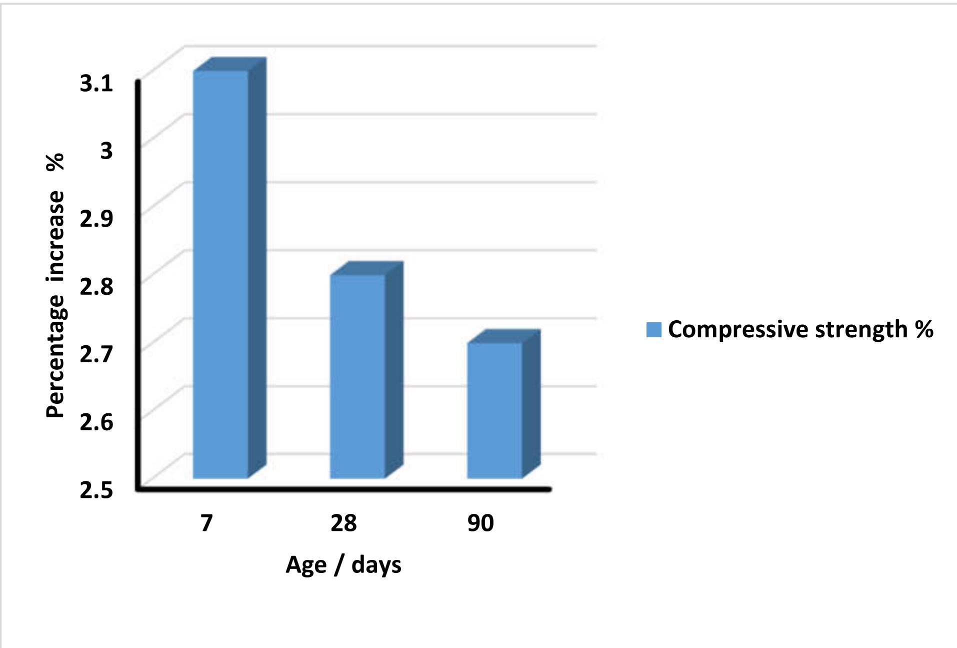


Figure (4-3) Strength percentage increases for MW compared to CT mix.

4-4 Treatment Prepared Concrete with Magnetized Water and Tap Water.

The prepared concrete with magnetic water MW (mixture with magnetized water) was treated using the electromagnetic device, by passing the mixture through the device tube with a density of (3000 Gauss), to produce a MWT mixture. Another concrete mixture was prepared using tap water CT and treated using the same device and previous method to produce the TWT mixture. The influence of each method on the properties of compressive strength was studied, and the results were compared between the reference mixture (MW) and the MWT (a mixture with magnetized water and electromagnetic treatment), and between another reference mixture CT and the TWT (a mixture of tap water and electromagnetic treatment).

The results were encouraging as shown in **Tables (4-5)** and **Figure (4-4)**, all treated mixtures were cured with magnetized water. The results indicate the efficient use of magnetic water technology in concrete and concrete treatment by exposing it to electromagnetic waves.

The reason for the increase in the compressive strength of the treated concrete is to charge the cement gel with the same electric charges and surround it with other similar electric charges, where the components of the gel begin to repel each other and disperse to form a better distribution of the cement groups and thus facilitate the distribution process, and the hydration process is more efficient when it flows Trapped mixing water after subjecting the mixture to electromagnetic field treatment. The efficiency of the hydration process leads to better bonding between the cement components and thus improves the compressive strength of the hardened concrete.

Table (4-5) Compressive strength of treatment concrete mixture (MWT) and (TWT).

Mix 'ID'	Description	Test "MPa"	the test's age (days)		
			7	28	90
MW	Mixture with magnetic water	Compressive strength	36.6	43.8	50.57
MWT	magnetized mixture with magnetic water	Compressive strength	38.70	46.72	51.30
TWT	magnetized mixture with tap water	Compressive strength	38.8	46.6	51.76

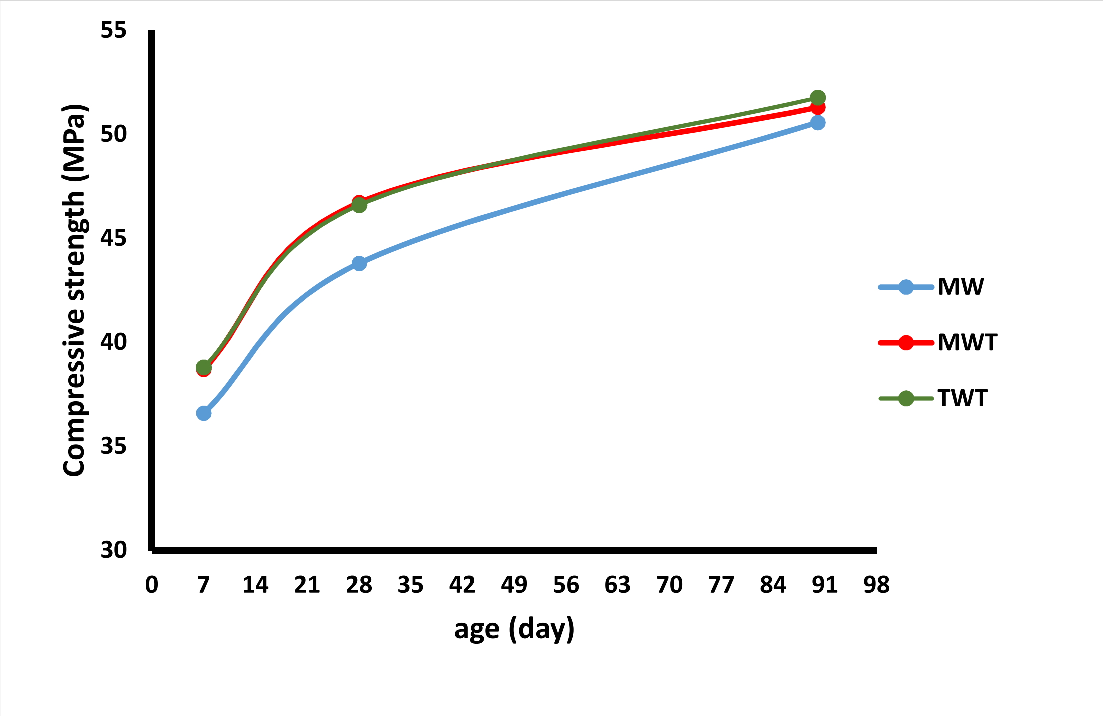


Figure (4-4) Compressive strength results for mixes (MW), (MWT) and (TWT).

4-5Comparison of the Reference Mixture with Mixtures of Magnetized Water and Magnetized Concrete (Mixed with Magnetized Water and Tap Water).

Depending on the previous results of the mixtures (MW), (MWT) and (TWT), it was found that there is an acceptable increase in the compressive strength of the mixture (MWT) when using magnetized water and treating the mixture with electromagnetic field, and a rise in the mixture's compressive strength (TWT) was also observed when using tap water and treating the mixture with the same device, the results were similar for the two mixtures shown in **Figure (4-5)**.

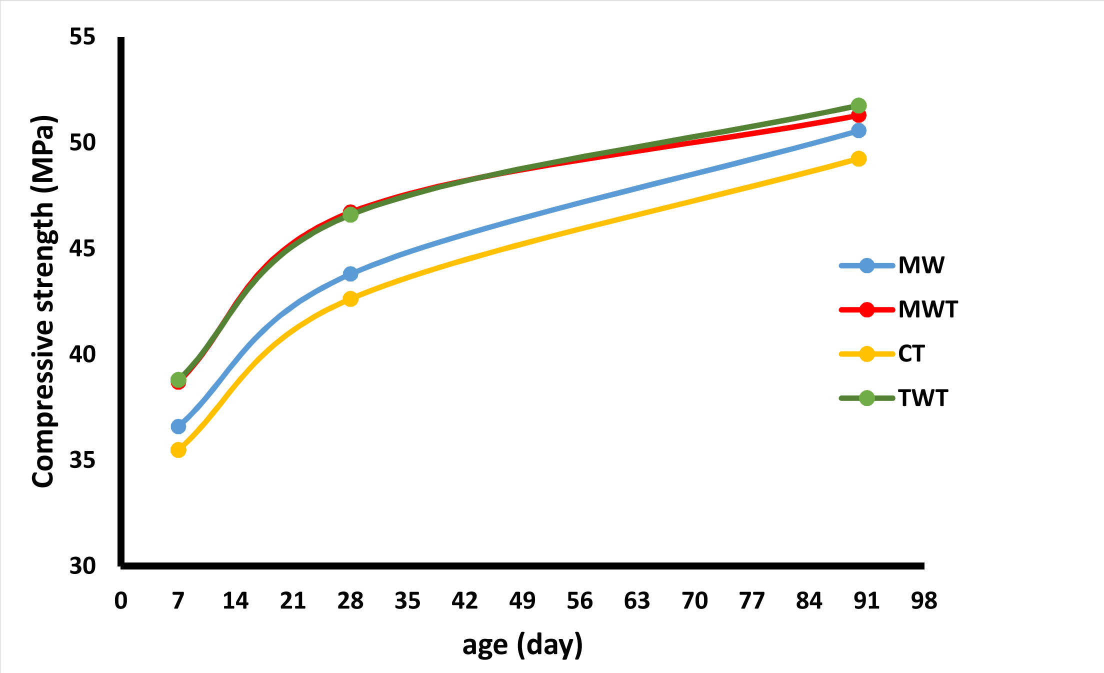


Figure (4-5) Comparison of the compressive strength of mixtures

The method of mixing using tap water and treating the mixture with an electromagnetic field (TWT) was adopted, due to the equality of results with the mixture (MWT), thus reducing the cost and effort spent to produce magnetized water, at the same time similar results were obtained when using tap water in the mixture and treating it with a generating device electromagnetic field.

4-5 Studying The Effect of Different Percentages of Sulfate Salt in Sand On Concrete Properties Before and After Treatment (Use OPC).

Compressive and flexural strength tests were performed for six mixtures, using ordinary Portland cement with sand containing three different proportions of SO_3 = (0.15, 0.3, 0.6%). In mixtures, the mixing proportions remained the same.

4-5-1 The Percentage of Sulfate Salts in the Sand SO_3=0.15

Compressive and flexural strength values for two mixes, CT (control mixture with tap water), and TWT (a mixture of tap water and electromagnetic treatment), are shown in **Table (4-6)** and **Figures (4-6)** and **(4-7)**, at 7, 28, and 90 days. The second mix (TWT), which was created using tap water with the use of sand with SO_3 = 0.15, then concrete was pumped through an electromagnetic device tube; with a magnetic intensity of 3000 Gauss, which demonstrated higher compressive and flexural strength than the reference mix (CT), the reference mix was prepared in the same way as the mix second, is using tap water with sand at a ratio of SO_3 =0.15, and without electromagnetic treatment.

4-5-2 The Percentage of Sulfate Salts in the Sand SO3=0.3

Compressive and flexural strength values for two mixes, CT* (control mixture with tap water), and TWT* (a mixture of tap water and electromagnetic treatment), are shown in **Table (4-6)** and **Figures (4-8)** and **(4-9)**, at 7, 28, and 90 days. The second mix (TWT*), which was created using tap water with the use of sand with SO_3 = 0.3, then concrete was pumped through an electromagnetic device tube; with a magnetic intensity of 3000 Gauss, which demonstrated higher compressive and flexural strength than the reference mix (CT*), the reference mix was prepared in the same way as the mix second, is using tap water with sand at a ratio of SO_3 = 0.3, and without electromagnetic treatment.

4-5-3 The Percentage of Sulfate Salts in the Sand SO3=0.6

Compressive and flexural strength values for two mixes, CT** (control mixture with tap water), and TWT** (a mixture of tap water and electromagnetic treatment), are shown in **Table (4-6)** and **Figures (4-10)** and **(4-11)**, at 7, 28, and 90 days. The second mix (TWT**), which was created using tap water with the use of sand with SO_3 = 0.6, then concrete was pumped through an electromagnetic device tube; with a magnetic intensity of 3000 Gauss, which demonstrated higher compressive and flexural strength than the reference mix (CT**), the reference mix was prepared in the same way as the mix second, is using tap water with sand at a ratio of SO_3 = 0.6, and without electromagnetic treatment.

