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THE USE OF WASTE FROM MARBLE WORKSHOPS AS AN ALTERNATIVE TO FINE AND COARSE AGGREGATES FOR THE PRODUCTION OF CONCRETE

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Master’s Thesis

Supervisor

Assoc. Prof. Dr. Sepanta NAİMİ

İstanbul, 2024

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The thesis titled THE USE OF WASTE FROM MARBLE WORKSHOPS AS AN ALTERNATIVE TO FINE AND COARSE AGGREGATES FOR THE PRODUCTION OF CONCRETE prepared by MOHAMED MOSTAFA AHMED SHOKSHOK and submitted on 20/03/2024 has been **accepted unanimously** for the degree of Master of Science in Civil Engineering.

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I hereby declare that this thesis meets all format and submission requirements for a Master's Thesis.

I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

Mohamed Mostafa SHOKSHOK

Signature

DEDICATION

To my parents, who planted the seed of knowledge in my mind and nurtured it. To those rare, beautiful friendships that change our lives forever. To my professor, who taught me the value of critical thinking and the power of the pen.

ABSTRACT

THE USE OF WASTE FROM MARBLE WORKSHOPS AS AN ALTERNATIVE TO FINE AND COARSE AGGREGATES FOR THE PRODUCTION OF CONCRETE

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The marble industry generates significant waste that negatively impacts the environment. Unfortunately, only a small portion is utilized in various applications. These vast quantities of waste, often dumped indiscriminately, can hinder soil porosity and permeability, leading to reduced water absorption. This can contribute to soil-borne diseases, particularly respiratory issues amongst nearby residents, while also polluting groundwater. Moreover, the visual impact on the landscape is undeniably detrimental.

This study investigated the potential of utilizing waste from marble workshops as an alternative to traditional Libyan aggregates (ploughing and blasting) in varying proportions for regular concrete production. The research explored both coarse and fine aggregates derived from marble waste. Fine aggregate was incorporated at various ratios (10%, 30%, and 50%) into the standard concrete mix alongside local sand. The suitability of these aggregates was evaluated through comprehensive mechanical and physical testing, encompassing not only the aggregates themselves but also the resulting concrete's workability and compressive strength.

The findings encourage the use of marble waste as both coarse and fine aggregate in regular concrete. Notably, the mechanical properties of the obtained aggregates met all relevant specifications. The concrete containing 50% coarse marble aggregate alongside blasting

aggregates exhibited a higher compressive strength than the reference mix crafted with local aggregates. Similarly, the concrete incorporating 30% fine marble aggregate displayed greater compressive strength compared to the standard formulation using local sand.

Based on these promising results, we recommend further exploration of utilizing marble workshop waste as an alternative to traditional aggregates within the boundaries established by this research.

Keywords: Marble Powder, Aggregate, Portland Cement , Strength, Hydration Products, FLY-ASH, Durability.

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1. INTRODUCTION

1.1 BACKGROUND TO THE STUDY

The topic of solid waste management has been gaining increasing attention worldwide due to the numerous problems it causes. In certain cities, industrial, residential, and commercial areas are intermixed, leading to overlapping issues concerning industrial waste disposal and residential areas. This is primarily due to the lack of adequate waste management facilities in the industrial areas located within or close to city limits. In some developing countries like Libya, the problem is compounded by the limited scope of local agencies, which can only handle street cleaning and residential waste transportation, thereby exacerbating the accumulation of solid industrial waste in factory sites. The use of aggregates in public construction projects worldwide is estimated to be around 26.8 billion tons per year, with aggregates comprising 70-80% of the total volume of concrete mix components[1][2]. Libya's construction industry is rapidly growing, leading to an increased use of natural aggregates. In the mid-20th century, there was a growing interest in using economically inexpensive materials during the production and manufacture of concrete. This led to research being conducted on the use of non-traditional sources of aggregates, such as industrial waste, building materials residues, and manufacturing residues. Utilizing such materials as fine or coarse aggregates in cement mortar and concrete can help to solve the problem of aggregate scarcity at various construction sites while simultaneously reducing environmental issues associated with the accumulation of such materials around extractive mills.

Throughout history, the versatile material of marble has found its way into various industries, including art, architecture, and design. This metamorphic rock is created through the recrystallization of calcite or dolomite, with a significant amount of calcium carbonate ($CaCO_3$) comprising its composition [3][4]. It is believed that the world currently possesses around 15 billion cubic meters of marble reserves[5]. Nonetheless, the extraction and processing of this resource often result in a considerable amount of waste, with estimates ranging from 30% to 75% [6][7][8].

In factories, marble waste typically comes in the form of flat stones, pallediens (Through the process of slicing plates into specific dimensions and the subsequent fracturing of said plates, minuscule remnants were left behind), and marble powder. Pallediens are often used for flooring, while flat stones are used for making kitchen sinks, gifts, and ornaments[9]. Marble powder is a residue that results from wet cutting and polishing, with a majority of it being less than 250µm in size[10]. During cutting, up to 50% of the waste produced may be in the form of powder, which is then purified of water and compressed or stacked in sedimentation pools[11][12].

And with the accumulation of thousands of tons of waste from the marble industry, the negative impact on the surrounding area is becoming increasingly evident. Although marble is a valuable material, the majority of this waste is still considered industrial waste and only a small amount is used in the tile industry. The disposal of this waste can lead to environmental issues, such as reducing soil porosity and permeability, causing respiratory problems for nearby residents, polluting groundwater, and harming the natural appearance of the area[10]. Furthermore, there are cost-related problems as well. The demand for building materials is increasing while the availability of raw materials is becoming scarce and energy prices are rising. Therefore, finding alternative materials that are environmentally friendly and sustainable is crucial. This research proposes using waste from the marble industry as an alternative material for local aggregates in concrete production, which can reduce costs and be more energy-efficient than blasting natural aggregates. As a result, exploring new sources for building materials should be a priority to ensure the preservation of natural resources and energy conservation[13].

In contrast the accumulating debris surrounding the quarry presents a visual blight, manifesting itself in the form of towering hills of masonry and supplementary access roads as depicted in Figure (1.1). As accumulation areas and their attendant connection roads proliferate, the once-thriving vegetation is gradually being decimated.

Figure 1.1: The Imposing Heaps Encircling The Quarries and The Decimation of Plant Life.

1.2 PROBLEM STATEMENT

While there have been some efforts to use recycled materials in concrete production, including the use of fly ash and slag as partial replacements for cement, there is still a need for more sustainable alternatives to natural aggregates such as sand and gravel[14][15]. The global demand for concrete is expected to continue to increase, with a projected 23% increase in demand by 2050[16], making the development of more sustainable practices in the construction industry critical for reducing environmental impact. The use of waste from marble workshops as an alternative to fine and coarse aggregates in concrete production represents a promising opportunity to address this issue. However, there are still significant gaps in our understanding of the physical and mechanical properties of concrete produced using waste from marble workshops as a complete substitute for natural aggregates[17][18]. In particular, it is important to assess the durability and long-term performance of this concrete, as well as its potential for scaling up to industrial levels.

part from environmental concerns, there are also cost-related issues. As demand for building materials increases, the cost of raw materials and energy prices also rise. As a result, there is a global interest in finding alternative building materials that are sustainable and eco-friendly. This research proposes the use of marble waste as a substitute for local aggregates, which can reduce the cost of concrete. Crushing marble waste is a more cost-effective process compared to blasting natural aggregates, which takes longer and is more expensive. By exploring new sources for building materials, we can save energy and protect natural resources. The marble industry produces an excessive amount of waste that can have a negative impact on the surrounding environment. This waste is currently classified as industrial waste, and only a small portion of it is utilized in industries such as tile production. Disposing of this waste in landfills can lead to soil porosity reduction, water saturation, and groundwater pollution, which can cause respiratory illnesses in nearby residents and harm the natural beauty of the area[19][20][21].

However, there is limited research on the use of waste from marble workshops as an alternative to fine and coarse aggregates for the production of concrete. Therefore, the aim of this study is to investigate the potential use of waste from marble workshops as an alternative to fine and coarse aggregates for the production of concrete. The study will evaluate the physical and mechanical properties of the resulting concrete and compare them to those of conventional concrete made with natural aggregates. The goal of the study is to provide a better understanding of the potential of using waste from the marble industry as a sustainable and environmentally friendly alternative to conventional concrete materials.

1.3 THE OBJECTIVES OF THE STUDY

By looking at the research related to the use of solid waste in concrete, it was noted that there were no extensive studies on the use of waste from marble workshops as a substitute for natural aggregate in the concrete mixture, and the information available about the use of this type of aggregate is very limited. Therefore, it was necessary to conduct more studies on the use of this type of aggregate and to know the properties of the aggregates of the wastes of the marble industry and its impact on concrete. Good properties.