Table (4-6) Concrete's compressive and flexural strength (MPa) for OPC.

"Description"			Test "MPa"	the test's age (days)		
				7	28	90
CT	with SO_3=0.15	Without magnetic Treatment	Compressive strength	35.50	42.63	49.25
			Flexural strength	2.50	4.70	5.41
TWT		magnetized mixture	Compressive strength	38.80	46.60	51.87
			Flexural strength	2.85	5.30	5.89
CT*	with SO_3=0.3	Without magnetic Treatment	Compressive strength	35.40	42	49
			Flexural strength	2.47	4.43	5.30
TWT*		magnetized mixture	Compressive strength	38.70	45.80	51.66
			Flexural strength	2.81	5	5.77
CT**	with SO_3=0.6	Without magnetic Treatment	Compressive strength	34.80	41.73	47.24
			Flexural strength	2.4	4.45	5
TWT**		magnetized mixture	Compressive strength	38	45.26	49.73
			Flexural strength	2.73	4.97	5.44

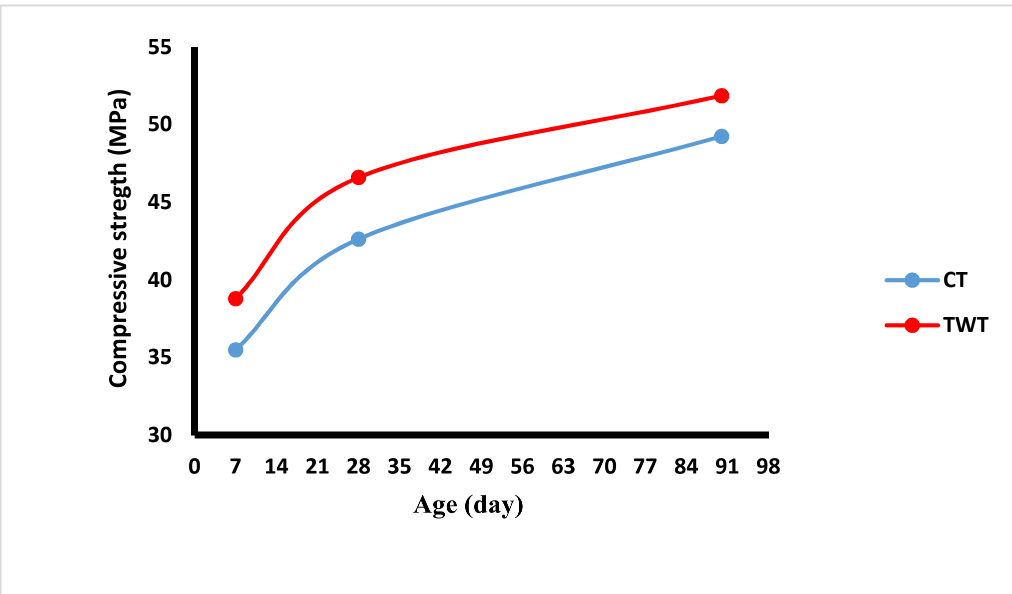


Figure (4-6) Evolution of compressive strength with age for mixtures (CT) and (TWT).

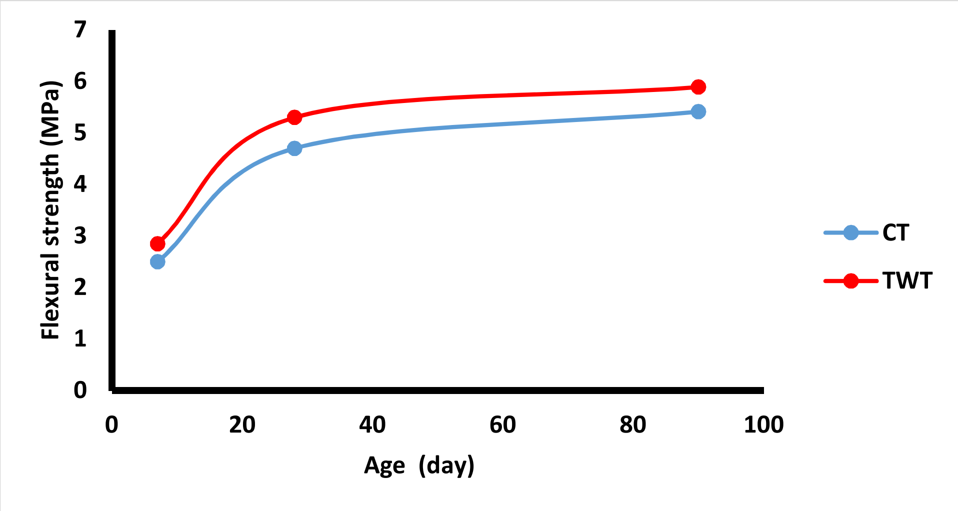


Figure (4-7) Results for flexural strength: CT and TWT mixes in MPa.

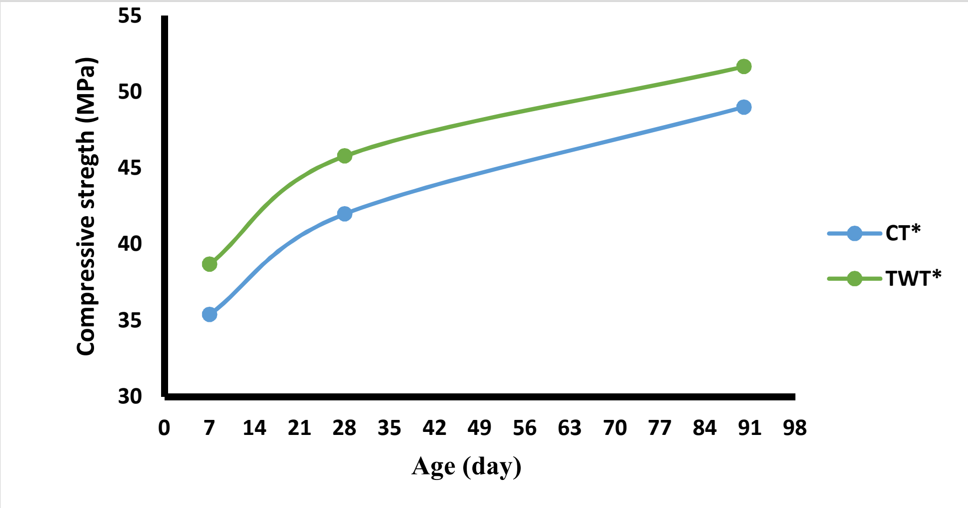


Figure (4-8) Evolution of compressive strength with age for mixtures (CT*) and (TWT*).

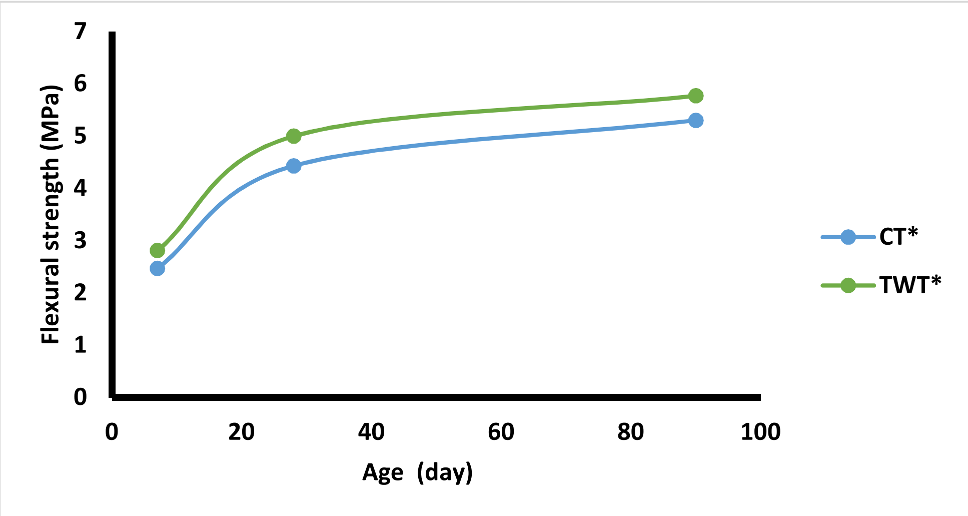


Figure (4-9) Results for flexural strength: CT* and TWT* mixes in MPa.

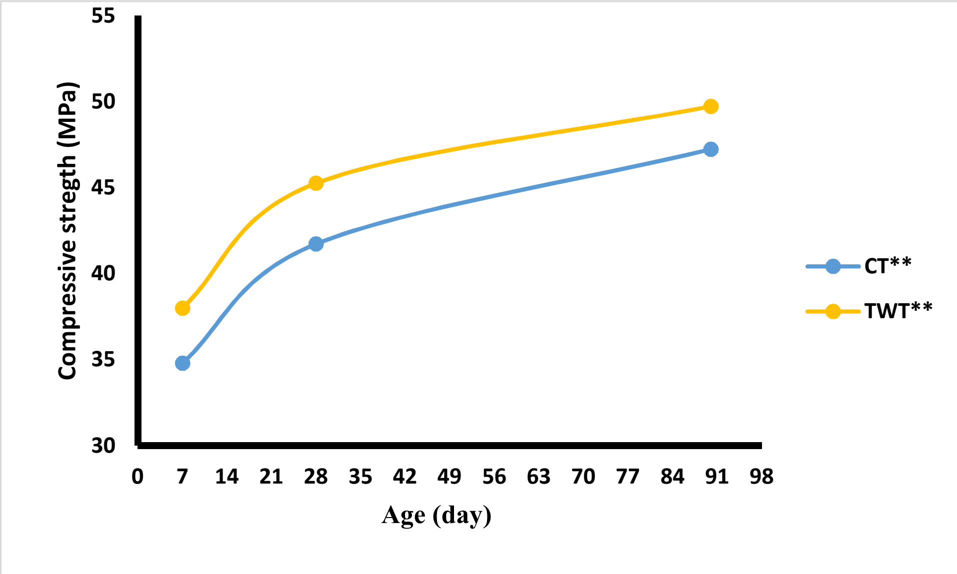


Figure (4-10) Evolution of compressive strength with age for mixtures (CT**) and (TWT**).

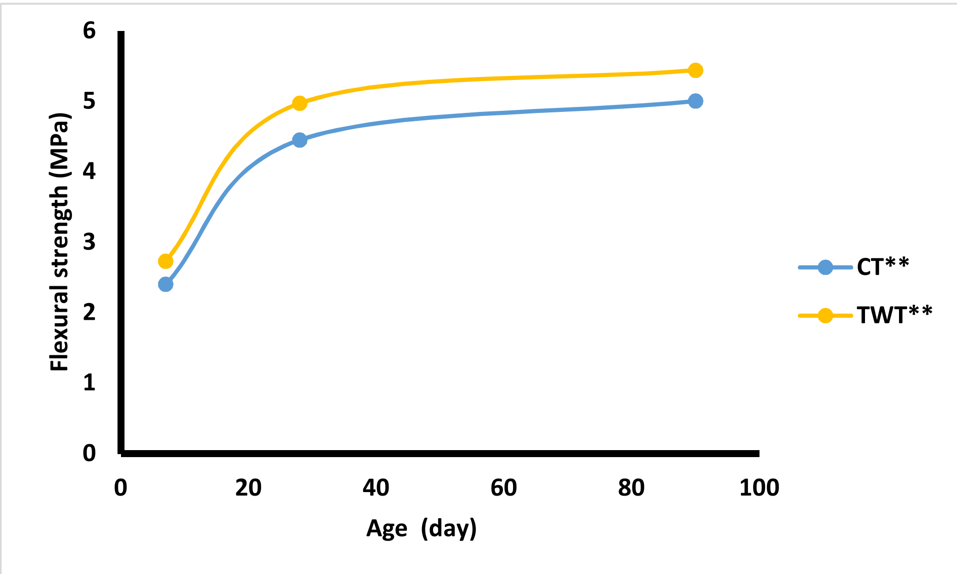


Figure (4-11) Results for flexural strength: CT** and TWT** mixes in MPa.

4-6 Comparison of Concrete Mixtures Containing Different Percentages of Sulfate Salts in Sand and Before and After Treatment.

Comparison of the compressive and flexural strength values for six mixes, CT, CT*, CT**, TWT, TWT* and TWT**, shown in **Figure (4-12)** and **Figure (4-13)**.