The main objective of this study is to obtain some information to try to use the wastes of the marble industry to produce concrete by replacing it instead of the local aggregate (divided into: coarse aggregate and fine aggregate) by 100% of the aggregate forming the concrete, and fine marble aggregate was used with proportions of fine aggregate In three mixtures (10%, 30% and 50%), and coarse aggregates were used in proportions (33.33%, 50%, 100%) and its effect on the properties of concrete was known through the workability (slump) and pressure resistance tests, and then the results were compared. When using plowing aggregates by 100% and using blasting aggregates by 100%, in addition to comparing the properties of marble aggregates with the properties of local aggregates in terms of specific weight, absorption, sieve analysis, crushing coefficient and wear coefficient.

Therefore, the research objectives to be reached in this study can be summarized in the following points:

a. To assess the physical and mechanical properties of concrete produced using waste from marble workshops as an alternative to traditional aggregates.
b. To investigate the potential environmental benefits of using marble waste in concrete production, such as reducing waste disposal and conserving natural resources.
c. To evaluate the economic feasibility of using marble waste as an alternative to traditional aggregates in concrete production.
d. To compare the performance of concrete made with marble waste to that of traditional concrete in terms of compressive strength, durability, and other relevant properties.
e. To identify any challenges or limitations associated with using marble waste in concrete production and propose solutions or recommendations to overcome them.
f. To contribute to the existing body of knowledge on sustainable construction materials and waste management by providing a case study on the use of marble waste in concrete production.

2. GENERAL INFORMATIONS AND LITERATURE REVIEWS

2.1 GENERAL AND BRIEF OF THE STUDY

The process of manufacturing marble and stone entails a series of intricate operations, including cutting, sawing, polishing, and surface leveling, all of which take place within specialized factories. However, this elaborate production process also gives rise to substantial amounts of waste in various forms. One aspect of this waste is the solid residue, which comes in diverse sizes and shapes. This solid waste necessitates appropriate disposal methods, and one common approach is its utilization within the concrete industry, various construction endeavors, and aggregate works.

In addition to the solid waste, there is another form of waste generated during the manufacturing process: a dense, viscous liquid byproduct. This liquid waste primarily consists of water, employed to cool the mechanisms employed in marble and stone factories. It also contains additives utilized for surface leveling purposes. Moreover, during the cutting operations, fine particles, sand, and sawdust are produced, which find their way into the liquid waste. Notably, these materials tend to coalesce and form a light, spreadable substance upon drying. Consequently, it is common practice to collect this substance in designated areas, such as lakes, to facilitate the drying process. However, the subsequent transformation into a very lightweight material presents challenges in its management and disposal. Often, this material is carelessly and randomly discarded, giving rise to environmental and health concerns [22][23].

Furthermore, the cutting and sawing processes employed in marble and stone factories result in the emission of considerable quantities of dust. This dust, consisting of fine particles, is released into the surrounding environment, potentially causing air pollution and respiratory health issues for workers and nearby communities [22][24].

Taken together, the manufacturing of marble and stone involves not only intricate techniques but also significant waste generation. Proper management and disposal of the solid waste, as well as the thick liquid waste and dust emissions, are essential to mitigate environmental and health problems associated with this industry.

2.2 WATER USED IN THE CONCRETE MIXES

Water used in concrete refers to the essential component of the concrete mixture that is added during the mixing process to facilitate hydration and achieve the desired workability and strength of the final product. It serves as a crucial ingredient in the chemical reaction between cement and other components, such as aggregates and admixtures, known as the hydration process. The water used in concrete plays multiple roles in the overall concrete mix. Firstly, it acts as a medium for the cement particles to dissolve and react, forming a paste that binds the aggregates together. This hydration process leads to the hardening and setting of the concrete [25][26].

Secondly, water contributes to the workability or consistency of the concrete mix. It helps in the smooth and efficient distribution of cement paste throughout the mixture, allowing for easier placement, compaction, and shaping of the concrete [26].

Moreover, the water-to-cement ratio (the ratio of water mass to cement mass) has a significant impact on the strength, durability, and other properties of the hardened concrete. It is essential to maintain an appropriate water-to-cement ratio to ensure the desired strength and durability while avoiding issues such as excessive shrinkage, cracking, or reduced strength due to inadequate hydration [27][28].

It is worth noting that the quality of the water used in concrete can also influence the overall performance and durability of the concrete. Factors such as the source, chemical composition, and impurities present in the water should be considered to prevent any adverse effects on the concrete's properties.

2.3 AGGREGATE USED IN CONCRETE

Aggregate is an inert granular material such as sand, gravel, and crushed rock. Together with water and cement, it forms the basic components of concrete. For a high-quality concrete mix, the aggregate must be clean, solid, and strong, and the aggregate particles must be free from any adsorbed chemicals or covered with any type of clay or any type of fine material that may contribute to the deterioration of the condition and quality of the concrete, and the aggregate that it constitutes (60-75) % of the total concrete volume. It can be divided into two classes [29]:

a. FINE AGGREGATE: Generally, it consists of natural sand or crushed rock so that the granules of that aggregate can pass through sieves with holes with diameters (4.75 mm).
b. COARSE AGGREGATE: its grains are greater than (4.75 mm). Gravel constitutes the majority of the volume of coarse aggregate, while crushed rock constitutes the remainder of the amount used in the mixture. Natural gravel and sand are usually obtained from drilling or dredging the bottoms of rivers, lakes or the sea. Crushed aggregate is produced by crushing boulders, large gravel and stones.

2.3.1 The Nature of The Formation of Aggregate

Aggregates are formed as a result of the deposition of minerals and their formation during geological processes, where particles of rubble fragment from rocks, either naturally as a result of weathering, ground and erosion processes, or industrially by crushing rocks with devices and machines, and many compounds are similar in their properties, while others differ according to their sources [29][30].

2.3.2 Clasification of Aggregate Sources

a. AGGREGATES FROM NATURAL SOURCES: It is the rubble of rivers and valleys, this type is extracted either by digging quarries in valleys or obtaining it from rivers by suction, and it is usually washed and separated into granular groups, and then re-mixed and formed as the required rubble in the places for its processing. Natural rocks extracted from quarries by crushers, where different sizes of gravel and sand are obtained[29].
b. LIGHTE TYPE AGGREGATES: It is a natural light aggregate such as volcanic slag as well as pumice stone and light industrial aggregate such as fired clay and blast furnace slag. It is worth mentioning that the light type is used to manufacture light concrete for thermal insulation[29].
c. HEAVY AGGREGATES : As for this type of aggregate, its materials are heavy and it is important for concrete, which is used to protect against radiation, for example[29].

2.3.3 The Importance of Aggreagates in the Concrete

Aggregates have a significant impact on the properties and quality of concrete because it occupies about (70-75)% of the total volume of the concrete mass [29]. Aggregates generally consist of rocky granules of varying size, including small granules such as sand (fine aggregate) and other large granules such as gravel (coarse aggregate) in addition To the fact that aggregates constitute the largest part of the concrete structure, which gives the concrete mass its stability and resistance to external forces and various weather factors such as heat, humidity and freezing, it reduces volume changes resulting from the freezing and hardening of the cement paste or the exposure of the concrete to moisture and dryness. Therefore, aggregates give the concrete a better durability than if a paste was used. Cement alone, and from what was stated previously, it is clear that the properties of aggregates greatly affect the durability and behavior of the concrete structure, and when selecting aggregates for the purpose of use in a specific concrete, attention must be paid in general to three requirements: (the economy of the mixture, the latent resistance of the hardened mass, and the potential strength of the concrete structure). Another important characteristic of the concrete aggregate is the gradation of its granules. The comprehensive grading tables are attached to the aggregate according to the largest notional size. For the purpose of obtaining a dense concrete structure, the gradation of the concrete aggregate must be appropriate by determining the proportion of fine aggregate and coarse aggregate in the mixture. In addition, the gradation of aggregate granules is an important factor in controlling the workability of fresh concrete. When determining the amount of aggregate present in a unit volume of concrete, the workability of the mixture is more when the gradation of the aggregate is appropriate, and thus the need for the amount of water required for the mixture is less, and this in turn leads to an increase in the resistance of the resulting concrete, as the aggregate affects the total cost of concrete. In general, the more aggregate is present in a specific volume of concrete, the more economical the resulting concrete will be, because the aggregate is cheaper than cement[31][32][33][34].