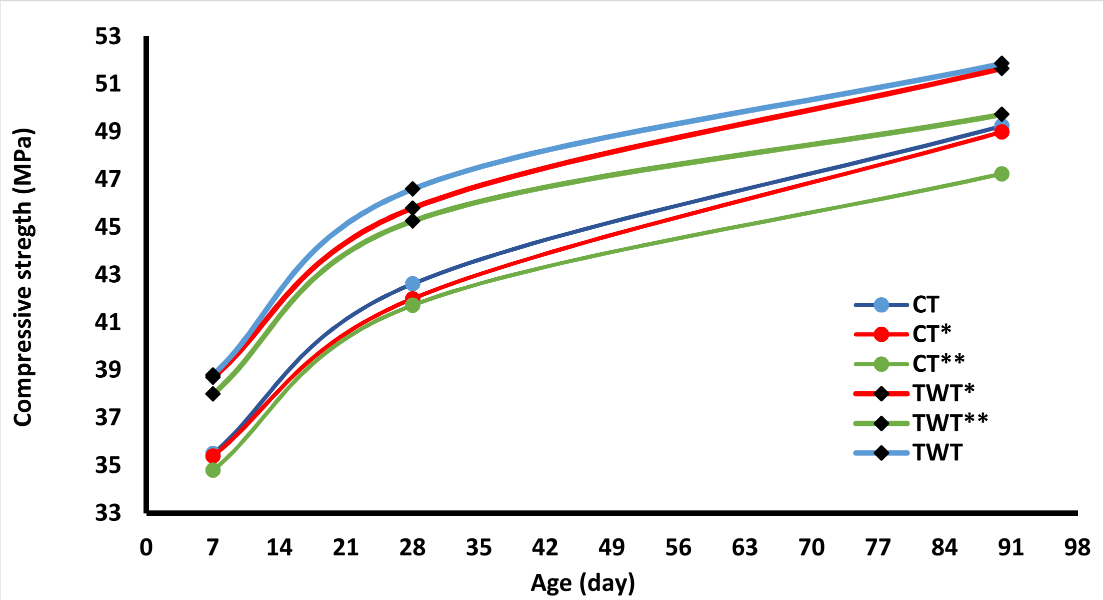


Figure (4-12) Comparison of the compressive strength of six mixtures.

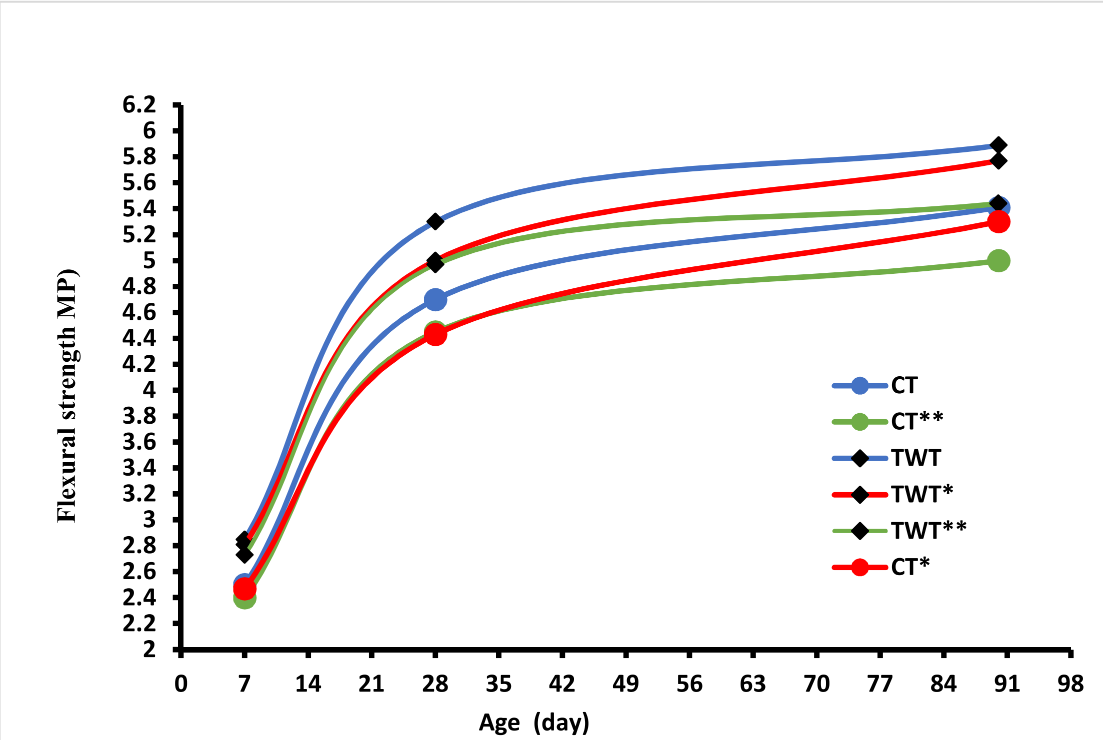


Figure (4-13) Comparison of the flexural strength of six mixtures.

Table (4-7) and **Figure (4-14)** demonstrate the percentage improvements in compressive strength for treated concrete (magnetized mixtures): (9.30, 9.31 and 5.32%) for SO_3=0.15, (9.32, 9.05 and 5.43%) for SO_3=0.3 and (9.20, 8.46 and 5.27%) for SO_3=0.6, flexural strength for the same magnetized mixtures (14, 12.77, and 8.87%) for SO_3=0.15; (13.76, 12.87 and 8.87%)

for SO_3=0.3 and (13.75,11.69 and 8.80%) for SO_3=0.6 at the 7, 28, and 90 days, respectively, just by passing the regular concrete mixture through the tube exposed to the electromagnetic field.

The reason for the increase in the compressive strength of the treated concrete, which contains different percentages of sulfate salts in the sand, is the efficiency of the hydration process after the mixture has been subjected to electromagnetic field treatment, due to the flow of the imprisoned mixing water and the completion of the hydration process more, the gel of cement disperses when exposed to the magnetic field. It forms better groups to facilitate the process of distribution and hydration, thus reducing the attack and interaction of sulfate salts to form ettringite after the concrete hardens.

The result of compressive and flexural strength at 28 days was higher than at 90 days, indicating low salt attack after 28 days of age.

The percentage of compressive strength improvement (9.31%), and flexural strength (12.77%) at the intensity of (3000 Gauss) is higher than the percentage obtained by the researcher **(Ahmed and Manar, 2021)** when using the intensity of (5000 Gauss); at the same age as it reached (8%);(10.7%) respectively for compressive and flexural strength.

Table (4-7) Compressive and flexural strength and the effects of electromagnetic therapy (TWT, TWT*, TWT** percentage increase against CT, CT*, CT**).

Test		Age of test (days)		
		7	28	90
Compressive strength with SO_3=0.15	TWT	9.30	9.31	5.32
Compressive strength with SO_3=0.3	TWT*	9.32	9.05	5.43
Compressive strength with SO_3=0.6	TWT**	9.20	8.46	5.27
Flexural strength with SO_3=0.15	TWT	14	12.77	8.87
Flexural strength with SO_3=0.3	TWT*	13.76	12.87	8.87
Flexural strength with SO_3=0.6	TWT**	13.75	11.69	8.80

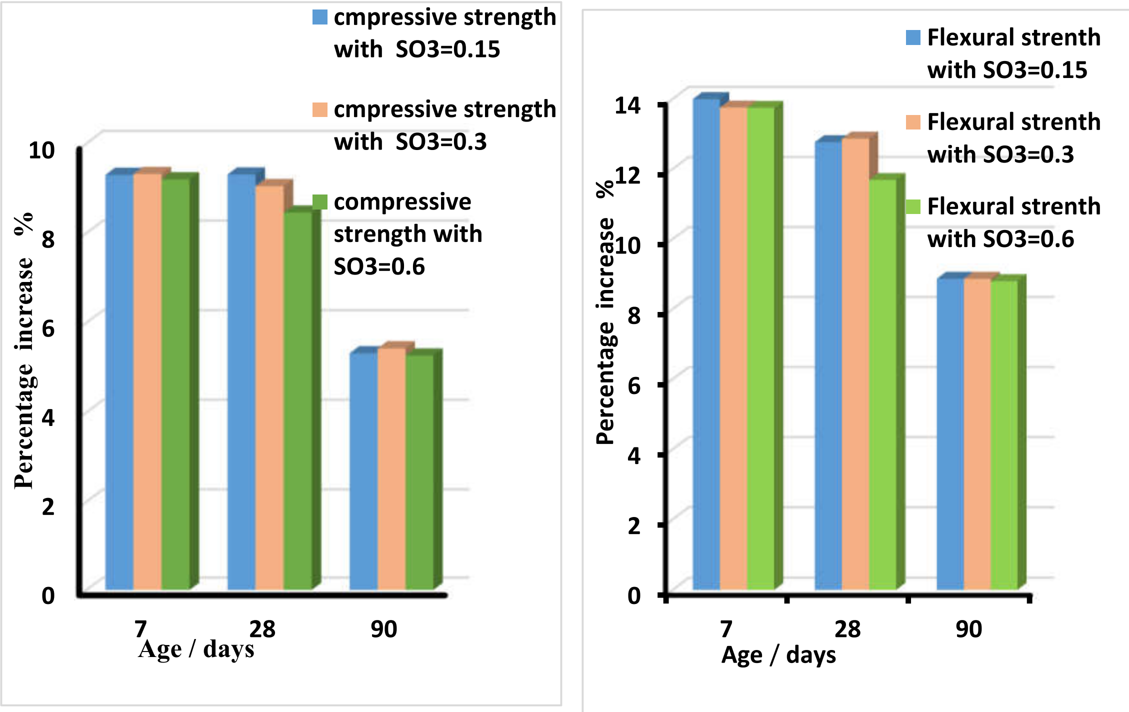


Figure (4-14) Strengths increase for compressive and flexural by percentages.

4-7 Studying The Effect of Different Percentages of Sulfate Salts in Sand On Concrete Properties Before and After Treatment (Use SRPC).

Compressive and flexural strength values were performed for four mixtures, using sulfate resistance Portland cement with sand containing two different proportions of SO_3 = (0.15, 0.6 %), as shown. In mixtures, the mixing proportions remained the same.

4-7-1 The Percentage of Sulfate Salts in The Sand SO_3=0.15

Compressive and flexural strength values for two mixes, CTr (control mixture with tap water), and TWTr (a mixture of tap water and electromagnetic treatment), are shown in **Table (4-8)** and **Figures (4-15)** and **(4-16)**, at 7, 28, and 90 days. The second mix (TWTr), which was created using tap water with the use of sand with SO_3 = 0.15, then concrete was pumped through an electromagnetic device tube; with a magnetic intensity of 3000 Gauss, which illustrated higher compressive and flexural strength than the reference mix (CTr), the reference mix was prepared in the same way as the mix second, is using tap water with sand at a ratio of SO_3 =0.15, and without electromagnetic treatment.

4-7-2 The Percentage of Sulfate Salts in The Sand SO_3=0.6

Compressive and flexural strength values for two mixes, CTr* (control mixture with tap water), and TWTr* (a mixture of tap water and electromagnetic treatment), are shown in **Table (4-8)** and **Figures (4-17)** and **(4-18)**, at 7, 28, and 90 days. The second mix (TWTr*), which was created using tap water with the use of sand with SO_3 = 0.6, then the concrete was pumped through an electromagnetic tube with a magnetic intensity of 3000 Gauss, which illustrated higher compressive and flexural strength than the reference mix (CTr*), the reference mix was prepared in the same way as the mix The second, is using tap water with sand at a ratio of SO_3 = 0.6, and without electromagnetic treatment.

Table (4-8) Concrete's compressive and flexural strength (MPa) for SRPC.