2.4 MARBLE OVERVIEW

Marble, an exquisite metamorphic rock, undergoes a transformative process within the Earth's crust, subjecting it to extreme temperatures and pressures that imbue it with its distinctive qualities. Composed predominantly of calcite, marble stands out due to its remarkable purity and is renowned for its captivating allure. Its diverse range of applications encompasses the realms of architecture, sculpture, commemorative monuments, interior decoration, and luxurious flooring[35].

Humanity has cherished and harnessed the beauty of marble for countless generations, utilizing it to adorn and embellish palaces, mosques, and an array of grand structures. The resplendent and vibrant colors of marble bestow a unique aesthetic charm to any space it graces. With the passage of time, the demand for marble has surged, prompting its desirability in homes across the globe. This surge in popularity has spurred the advancement of marble industries, leading to the development of superior varieties and innovative shapes that exhibit heightened quality and longevity. As a result, these refined marble products offer extended durability, ensuring they can be utilized for an extended period without the risk of fracturing or shattering[36].

2.4.1 Marble Materiel Propereties

In it, we talk about the most important characteristics that distinguish marble, and there are several types of marble, each of which has characteristics that distinguish it from other types, and we mention, for example[35]:

a. ALBASTER: It is highly crystalline and is characterized by its semi-transparent feature and clear lines.
b. MEXICAN ALBASTER: It is a type of chalcedony and is characterized by the intensity of its lines and is sometimes used as precious stones.
c. GREEN AGGREGATE: the vein that contains the dark green mineral serpentine. It is composed of aqueous magnesium silicate and cut with veins of light-colored minerals. It is customary to place it under the marble stones as a result of its ability to polish and the presence of veining similar to the veining of marble.

2.4.2 Marble Adavntages

a. It is characterized by rigidity.
b. It is not affected by weather conditions.
c. The multiplicity of its types and forms.

2.5 EFFECT OF MARBLE WASTE AGGREGATES ON THE PROPERETIES OF CONCRETE

The possibility of using marble aggregate waste as a substitute for natural aggregate to produce concrete with good properties was the focus of a study by Hebhoub and others [37] where he used three concrete mixtures, the first mixture in which coarse natural aggregate was replaced by coarse marble aggregate, and in the second mixture natural sand was replaced by marble aggregate Fine, but in the third plan, both fine and coarse aggregates were used instead of the natural aggregates that make up the mixture, where the replacement percentage was (25%, 50%, 75%, 100%). In all mixtures, the ratio of water to cement was fixed (0.5). The results of this study showed the possibility of using marble residues in concrete, and this leads to improving some properties of concrete such as compressive and tensile strength. In addition, it was noted that the percentage of trapped air was less when the replacement percentage was (25%-75%).

Another study from DOĞAN, Cüneyt DEMİR, İsmail[38] .The recycling potential of waste marble as an aggregate in polymer concrete technology was investigated in this study. Various sizes of waste marble powder were combined with a polyester-based resin, specifically the PolyPol 314 filler-type polyester, resulting in the production of a series of seven polymer concrete samples. The samples were subjected to physical and mechanical analyses to assess their properties. The research focused on examining the influence of marble powder particle size on the characteristics of the polymer concrete. The most favorable physical and mechanical properties were observed in the samples that utilized waste marble with a grain size ranging from 0.075 to 0.150 mm as the primary constituent material.

In a study conducted by Ural et al[39]. the potential of waste marble as a replacement for fine aggregate in concrete was investigated. The researchers focused on assessing the physical, mechanical, and physicochemical properties of clayey soil mixed with marble powder. Through various tests and analyses, they observed a certain degree of enhancement in the behavior of the clayey soil when incorporating marble powder. Consequently, it was concluded that waste marble could be utilized as a filling material instead of fine aggregate in concrete production. The study further highlighted that the optimal ratio of waste marble for replacing fine aggregate was determined to be 5%.

Uysal & Yılmaz [40] conducted a study to investigate the impact of marble dust, basalt powder, and limestone powder on both fresh and hardened self-compacting concrete (SCC). The researchers performed elasticity modulus tests to assess various characteristics of the concrete, including volume, air content, unit volume weight, compressive strength, and ultrasound velocity.

The results showed that SCC incorporating marble powder exhibited the highest compressive strength compared to the other mineral additives. However, different performances were observed with the addition of various minerals, indicating that each additive had a distinct effect on the concrete properties.