"Description"			**Test "MPa"**	**Age at testing (days)**		
				7	**28**	**90**
CTr	**with SO_3=0.15**	Without magnetic Treatment	Compressive strength	39.30	44.3	49.67
			Flexural strength	2.46	4.74	5.78
TWTr		magnetized mixture	Compressive strength	41.44	46.73	52.5
			Flexural strength	2.78	5.42	6.22
CTr*	**with SO_3=0.6**	Without magnetic Treatment	Compressive strength	38	43	49.21
			Flexural strength	2.4	4.54	5.6
TWTr*		magnetized mixture	Compressive strength	40.74	46	50
			Flexural strength	2.7	5.4	6.14

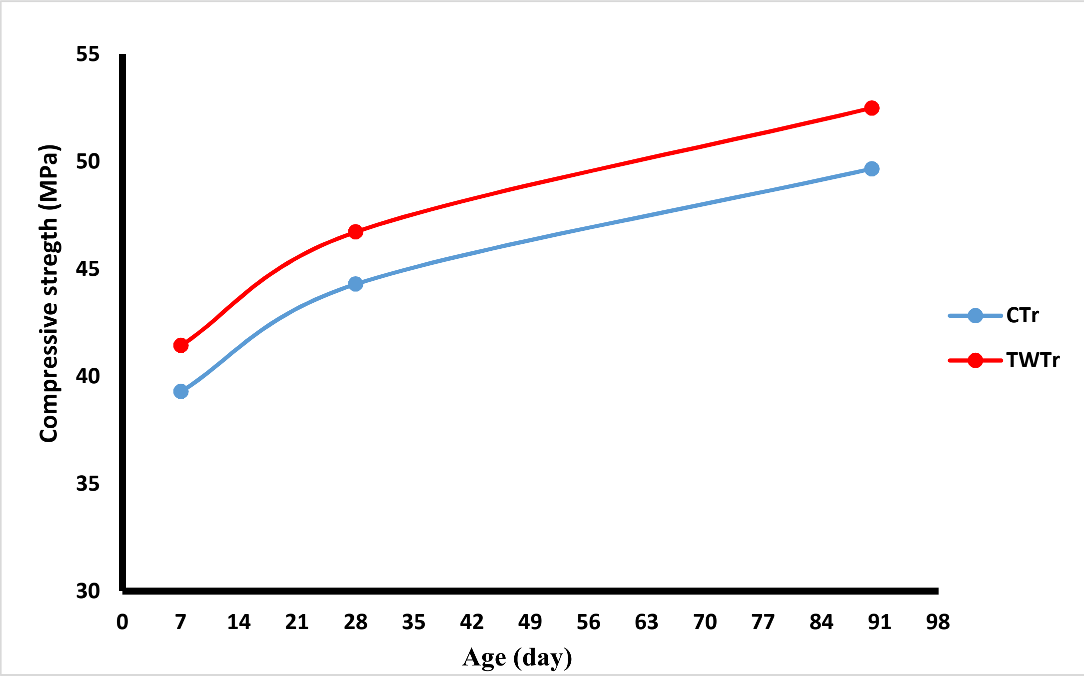


Figure (4-15) Compressive strength results for mixes (CTr) and (TWTr).

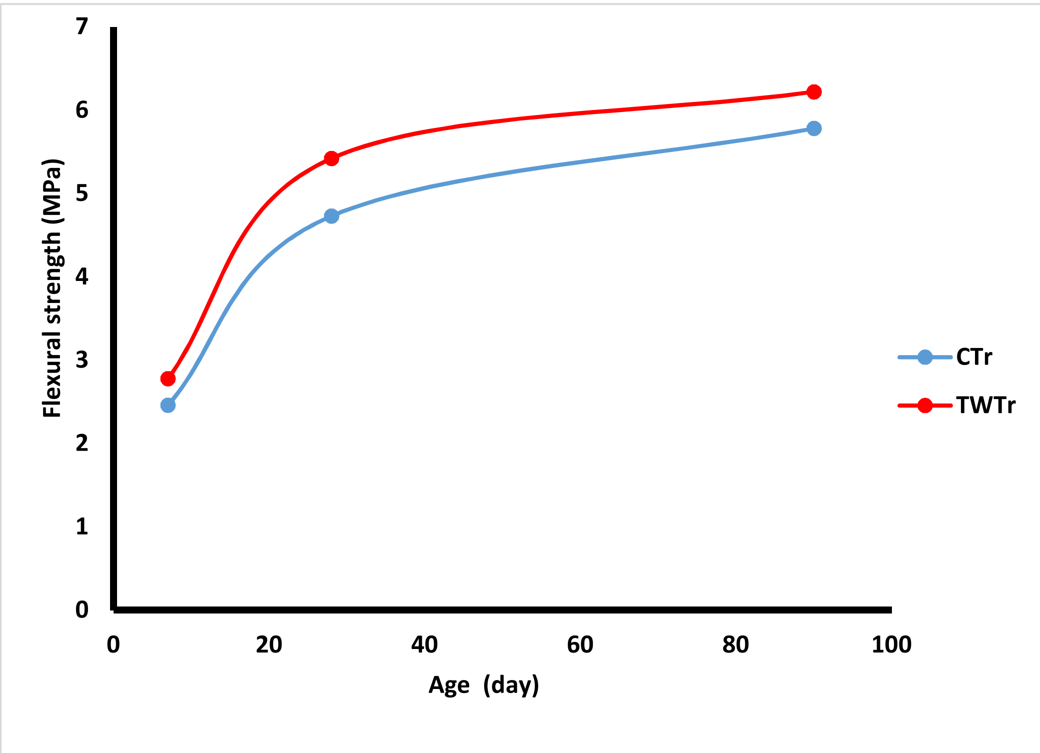


Figure (4-16) Results for flexural strength: CTr and TWTr mixes in MPa.

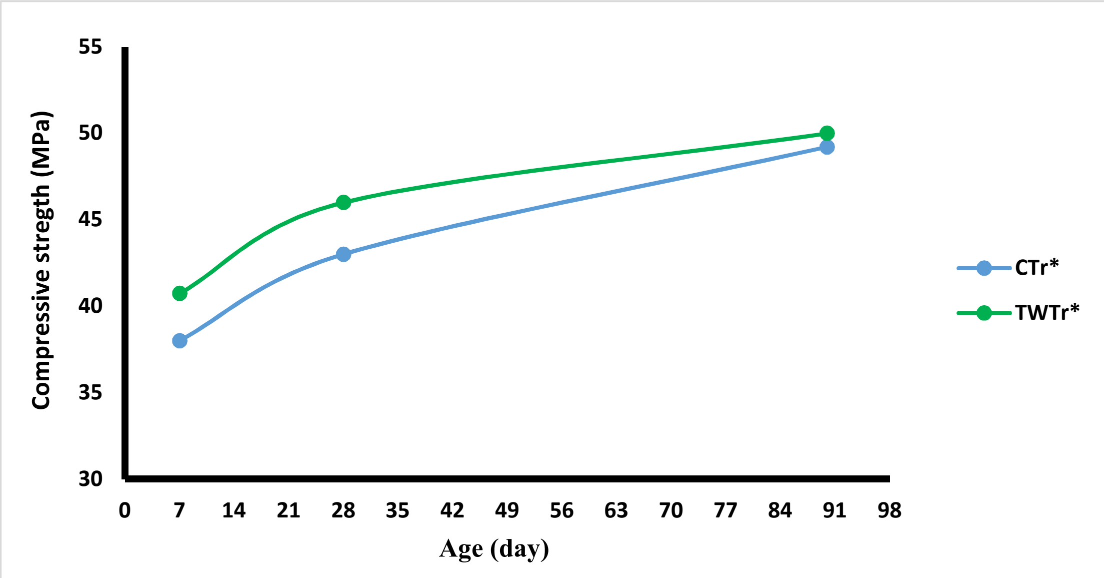


Figure (4-17) Compressive strength results for mixes (CTr*) and (TWTr*).

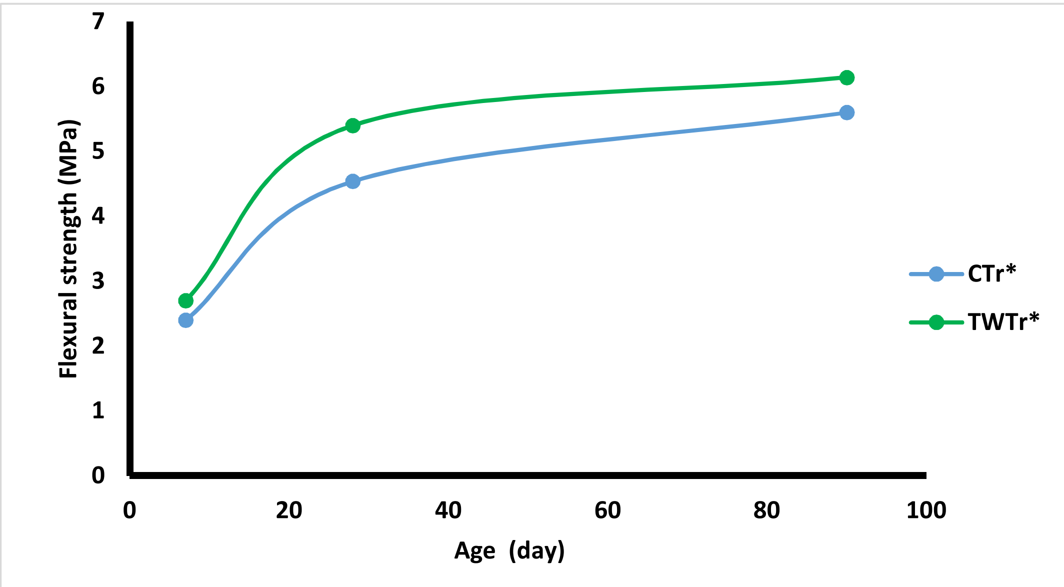


Figure (4-18) Results for flexural strength: CTr* and TWTr* mixes in MPa.

Table (4-9) demonstrates the percentage improvements in compressive and flexural strength, for treated concrete (magnetized mixtures), at 7, 28, and 90 days, just bypassing the regular concrete mixture through the tube exposed to the electromagnetic field.

Table (4-9) Compressive and flexural strength and the effects of electromagnetic therapy (TWTr, TWTr* percentage increase against CTr, CTr*).

Test		Age of test (days)		
		7	28	90
Compressive strength with SO_3=0.15	TWTr	5.45	5.5	5.7
Compressive strength with SO_3=0.6	TWTr*	7.2	7	4.6
Flexural strength with SO_3=0.15	TWTr	13	15.35	8
Flexural strength with SO_3=0.6	TWTr*	12.5	18.9	9.6

4-8 SO_3% Total and Total Effective in The Concrete Mix.

The percentage of total sulfate content of all concrete mixture ingredients was calculated and compared with the percentage of total effective sulfate content calculated using the empirical equation of **(Al-Rawi, 2000)** because the content of total effective sulfate of the aggregates (sand and crushed gravel) is less than the total sulfate content of the concrete mixture ingredients. **Table (4–10)** shows the computations that will help understand the outcomes in different combinations later.

Total SO_3 % = SO_3 % in cement + SO_3 % in sand from the mix

+ SO_3 % in crushed gravel from the mix ……… (4-1)

(Total effective SO_3 %) = SO_3 % in cement + (SO_3 % in sand from the mix * the effective SO_3 % in sand) + (SO_3 % in crushed gravel from the mix * the effective SO_3 % in crushed gravel) ………… (4-2)

Where the empirical equation by "**Al-Rawi**" :

(The effective SO_3 %)= 0.9 – 0.25 $\sqrt{FM}$………………… (4-3)

(F.M.): "fineness modules"

For instance, in the case of a reference concrete mix, the mix proportion = (1:1.7:2.45), SO_3% in cement=2.22, SO_3% in sand = 0.15, SO_3% in crushed gravel = 0.03, stated by **(Al-Rawi, 2000)** guidelines for the effective SO_3% in sand and crushed gravel are 0.50% and 0.25%, respectively.

Total SO_3 % = 2.22 + (0.15 * 1.7) + (0.03 * 2.45) = 2.55 %

Total effective SO_3 % = 2.22 + (0.15 * 1.7) * (0.50) + (0.03 * 2.45)

*(0.25) = 2.37 %

Table (4-10) the proportion of overall and overall effective sulfates in the components of concrete mixtures*.

mix ID	SO_3 in sand	SO_3 in gravel	Total SO_3%	Total effective SO_3%
CT	0.15	0.03	2.55	2.37
CT*	0.3	0.03	2.8	2.50
CT**	0.6	0.03	3.31	2.75
CTr	0.15	0.03	2.48	2.40
CTr*	0.6	0.03	3.42	2.86

*In all mixtures, cement has a sulfate content of 2.22% for OPC and 2.33% for SRPC.