Moreover, the study revealed that SCC with 20% waste marble had the highest static modulus of elasticity. This suggests that the concrete mixture with 20% waste marble demonstrated increased stiffness and resistance to deformation. Additionally, SCC with 10% waste marble showed the highest dynamic elasticity modulus, indicating its superior ability to withstand dynamic loads and vibrations.

In summary, Uysal & Yılmaz's study demonstrated the varying effects of marble dust, basalt powder, and limestone powder on the properties of self-compacting concrete. The incorporation of marble powder resulted in the highest compressive strength, while the specific percentages of waste marble affected the static and dynamic modulus of elasticity. These findings contribute to understanding the potential benefits of using marble dust in SCC applications.

In a study conducted by Omar et al.[41], the utilization of limestone waste as a replacement for fine aggregate in concrete was investigated. As part of the study, waste marble powder was incorporated as an additive. Concrete mixtures were prepared by substituting sand with limestone waste at rates of 25%, 50%, and 75%, and waste marble powder was added at levels of 5%, 10%, and 15%.

To assess the characteristics of the concrete in both fresh and hardened states, various tests were performed, including flexural strength, compressive strength, splitting tensile strength, elasticity modulus, and permeability tests. The researchers aimed to determine the impact of the limestone and marble powder additives on the properties of the concrete.

The findings of the study indicated that the use of limestone waste as a fine aggregate led to an increase in the fresh concrete slump, which refers to its workability and flow ability. However, the unit weight of the concrete did not show significant changes. Moreover, after the addition of marble dust to the concrete mix, improvements were observed in the performance of the concrete, as evidenced by the results of the conducted tests.

In summary, the study by Omar et al. highlights the potential of utilizing limestone waste and waste marble powder in concrete production. The addition of these materials demonstrated positive effects on the fresh and hardened characteristics of the concrete, suggesting their potential as sustainable alternatives in the construction industry.

In another study conducted by Fatima Masoud Al-Mazoghi et all.[42] using the wastes of marble factories as a partially substituted material for cement to produce self-compacting concrete, where they studied the properties of self-compacting concrete and the possibility of implementing it by taking advantage of the wastes of marble to be partially replaced instead of cement in proportions of 5-10-15 %.

The plastic properties were studied and the SLUMP FLOW, G-ring and L-BOX tests were conducted and it was found that it is possible to benefit from the marble waste in the production of self-compacting concrete and thus reduce the percentage of cement, and the best percentage for replacing marble instead of cement was 15%.

The present study is believed to make valuable contributions to the marble industry, environmental preservation, human health, and the economy. A comprehensive review of the existing literature on the subject was conducted and thoroughly presented in this study. Moreover, the study has derived practical formulas for estimating the compressive strength and splitting tensile strength of concrete, which eliminates the need for conducting physical tests to determine concrete strength. These findings are anticipated to provide significant insights and practical benefits to the field.

3. STUDY METHODOLOGY

3.1 DETAILING THE METHODOLOGY OF THE STUDY

This chapter deals with three main topics, which are the materials used in concrete mixtures, how to prepare the concrete mixture, and the laboratory tests that were conducted during this study. It touched on the design of the concrete mixture and the equipment used in designing the studied mixture and how to prepare this mixture. This chapter also touched on the most important tests used, which included specific weight, sieve analysis, impact coefficient, crushing coefficient of coarse aggregate, slump test, pressure resistance, indirect tensile strength and density, as well as ultrasound testing. for concrete.

3.2 MATERIAL USED

3.2.1 Ordinary Portland Cement

Ordinary Portland cement was used from the production of Al-Burj Cement Factory of the Union Company (Zliten),

Table 3.1: The Chemical Composition of Cement.

Chemical Composition	Percentage (%)
Silica SiO_2	21.3
Iron oxide Fe_2O_3	3.78
Alumina Al_2O_3	4.99
Calcium oxide Cao	62.87
Magnesium Oxide MgO	3.47
Sulfur trioxide SO_3	2.24
L.O.I	0.39
Tricalcium silicate C_3S	43.73
Dicalcium silicate C_2S	27.73

Table 3.1: The Chemical Composition of Cement "Table Contuned".

Tricalcium aluminate C3A	5.83
C4AF Quaternary Calcium Ferric Aluminate C_4AF	11.49
Free calcium oxide FCaO	1.21

and its physical properties conform to British specifications [43]. Table (3.1) shows the properties of the used Portland cement, and Table (3.2) shows the chemical composition of the cement.