4-9 Concrete Strength Before and After Electromagnetic Field Treatment and The Impact of SO_3 Content.

4-9-1 Compressive Strength.

As a result of the reactions between cement hydration products (C_3A) and sulfate to form ettringite in significant amounts, the failed sand was employed in concrete mixtures to evaluate the influence of sulfate on the strength deterioration. **(Khreef and Abbas, 2021a), (Ibrahim and Abbas, 2021a), (Al-Hubboubi and Abbas, ,2018), (Kadhim et al., 2020), (Zhang and Li, 2016)**.

For the purpose of evaluating the effectiveness of magnetized concrete, concrete mixtures were treated before being poured. It was noted that the results of the strength of the treated concrete were encouraging and higher than the untreated reference mixtures, and had no side or negative effects.

Improving the compressive strength properties of treated concrete with increasing density and reducing voids, as well as long-term performance, in addition to that the cement gel in the treated mixture has greater and brighter activity, and its distribution around the packing components of the mixture is excellent **(Ahmed and Manar, 2021)**.

4-9-1-1 Behavior of The Compressive Strength of Concrete Mixes With Different Amounts Of SO_3 in The Sand.

The compressive strength tests shown in **Table (4-11)** and **Figures (4-19)**, **(4-20)** were conducted on concrete mixtures made with failed sand (CT**, CTr*) and electromagnetic field-treated mixture (TWT**, TWTr*) for two different cement types (OPC, SRPC). A comparison of the ratio of change in compressive strength of mixtures (CT**, TWT**), and (CTr*, TWTr*) shown in **Table (4-12)**, at age of (7, 28, and 90 days).

After 28 days, OPC starts to lose compressive strength due to the usage of sand with a high sulfate concentration. The compressive strength of concrete made using failed sand (CT**) was shown to decrease by (1.97, 2.11, and 4.10) % with ages of 7, 28, and 90 days; as compared to the reference mixture (CT), respectively. These findings are consistent with those of other studies **(Fawzi et al., 2015), (Khreef and Abbas, 2021a), (Al-Hubboubi and Abbas, ,2018).**

For SRPC, it was observed that the percentage decrease in the compressive strength of the concrete mixture containing failed sand (CTr*), was (3.30, 2.93, 0.93) % with ages of (7, 28, 90) days, compared with the reference mixture (CTr).

Decreased strength can be traced back to the presence of sulfates (gypsum) in the aggregate especially "sand" and their interaction with (C_3A); cement hydration products, leading to the development of ettringite. Much of the blame for the growth and destruction of concrete buildings have been placed on the emergence of the ettringite. Early ettringite formation (EEF) refers to the phase of ettringite formation that happens uniformly within the first few hours after a batch of concrete has been poured and does not affect the concrete in any way. Instead, cracking in concrete structures is caused by "secondary ettringite formation," also known as "delayed ettringite formation" (DEF), which takes place months or even years after the heat treatment temperatures have been too high **(Kadhim et al., 2020).**

To treat the harmful effect of sulfates in the fine aggregate, the concrete was treated with electromagnetic wave technology; (exposing the mixture to the electromagnetic field of the device to produce magnetized concrete), where the results of the strength of the concrete mixture containing the failed sand, and treated with the electromagnetic field were higher than the results of the reference mixture.

After processing the concrete (CT**, CTr*) using cement (OPC, SRPC), with the use of sand with a sulfate ratio of 0.6, it was noted that the results of the compressive strength of the mixtures (TWT**, TWTr*) after treatment with the electromagnetic field, were close to the reference mixtures (CT, CTr); which were prepared using sand with a percentage of Sulfate 0.15.

It is important to highlight the mixture (CT**, CTr*), and note that the total SO_3 = (3.31, 3.42), is a larger quantity than what is in the concrete mixture (CT, CTr), with the total SO_3= (2.55, 2.48). The decrease in compressive is smaller than the empirical equation that is recommended for **(Al-Rawi, 2000)**.

Table (4-11) Results for mixtures of (CT** and TWT**) (CTr*and TWTr*) compression strength.

Mix ID	Description	Compressive strength (MP)		
		7 day	28 day	90 day
CT	(Sand SO_3=0.15%), and (gravel SO_3=0.03%) with tap water.	35.50	42.63	49.25
CT**	(Sand SO_3=0.6%), and (gravel SO_3=0.03%) with tap water.	34.80	41.73	47.24
TWT**	(Sand SO_3=0.6%), and (gravel SO_3=0.03%) with tap water, magnetized concrete.	38	45.26	49.73
CTr	(Sand SO_3=0.15%), and (gravel SO_3=0.03%) with tap water.	39.30	44.30	49.67
CTr*	(Sand SO_3=0.6%), and (gravel SO_3=0.03%) with tap water.	38	43	49.21
TWTr*	(Sand SO_3=0.6%), and (gravel SO_3=0.03%) with tap water, magnetized concrete.	40.74	46	50

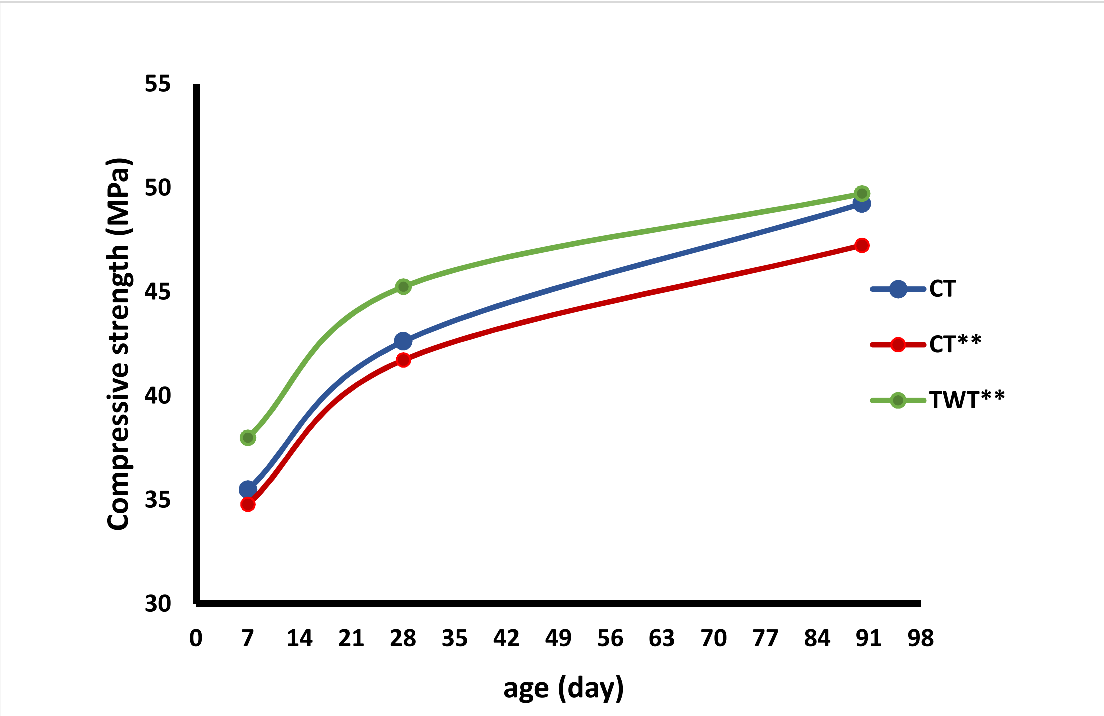


Figure (4-19) Results for (**CT**** and **TWT****) mixtures' compressive strengths when compared to the reference mix **CT.**

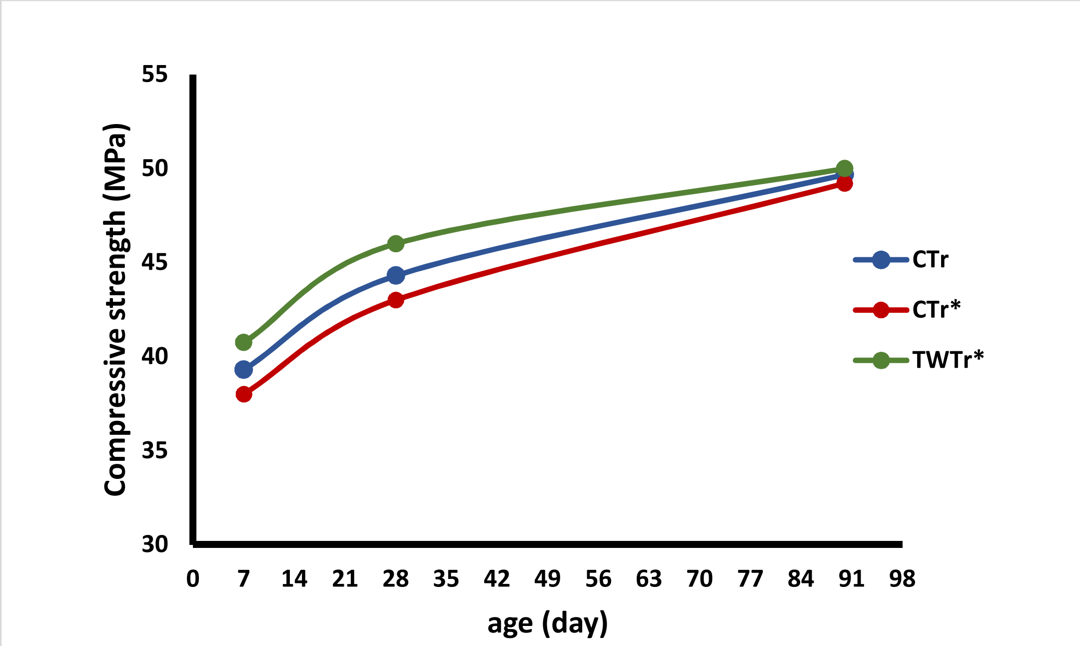


Figure (4-20) Results for **(CTr* and TWTr*)** mixtures' compressive strengths when compared to the reference mix **CTr**.

Table (4-12) Compressive strength variation in percentage for (CT**, TWT**) and (CTr*, TWTr*) mixes in comparison to the reference mix CT and CTr.

Mix ID	Description	Percentage variance%		
		7 day	28 day	90 day
CT**	(Sand SO3=0.6%), and (gravel SO3=0.03%) with tap water.	- 1.97	-2.11	-4.1
TWT**	(Sand SO3=0.6%), and (gravel SO3=0.03%) with tap water, magnetized concrete.	7.04	6.17	0.98
CTr*	(Sand SO3=0.6%), and (gravel SO3=0.03%) with tap water.	-3.30	-2.93	-0.93
TWTr*	(Sand SO3=0.6%), and (gravel SO3=0.03%) with tap water, magnetized concrete.	3.7	3.84	0.7

4-9-2 Flexural Strength

Concrete mixtures (CT**, TWT**, and CTr*, TWTr*) showed a decrease in flexural strength when sand with a high sulfate content was used, the decrease in strength being due to the same factors previously discussed in compressive strength. The concrete mixture was processed using an electromagnetic field generator device, bypassing the concrete mixture through the device tube, the results illustrated a significant increase in flexural strength.

Testing results for flexural strength are shown in **Table (4-13)** and **Figures (4-21) and (4-22),** for two types of cement (OPC and SRPC), and for concrete mixtures incorporating failed sand (CT** and CTr*), and mixtures treated with electromagnetic field (TWT** and TWTr*). The percentage of change in bending strength of mixtures (CT**, TWT**) at 7, 28, and 90 days of age shown in **Table (4-14).**

For two types of OPC and SRPC cement, there was a decrease in flexural strength observed in mixtures containing failed sand (CT**, CTr*), and the reason is consistent with what was previously explained in compressive strength. The percentage of decrease in flexural strength of mixtures containing failed sand (CT**), was (4, 5.32, 7.58) % and (CTr*) was (2.44, 4.22, 3.11%), compared with reference mix (CT, CTr). The effectiveness of the Electromagnetic field method of treating concrete was demonstrated by the results of magnetized concrete containing failed sand (TWT**, TWTr*), which showed results in flexural strength higher to those of the reference mix (CT, CTr).

Table (4-13) Results for blends with (CT**, TWT**) and (CTr*, TWTr*) flexural strength.

Mix ID	Description	Flexural strength (MP)		
		7 day	28 day	90 day
CT	(Sand SO_3=0.15%), and (gravel SO_3=0.03%) with tap water.	2.5	4.70	5.41
CT**	(Sand SO_3=0.6%), and (gravel SO_3=0.03%) with tap water.	2.4	4.45	5
TWT**	(Sand SO_3=0.6%), and (gravel SO_3=0.03%) with tap water, magnetized concrete.	2.73	4.97	5.44
CTr	(Sand SO_3=0.15%),and (gravel SO_3=0.03%) with tap water.	2.46	4.74	5.78
CTr*	(Sand SO_3=0.6%), and (gravel SO_3=0.03%) with tap water.	2.4	4.54	5.60
TWTr*	(Sand SO_3=0.6%), and (gravel SO_3=0.03%) with tap water, magnetized concrete.	2.7	5.4	6.14

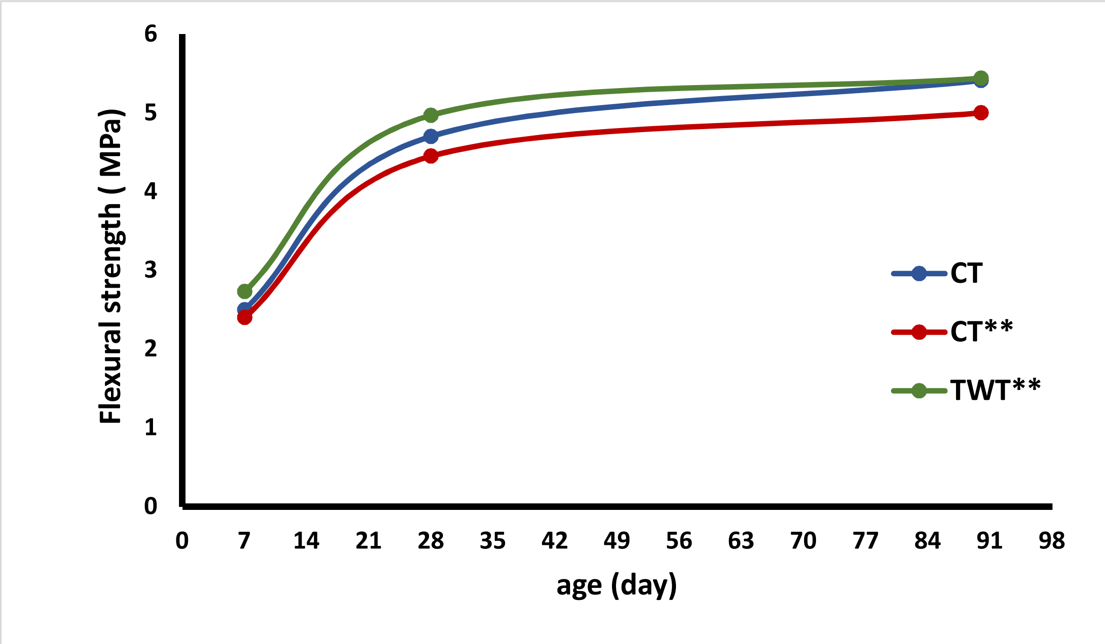


Figure (4-21) Results for (CT** and TWT**) mixtures' flexural strengths when compared to the reference mix CT.

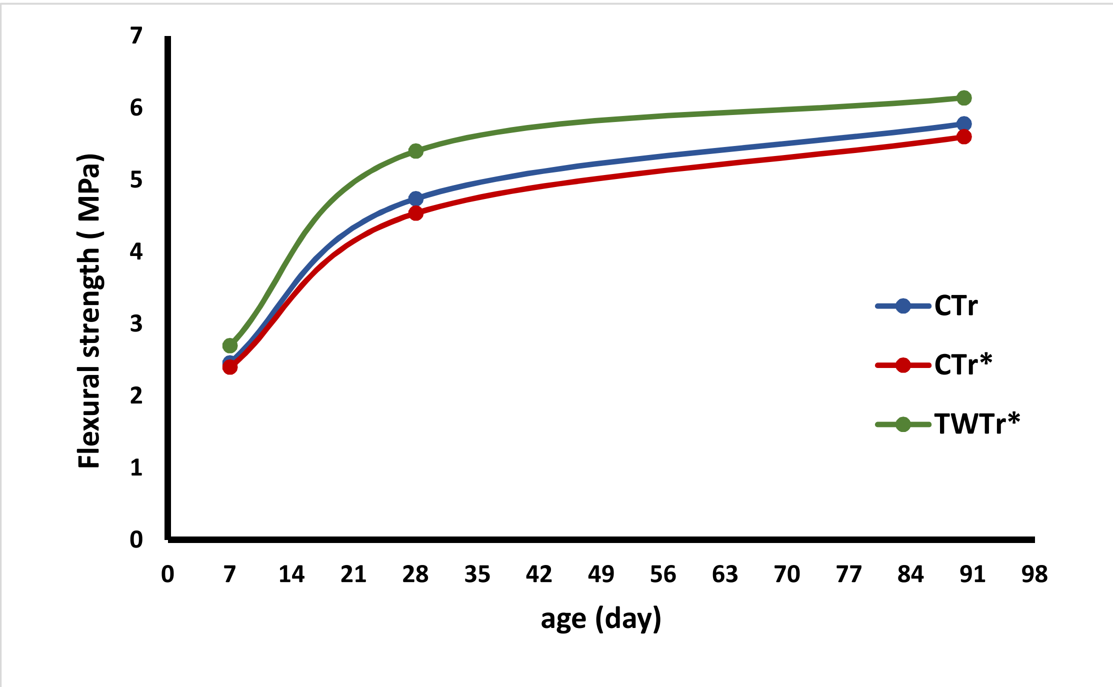


Figure (4-22) Results for (CTr* and TWTr*) mixtures' flexural strengths when compared to the reference mix CTr.

Table (4-14) flexural strength variation in percentage for (CT**, TWT**) and (CTr*, TWTr*) mixes in comparison to the reference mix CT and CTr.

Mix ID	**Description**	**percentage variance%**		
		7 day	**28 day**	**90 day**
CT**	(Sand SO3=0.6%), and (gravel SO3=0.03%) with tap water.	- 4	-5.32	- 7.58
TWT**	(Sand SO3=0.6%), and (gravel SO3=0.03%) with tap water, magnetized concrete.	9.2	5.74	0.55
CTr*	(Sand SO3=0.6%), and (gravel SO3=0.03%) with tap water.	-2.44	- 4.22	-3.11
TWTr*	(Sand SO3=0.6%), and (gravel SO3=0.03%) with tap water, magnetized concrete.	9.76	13.92	6.23

CHAPTER FIVE

CHAPTER 5

Conclusions and Recommendations

5.1 Introduction.

The main objective of the current thesis is to study the behavior of wet concrete treated with a magnetic field of an electromagnet device, with the use of fine aggregate "sand" that contains different proportions of sulfate salts, and to compare the behavior of hardened concrete in terms of compressive and flexural strength with normal untreated concrete. On the other hand, a secondary objective of the thesis was, to try to develop the technique of magnetic water treatment to treat fresh concrete in order, to reduce effort and cost and shorten time, in addition to treating all materials involved in the preparation of concrete, including tap water and sulfate sand.

5.2 Principal Conclusions.

Based on the results obtained in the laboratory and through this work, some conclusions were drawn, which are clarified in several important pivotal paths:

The first path involves improving the properties of ordinary concrete, by using tap water; and treating the fresh mixture, and compared to the reference concrete mix. While the second track showed the bad effect of sulfates present in the fine aggregate used in concrete mixtures with the use of different proportions, while the third track dealt with the treatment of fresh mix, including sulfate salts in the sand, and making the properties of hardened concrete within acceptable limits using the principle of electromagnets. To obtain a vision clearer and better, two types of cement were used, namely ordinary cement and sulfate-resistant cement, during the application of the three axial tracks of this work, with the same mixing ratios.

A fourth path was used for comparison purposes, in which ordinary cement was used with magnetized water in the concrete mixture and it was divided into two parts: the first as a reference mixture; and the second part is treated with a magnetic field.

The mechanical properties of all the treated and untreated concrete mixtures were investigated after hardening at different ages using the maximum magnetic intensity.

5.2.1 Effect of Using Magnetized Water Instead of Tap Water on Concrete Strength.

A. Magnetic water production process (3000 Gauss), which can provide magnetized water with special characteristics; and is considered an environmentally friendly and clean technology.

B. Magnetic water technology provides an encouraging improvement in the mechanical characteristics of concrete "compressive and flexural strength" without requiring supplementary additives.

C. Laboratory results showed that the compressive strength of regular concrete prepared with magnetized water increased by (3.1, 2.8, and 2.7%) at ages (7, 28, and 90 days), respectively, compared to the concrete prepared with tap water.

5.2.2 The Negative Impact of Sulfates in Fine Aggregates "Sand," on The Characteristics of Concrete.

Concrete mixture prepared using failed sand containing sulfate at a percentage (0.6%) showed little effect on the strength properties in 7 days, while the effect was more pronounced and developed at later ages up to 90 days when using ordinary Portland cement. While it showed little effect at the age of 90 days when using resistant Portland cement.

5.2.2.1 Sulfates in Sand SO_3=0.15

A. Concrete mixture (CT), "control mix with tap water, containing sulfate SO_3 = 0.15%", showed a decrease in compressive strength up to (5.1) % at (90) days of age compared to the treated mixture.
   While concrete mixture (CTr), "control mix with tap water and SRPS, showed a decrease in compressive strength up to (5.4) %.

B. The flexural strength of the concrete mix (CT) showed a decrease of up to (8) % at the age of (90) days compared to the treated mix. While (CTr) showed a decrease of up to (7.1) %

5.2.2.2 Sulfates in Sand SO_3=0.3

A. Concrete mixture (CT*), " control mixture with tap water, containing sulfate SO_3 = 0.3 %", showed a decrease in compressive strength up to (5.12) % at (90) days of age; compared to the treated mixture.

B. The flexural strength of the concrete mix (CT*) showed a decrease of up to (8.12) % at the age of 90 days compared to the treated mix.

5.2.2.3 Sulfates in Sand SO_3=0.6

A. Concrete mixture (CT**), " control mixture with tap water, containing sulfate SO_3 = 0.6 %", showed a decrease in compressive strength up to (5) %, at (90) days of age; compared to the treated mixture, while showed a decrease up to (4.1) % at the age of 90 days compared to the untreated reference mix with (SO_3 % = 0.15).

B. While concrete mixture (CTr*), "control mix with tap water and SRPS, showed a decrease in compressive strength up to (1.58) %, compared to the treated mixture, and (0.93) %, compared to the untreated reference mix with (SO3 % = 0.15).

C. The flexural strength of the concrete mix (CT**) showed a decrease of up to (8.1) %, at (90) days of age compared to the treated mix, while indicated a decrease up to (7.5) %, at the age of 90 days, compared to the untreated reference mix with (SO_3 % = 0.15).

   While (CTr*) showed a decrease of up to (8.8) %, compared to the treated mix.

5.2.3 Treating Fresh Concrete Containing Sulfate Sand with Magnetic Field.

The technique of treating fresh concrete mixture using principle of electromagnets achieved, apparent success in reducing the effect of sulfate percentage on the properties of hardened concrete, by using a magnet with intensity (3000 Gauss), to treat the mixture with the field generated by the electromagnet, on both sides of the tube through which concrete mixture passes.

5.2.3.1 Determine Optimal Magnetic Intensity for the Processing Device.

The optimum magnetic intensity treating fresh concrete and water used for curing was determined (3000 Gauss).

There was a direct relationship between compressive strength and magnetic field strength.

The relationship between the percentage of sulfate in fine aggregate and the intensity of the magnetic field was, positive for the types of sand used with the three sulfate ratios. It was observed that the sulfate content of more (SO_3) in the sand needs the same magnetic intensity used to reach positive results close to other ratios, and at all ages.

5.2.3.2 The Positive Effect of Fresh Concrete Treatment on the Properties of Harden Concrete.

1) Treatment of the fresh mixture with SO_3% = (0.15) in the sand: -

   The concrete mix (TWT)," a mixture of tap water and electromagnetic treatment, and used sand with SO_3 content equal to (0.15%) ", showed an increase in (compressive and flexural strength) up to (9.31,12.77 %), respectively, at 28 days of age, in comparison to the reference mix (CT), " control mix with tap water".