Table 3.2: Properties of Used Portland Cement.

The test	Results	British Standard Limits (BS.12:1996).
The time of initial doubt	174 minutes	not less than 45 minutes
The time of final doubt	4:28 hours	no more than 10 hours
The softness	3297	Not less than 2500
Dilation	0.6 mm	no more than 10 mm
Specific weight	3.15	-

3.2.2 Fine Aggregate

Fine aggregate was imported from the city of Zliten, and it is natural sand free from impurities. The results of the laboratory tests conducted on it in the concrete factory of the College of Engineering - Al-Khums showed that its physical properties conform to British specifications (BS812:1992) [44].

Table 3.3: Chemical Composition of Fine Aggregate.

Chemical Composition	Percentage (%)
Silicon oxide (SiO_2)	20.14
Iron oxide (Fe_2O_3)	2.99
Aluminum oxide (Al_2O_3)	5.91

Table (3.3) shows the results The chemical composition, Table (3.4) shows the results of the physical properties, Table (3.5) shows the results of the sieve analysis,

Table 3.4: Physical Properties of Fine Aggregate.

The test	Test results	Specification limits (BS:812)
Specific weight	2.64	2.7 - 2.5
Soft material %	%2.55	not more than 4%
Apparent density	1650 kg/m^3	1800 - 1400

and Figure (3.1) shows the minimum and maximum levels of granular gradation according to British specifications [44].

Table 3.5: Sieve Analysis of Fine Aggregate According to British Specifications.

Sieve size (mm)	reserved weight (g)	Cumulative weight reserved (g)	Reserved Percentage (%)	Passing percentage (%)	Limitations of the specification (BS:812:1992).
2.36	0	0	0	100	80 - 100
1.18	0	0	0	100	70 - 100
0.6	3.1	3.1	0.62	99.38	55 - 100

Table 3.5: Sieve Analysis of Fine Aggregate According to British Specifications "Table Contuned".

0.3	268.7	271.8	54.36	45.64	5 - 70
0.15	215.6	487.4	97.48	2.52	0 - 5
0.075	9.3	496.7	99.34	0.66	-
Pan	3.3	500	100	0	-

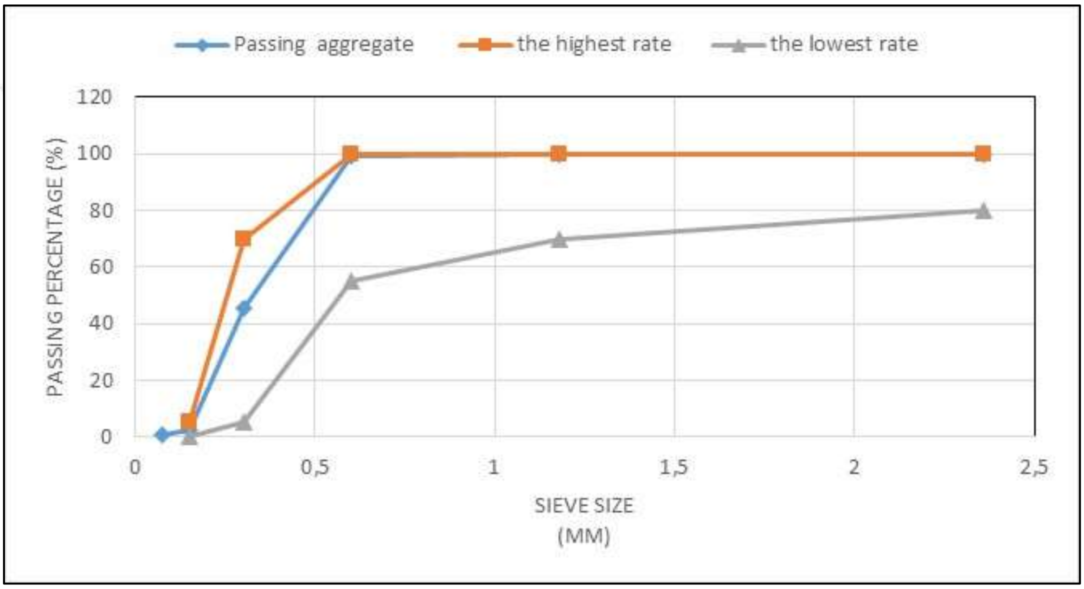

Figure 3.1: Gradual Gradation of Fine Aggregate.