2) While (TWTr) with SRPC, showed an increase in (compressive and flexural strength) up to (5.5,15.35 %), respectively, compared to the reference mix (CTr).

3) Treatment of the fresh mixture with SO_3% = (0.3) in the sand: -

   The concrete mix (TWT*), " mixture of tap water and electromagnetic Treatment, and used sand with SO_3 content equal to (0.3%)", showed an increase in compressive and flexural strength up to (9.05,12.87 %), respectively, at 28 days of age in comparison to the reference mix

(CT*), " control mix with tap water".

4) Treatment of the fresh mixture with SO_3% = (0.6) in the sand: -

The concrete mix (TWT**), " mixture of tap water and electromagnetic treatment, and used sand with SO_3 content equal to (0.6%)", showed an increase in (compressive and flexural strength) up to (8.46,11.69 %), respectively, at 28 days of age; compared to the reference mix (CT**)," control mix with tap water".

5) While (TWTr*) with SRPC, showed an increase in compressive and flexural strength up to (7, 18.9 %), respectively, compared to the reference mix (CTr*).

5.3 Suggestion for Further Studies

1) Improving the properties of hardened concrete by using high magnetic intensity to treat fresh concrete using aggregates with higher percentages of sulfates or using different additives and studying their effect.
2) Research the cost of this device when using permanent magnets with high magnetic intensity and know the economic feasibility in detail.
3) Using recyclable materials (sustainable materials) with aggregates containing salts, treating them with the electromagnetic field of the device and with different magnetic strengths, and monitoring the results.
4) Studying the attack of internal and external sulfates on the properties of concrete when using magnetic treatment of fresh concrete during mixing and curing for a long period of time.

REFERENCES

ABBAS, Z. K., AL-BAGHDADI, H. A. & IBRAHIM, E. M. 2022. Concrete strength development by using magnetized water in normal and self-compacted concrete. *Journal of the Mechanical Behavior of Materials,* 31**,** 564-572.

ABDEL-MAGID, T. I. M., HAMDAN, R. M., ABDELGADER, A. A. B. & OMER, M. E. A. 2017. Effect of magnetized water on workability and compressive strength of concrete. *Procedia engineering,* 193**,** 494-500.

ACI 211.1-91. . Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete. 1991. Reported by ACI Committee 211.

AFSHIN, H., GHOLIZADEH, M. & KHORSHIDI, N. 2010. Improving mechanical properties of high strength concrete by magnetic water technology. *Scientia Iranica,* 17**,** p.p 74-79.

AHMED, S. M. 2009. Effect of magnetic water on engineering properties of concrete. *Al-Rafidain Engineering,* 17**,** 71-82.

AHMED, S. M. & MANAR, D. F. 2021. Effect of static magnetic field treatment on fresh concrete and water reduction potential. *Case Studies in Construction Materials,* 14**,** e00535.

AL- JUTHERY, H. W. A., ALI, A. K. & & SKABEN, L. A. 2013. The Effect Of Magnetic Water Condition In Leaching Salts Of Soil And Ionic Balance. . *Al-Muthanna Journal of Agricultural Sciences,,* 1**,** 55–69.

AL-ATTAR, T. S. 2018. Resistance of High-Volume Fly Ash Self-Compacting Concrete to Internal Sulfate Attack. *Engineering and Technology Journal,* 36.

AL-GALAWI, N. M. & HASSOONI, S. A. 2016. The Effect of Cement and Admixture Types on the Resistance of High Performance Concrete to Internal Sulphate Attack. *Journal of Engineering,* 22**,** 74-92.

AL-HUBBOUBI, S. K. & ABBAS, Z. K. 2018. Treatment of sulfate in sand by using magnetic water process. *Association of Arab Universities Journal of Engineering Sciences,* 25**,** 122-131.

AL-HUBBOUBI, S. K. & ABBAS, Z. K.,2018. Treatment of sulfate in sand by using magnetic water process. *Association of Arab Universities Journal of Engineering Sciences,* 25**,** 122-131.

AL-MALIKI, A. A. K., ASWED, K. K. & ABRAHEEM, A. K. Properties of concrete with magnetic mixing water. AIP Conference Proceedings, 2020. AIP Publishing LLC, 020146.

AL-OBAIDI, A. 2014. Effect of internal sulphate attack on concrete by using manufactured blended cement with grinded local rocks. *BAGHDAD.*

AL-OBAIDY, H. K. A. 2017. Influence of Internal Sulfate Attack on Some Properties of Self Compacted Concrete. *Journal of Engineering,* 23**,** 27-46.

AL-RAWI, R. S. 2000. Some Problems in Concrete Manufacture in The Arab Homeland and Suggested Remedial Measures. *Arab Confrerence of Construction Materials in Egypt,***,** 669–681.

ASTM C192. 2016. Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory. ASTM International.

ASTM C 78. 2016. Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)1. *ASTM International.*

ASTM C 143. 2015. Standard Test Method for Slump of Hydraulic-Cement Concrete. *ASTM International.*

BARHAM, W. S., ALBISS, B. & LATAYFEH, O. 2021. Influence of magnetic field treated water on the compressive strength and bond strength of concrete containing silica fume. *Journal of Building Engineering,* 33**,** 101544.

BS 1881: PART 108: 1983. Method for making Test Cubes from Fresh Concrete. *British standard institution.*

BS EN 12390-3. 2001. Testing hardened concrete compressive strength of test specimens. *British standards Institution.*

CAMPOS, A., LóPEZ, C. & AGUADO, A. 2016. Diffusion–reaction model for the internal sulfate attack in concrete. *Construction and Building Materials,* 102**,** 531-540.

CHEN, W., HUANG, B., YUAN, Y. & DENG, M. 2020. Deterioration process of concrete exposed to internal sulfate attack. *Materials,* 13**,** 1336.

CHIBOWSKI, E. & SZCZEŚ, A. 2018. Magnetic water treatment–A review of the latest approaches. *Chemosphere,* 203**,** 54-67.

COLMAN, C., BULTEEL, D., REMOND, S., ZHAO, Z. & COURARD, L. 2020. Valorization of fine recycled aggregates contaminated with gypsum residues: Characterization and evaluation of the risk for secondary ettringite formation. *Materials,* 13**,** 4866.

DE SOUZA, D., MEDEIROS, M., HOPPE, J. & SANCHEZ, L. The Uses of Finely Ground Materials to Mitigate the External Sulphate Attack (ESA) on Cementitious Materials. External Sulphate Attack–Field Aspects and Lab Tests: RILEM Final Workshop of TC 251-SRT (Madrid-SPAIN, 2018), 2020. Springer, 139-151.

DIVYA, M. 2020. Study on effect of magnetic field treated water on fresh and hardened concrete properties. *IJIRT,* 6**,** 12.

EL-SABROUT, K. & EL-HANOUN, A. 2019. Does magnetised drinking water influence poultry's health and production? *World's Poultry Science Journal,* 75**,** 411-416.

ELSHAMI, A., ESSAM, N. & YOUSRY, E.-S. M. 2022. Improvement of hydration products for self-compacting concrete by using magnetized water. *Frattura ed Integrità Strutturale,* 16**,** 352-371.

ENG-TIPS.COM. 2019. Diagnosing Sulfate Attack in SOG. *https://www.eng-tips.com/viewthread.cfm?qid=454558.*

FAWZI, N. M., ABBAS, Z. K. & JABER, H. A. 2015. Influence of internal sulfate attack on some properties of high strength concrete. *Journal of engineering,* 21**,** 1-21.

GHORBANI, S., MOHAMMADI-KHATAMI, M., GHORBANI, S., ELMI, A., FARZAN, M., SOLEIMANI, V., NEGAHBAN, M., TAM, V. W. & TAVAKKOLIZADEH, M. 2021. Effect of magnetized water on the fresh, hardened and durability properties of mortar mixes with marble waste dust as partial replacement of cement. *Construction and Building Materials,* 267**,** 121049.

GORGIS, I. N., JABER, A. A. & HASSAN, M. S. 2018. SULFATE AND CHLORIDE RESISTANCE OF NANOSILICA AND MICROSILICA CONTAINED SELF-CONSOLIDATING CONCRETES. *Kufa Journal of Engineering,* 9.

HALSTEAD, C. O. A. W. J. 1995. Improved Concrete Quality with Combinations of Fly Ash and Silica Fume. *ACI Materials journal* 91**,** pp 587 – 594

HAMZA, J. N. 2019. Investigation on using magnetic water technology for leaching high saline-sodic soils. *Environmental monitoring and assessment,* 191**,** 1-11.

HARSHA, R. & SRUTHI, D. K. K., . 2018. An experimental study on the use of magnetized water in concrete with M sand as fine aggregate. *International organization of Scientific Research, IOSR Journal of Engineering (IOSRJEN),* 8**,** 26-32.

HASHIM, A. K., ALI, A. K. & BASHEER, M. I. 2019. Effect of Magnetic Treatment of Water on Corrosion Rate. 5.

HASSAN, A. F. 2008. Effect of magnetized water on the properties of cement mortars at the earlier ages. *Al-Qadisiyah journal for Engineering Sciences,* 1**,** 95-108.

HODHOD, O. & SALAMA, G. 2013. Developing an ANN model to simulate ASTM C1012-95 test considering different cement types and different pozzolanic additives. *HBRC Journal,* 9**,** 1-14.

HORKOSS, S., ESCADEILLAS, G., RIZK, T. & LTEIF, R. 2016. The effect of the source of cement SO3 on the expansion of mortars. *Case Studies in Construction Materials,* 4**,** 62-72.

IBRAHIM, E. M. & ABBAS, Z. K. 2021a. Solving high sulfate content of sand used in concrete by magnetic water process. *Materials Today: Proceedings,* 42**,** 2808-2814.

IRAQI SPECIFICATION. 1992. No. 1703: Water used in concrete. *Baghdad, Iraq: Central Organization for Standardization and Quality Control*.

IRAQI STANDARD SPECIFICATION NO.5. 2019. Iraqi Organization of Standards. IQS.

IRAQI STANDARD SPECIFICATIONNO.45. 1984. Aggregates from natural resources used in concrete and Central construction organization for standardization and quality control. *ministry of planning Iraq*.

JAIN, A., LAAD, A., SINGH, K., MURARI, K. & STUDENT, U. 2017. Effect of magnetic water on properties of concrete. *International Journal of Engineering Science and Computing,* 7.

JIHAD, E. Y. 2009. The Properties of Produced Concrete by Using Fine Aggregate with Sulphate Content Higher Than Iraqi Specification Limits. *Engineering and Technology Journal,* 27.

JOUZDANI, B. E. & REISI, M. 2020. Effect of magnetized water characteristics on fresh and hardened properties of self-compacting concrete. *Construction and Building Materials,* 242**,** 118196.

KADHIM, Z. J., AL-ADHADH, A. R. & SAKBAN, H. K. 2020a. Study and improvement the effect of internal sulphate on properties of normal and light weight concrete. *Periodicals of Engineering and Natural Sciences (PEN),* 8**,** 1817-1828.

KADHIM, Z. J., AL-ADHADH, A. R. & SAKBAN, H. K. 2020b. Study and improvement the effect of internal sulphate on properties of normal and light weight concrete. *Periodicals of Engineering and Natural Sciences,* 8**,** 1817-1828.

KARAM, H. & AL-SHAMALI, O. Effect of using magnetized water on concrete properties. Third International Conference on Sustainable Constructional Materials and Technologies held at Kyoto Research Park, Kyoto, Japan on 18th–22nd August, 2013. 1-12.

KARKUSH, M. O., AHMED, M. D. & AL-ANI, S. 2019. Magnetic field influence on the properties of water treated by reverse osmosis. *Engineering Technology Applied Science Research,* 9**,** 4433-4439.

KARTHIK, D. E., MRUDUNAYANI, P. & BABU, S. Influence of Magnetic Water on Self-compacting Concrete Using Sulphate Resisting Cement. Annales de Chimie: Science des Matériaux, 2019. 347-352.

KAUSHIK, V. S. S., PAVAN, V. R. N. V. D., & DEERENDRA 2015. Influence of Magnetized water on strength parameters of concrete. *International Journal for Research and Developement in Technology,* .

KHARCHENCO, I. & ALEKSEEV, V. Effect of ettringite morphology on the properties of expanding cement systems. E3S Web of Conferences, 2019. EDP Sciences, 01037.

KHREEF, S. M. & ABBAS, Z. K. Investigation the Quality of the Treatment Sand from Sulfite using Magnetic Water in Reactive Powder Concrete. IOP Conference Series: Materials Science and Engineering, 2021a. IOP Publishing, 012057.

MAILVAGANAM, N. P., RIXOM, M., MANSON, D. P. & GONZALES, C. 1999. *Chemical admixtures for concrete*, Crc Press.

MALATHY, R., KARUPPASAMY, N. & BARANIDHARAN, S. 2017. Effect of magnetic water on mixing and curing of M25 grade concrete. *International Journal of ChemTech Research,* 10**,** 131-139.

MANJUPRIYA, T. & MALATHY, R. 2016. Experimental investigation on strength and shrinkage properties of concrete mixed with magnetically treated water. *Magnesium,* 290**,** 195.

MAZLOOM, M. & MIRI, S. M. 2017. Interaction of magnetic water, silica fume and superplasticizer on fresh and hardened properties of concrete. *Advances in concrete construction,* 5**,** 087.

MERIDA, A. & KHARCHI, F. 2015. Pozzolan concrete durability on sulphate attack. *Procedia Engineering,* 114**,** 832-837.

MOSIN, O. & IGNATOV, I. 2015. Magnetic Water Treatment for Eliminate of Carbonate, Chloride and Sulfate Salts of Ca2+, Mg2+, Fe2+ and Fe3+ Cations. *Journal of Medicine, Physiology and Biophysics,* 12**,** 82-96.

NADIR, H. & AHMED, A. 2022. The Mechanisms of Sulphate Attack in Concrete–A Review. *Modern Approaches on Material Science,* 5**,** 658-670.

NAN, S. & CHEA-FANG, W. 2003. Effect of magnetic field treated water on mortar and concrete containing fly ash. *Cement and concrete composites,* 25**,** 681-688.

NARMATHA, M., ARULRAJ, P. & ABDUL BARI, J. 2021. Effect of magnetic water treatment for mixing and curing on structural concrete. *Materials Today: Proceedings,* 37**,** 671-676.

NWOFOR, T. & AZUBUIKE, C. 2020. Determination of the optimum magnetic exposure time for magnetic water concrete. *International Journal of Construction Engineering and Planning,* 6**,** 34-42.

OMNI ENVIRO WATER SYSTEM. 2021. Magnetized Water,. *https://www.omnienviro.com/magnetized-water/,*.

OWSIAK, Z. 2010. Effect of delayed ettringite formation and alkali-silica reaction on concrete microstructure. *Ceramics-Silikaty,* 54**,** 277-283.

PREETHI, P., BALASUNDARAM, N. & PRATHEBA, S. 2022. Utilization of magnetized water in steel fibre reinforced concrete. *Materials Today: Proceedings*.

RAMACHANDRAN, H., & K, S. D. K. 2018a. An Experimental Study on the Use of Magnetized Water in Concrete with M Sand as Fine Aggregate. *2018, 08(6), 26–32.*

RAMACHANDRAN, H. K., S. D. K. 2018b. An Experimental Study on the Use of Magnetized Water in Concrete with M Sand as Fine Aggregate. *2018, 08(6), 26–32.*

RAMALINGAM, M., NARAYANAN, K., MASILAMANI, A., KATHIRVEL, P., MURALI, G. & VATIN, N. I. 2022. Influence of Magnetic water on concrete properties with different magnetic field Exposure Times. *Materials,* 15**,** 4291.

RAOUF, Z. E.-A., AL-SUHAILI, R. H. & MAHDI, Z. H. 2016. Some properties of carbon fiber reinforced magnetic reactive powder concrete containing Nano silica. *Journal of Engineering,* 22**,** 103-124.

REDDY, B. S. K., GHORPADE, V. G. & RAO, H. S. 2014. Influence of magnetic water on strength properties of concrete. *Indian journal of science and technology,* 7**,** 14-18.

REDDY M, V. K. A. R. C. 2019. Flexural behavior of magnetic water concrete with varying durations of magnetization. *International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES) 5*.

RONNE, M. 1989. Effect of condensed silica fume and fly ash on compressive strength development of concrete. *Special Publication,* 114**,** 175-190.

SALEH, I. S. 2017. Effect of external and internal sulphate on compressive strength of concrete. *Int. J. App. Eng. Res,* 12**,** 10324-10333.

SEVIM, O., DEMIR, İ., ALAKARA, E. H., GUZELKUCUK, S. & BAYER, İ. R. 2023. The Effect of Magnetized Water on the Fresh and Hardened Properties of Slag/Fly Ash-Based Cementitious Composites. *Buildings,* 13**,** 271.

SHARMA, H. 2018. Water-General Introduction. Module prepared for ePG Pathshala (a MHRD Project) for Environmental Sciences subject, paper Water Resources and Management.
SHYNIER, A., ABED, M., FOUAD, Z., KAZIM, A., ISSE, R., REHEEM, N. & SADEQ, J. 2014. Improving some of mechanical properties of concrete by magnetic water technology. *Ministry of Science and Technology*.
SRINIDHI, P., NAVANEETHAN, K., DHEERAN, A. & ANANDAKUMAR, S. 2019. Comparative study on concrete materials using normal and magnetized water. *International Research Journal of Engineering and Technology,* 6**,** 83-87.
SU, N. & WU, C.-F. 2003. Effect of magnetic field treated water on mortar and concrete containing fly ash. *Cement and concrete composites,* 25**,** 681-688.
TARBOZAGH, A. S., REZAIFAR, O. & GHOLHAKI, M. Electromagnetism in taking concrete behavior on demand. Structures, 2020. Elsevier, 1057-1065.
TOUMA, H. N. 2008. AN APPORXIMATE METHOD TO IMPRORVEEMENT THE COMPRESSIVE STRENGTH OF CONCRETE CONTAINING HIGH PERCENTAGE OF SULPHATE. *Iraqi Academic Scientific Journals, ,* 21**,** 26-31.
VENKATESH, S. & JAGANNATHAN, P. An experimental study on the effect of magnetized water on mechanical properties of concrete. IOP Conference Series: Materials Science and Engineering, 2020. IOP Publishing, 032081.
XIAO-FENG, P. & XING-CHUN, Z. 2013. The magnetization of water arising from a magnetic-field and its applications in concrete industry. *International journal of engineering research and applications,* 3**,** 1541-1552.
YAN MC, T. W., YEUNG TH ET AL., 2009. Chemistry of magnetic water. *International Chemistry Olympiad. IChO, UK.*
ZHANG, G. & LI, G. 2016. Effects of mineral admixtures and additional gypsum on the expansion performance of sulphoaluminate expansive agent at simulation of mass concrete environment. *Construction and Building Materials,* 113**,** 970-978.
ZIYAD, A. M., AL-SAFI, S. & AL-MUTAWAKKIL, M. 2015. The effect of water exhibited to magnetic field on some properties of concrete. *Journal of Science and Technology,* 20.

الخلاصة

يعد استخدام تكنولوجيا المجال المغناطيسي ذو المبدأ الكهربائي لإنتاج الخرسانة الممغنطة طريقة تجريبية جديدة في مجال الطاقة المتجددة والصديقة للبيئة؛ لتقليل مشاكل أملاح الكبريتات في الخرسانة. يتطلب بناء هياكل خرسانية قوية وطويلة الأمد يمكنها تحمل الظروف الجوية مواد وتكنولوجيا مبتكرة. تعتبر أملاح الكبريتات من أكبر مشاكل الخرسانة في مدن الشرق الأوسط. يعود سبب مشكلة ارتفاع نسبة الأملاح في التربة والركام والمياه إلى ظاهرة الاحتباس الحراري والذي يؤدي إلى ارتفاع درجات الحرارة وقلة مصادر المياه الصالحة للاستعمال. يعتبر هجوم الكبريتات الداخلية على الخرسانة من أهم المشاكل التي تؤدي إلى تدهور مقاومة الخرسانة بسبب النسبة العالية من SO_3 في الركام الخشن والناعم على وجه الخصوص. تعتبر الكبريتات ($CaSO_4 .2H_2O$) هي الأقل قابلية للذوبان في ماء الصنبور، حيث توجد بكميات عالية على سطح حبيبات الركام وداخل مسامها.

تضمن العمل التجريبي تصنيع جهاز مغناطيسي بمبدأ كهربائي يعمل بكفاءة ويمكن استخدامه مع جهاز الضخ في موقع العمل أثناء صب الخرسانة. يتلخص عمل الجهاز في عدة مراحل، الأولى: الحصول على الخرسانة الممغنطة باستخدام ماء الصنبور. تم تعريض الخليط لثلاث درجات من الشدة المغناطيسية (2000، 2500، 3000) غاوس، حيث تم الحصول على أعلى قوة ضغط للخرسانة المتصلدة بأعلى شدة مغناطيسية تبلغ (3000 جاوس) في (7، 28، 90) يومًا. وهذه الشدة تم اعتمادها في اختبارات هذا البحث. المرحلة الثانية: إنتاج الماء الممغنط لاستخدامه في خلط ومعالجة الخرسانة. المرحلة الثالثة: إنتاج الخرسانة الممغنطة باستخدام الماء الممغنط. أثبتت التجارب المختبرية كفاءة تقنية الجهاز في معالجة المخاليط مع المجال الكهرومغناطيسي وتحسين الخواص الميكانيكية للخرسانة المحتوية على نسب مختلفة من أملاح الكبريتات.

أظهرت نتائج مقاومة الانضغاط والانحناء تحسنًا واضحًا في الخرسانة عند تعرضها للمجال الكهرومغناطيسي للجهاز؛ زادت مقاومة الانضغاط للخرسانة الممغنطة بنسبة (9.30 و 9.31 و 5.32٪) عند SO_3 = 0.15٪، و (9.32 و 9.05 و 5.43٪) عند SO_3= 0.3٪، و (9.20 و 8.46 و 5.27٪) عند SO_3= 0.6٪، في 7 و 28 و 90 يومًا على التوالي ، فقط عند مرور خليط الخرسانة عبر الأنبوب المعرض للمجال الكهرومغناطيسي. تم تحضير عدة خلائط خرسانية قبل وبعد المعالجة بمجال كهرومغناطيسي باستخدام رمل يحتوي على (0.15، 0.3) % من أملاح الكبريتات ورمل

فاشل يحتوي على (0.6) بالمائة من الكبريتات. يُلاحظ من تسجيل نتائج الاختبار أن هناك انخفاضًا في مقاومة الانضغاط وقوة الانثناء في جميع الأعمار، خاصة في الأعمار المتأخرة بسبب تأثير الأملاح، حيث تم تسجيل انخفاض في مقاومة الانضغاط حوالي (0.93، 4.1) عند عمر 90 يومًا للخلطات الخرسانية (CT**, CTr*) على التوالي، مقارنة بمزيج الخرسانة المرجعي (CT, CTr). كان تدهور الخرسانة بسبب التطور السلبي للملح، وكانت هناك حاجة لاستخدام طريقة تجريبية لتقليل تأثير نسب الملح على خواص الخرسانة من خلال استخدام الجهاز الكهرومغناطيسي المصنوع محليًا.

أظهرت نتائج فحص الخرسانة الممغنطة المحتوية على نسب مختلفة من أملاح الكبريتات نتائج مشجعة، حيث كانت نسبة الزيادة في مقاومة الانضغاط (3.84، 6.17)؛ بعمر 28 يومًا لخليط الخرسانة (TWT**, TWTr*) على التوالي، مقارنة بالخرسانة المرجعية (CT, CTr).

جمهورية العراق

وزارة التعليم العالي والبحث العلمي

جامعة بابل/كلية الهندسة

قسم الهندسة المدنية

تحسين الخرسانة المحتوية على نسبة عالية من الكبريتات بطريقة المعالجة المغناطيسية

رسالة

مقدمة إلى كلية الهندسة / جامعة بابل

كجزء من متطلبات نيل درجة ماجستير في الهندسة المدنية / مواد إنشائية

من قبل

الاء عبد الكاظم عبد الله

(بكالوريوس ٢٠٠٦)

بإشراف الاستاذ

سامر عبد الأمير المشهدي

شعبان / 1445   مارس / 2023