3.2.3 Blasting Coarse Aggregate

The blasting rubble was supplied from the shnin crusher in the city of Zliten, and it is an angular shaped rubble with a maximum nominal size of 19 mm. Table (3.6) shows the results of the sieve analysis of the aggregates according to the approved British specifications (BS882:2002) [44]. Figure (3.2) shows the minimum and maximum limits of granular gradation according to British specifications .

Table 3.6: Sieve Analysis of Blasting Aggregate According to British Specifications.

Sieve size (mm)	reserved weight (g)	Cumulative weight reserved (g)	Reserved Percentage (%)	Passing percentage (%)	Limitations of the specification (BS.882:2002)
37.5	0	0	0	100	100
19	698	698	13.96	86.04	100-85
14	3375	4073	81.46	18.54	70-0
10	764	4837	96.74	3.26	25-0
4.75	142	4079	99.58	0.42	5-0
Pan	21	5000	100	0	-

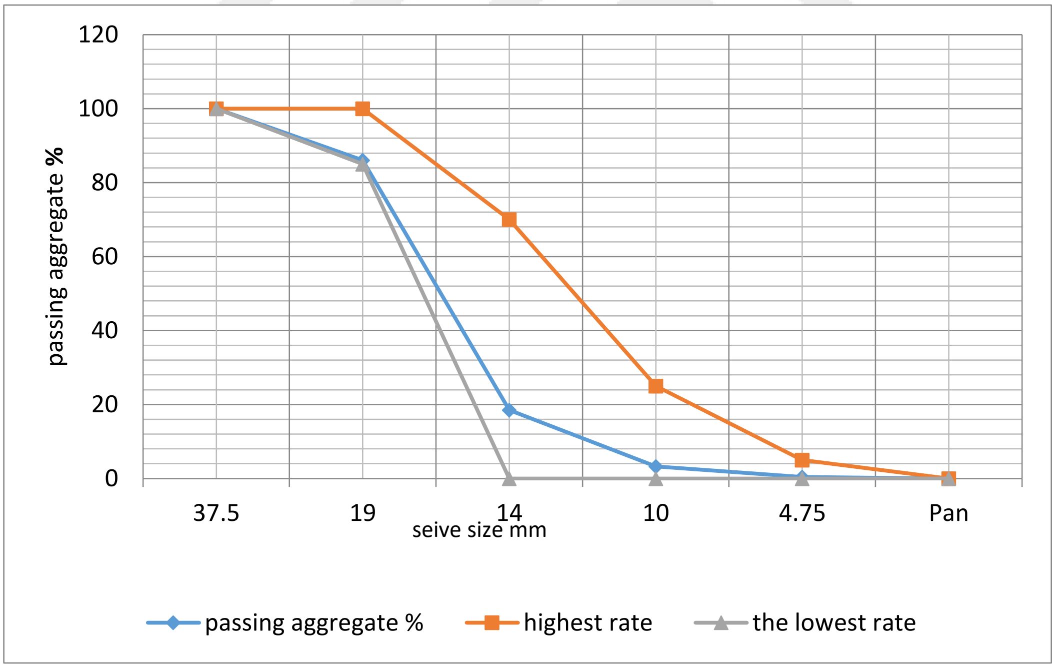

Figure 3.2: Gradual Gradation of Blasting Aggregate.

3.2.4 Plowed Coarse Aggregate

This type of aggregate was supplied from the Shanin crusher in the city of Zliten, and it is crushed gravel resulting from the plowing operations of non-hard rocks with a maximum nominal size of 19 mm, and Table (3.7) shows the results of the sieve analysis of the aggregate according to the approved British specifications (BS882:2002) [44] .Figure (3.3) shows the minimum and maximum levels of granular gradation according to British specifications.

Table 3.7: Sieve Analysis of Plowed Aggregate According to British Specifications.

Sieve size (mm)	reserved weight (g)	Cumulative weight reserved (g)	Reserved Percentage (%)	Passing percentage (%)	Limitations of the specification (BS.882:2002)
37.5	0	0	0	100	100
19	210	210	4.2	95.8	100-85
14	3461	3671	73.42	26.58	70-0
10	1210	4881	97.62	2.38	25-0
4.75	113	4994	99.88	0.12	5-0
Pan	6	5000	100	0	-

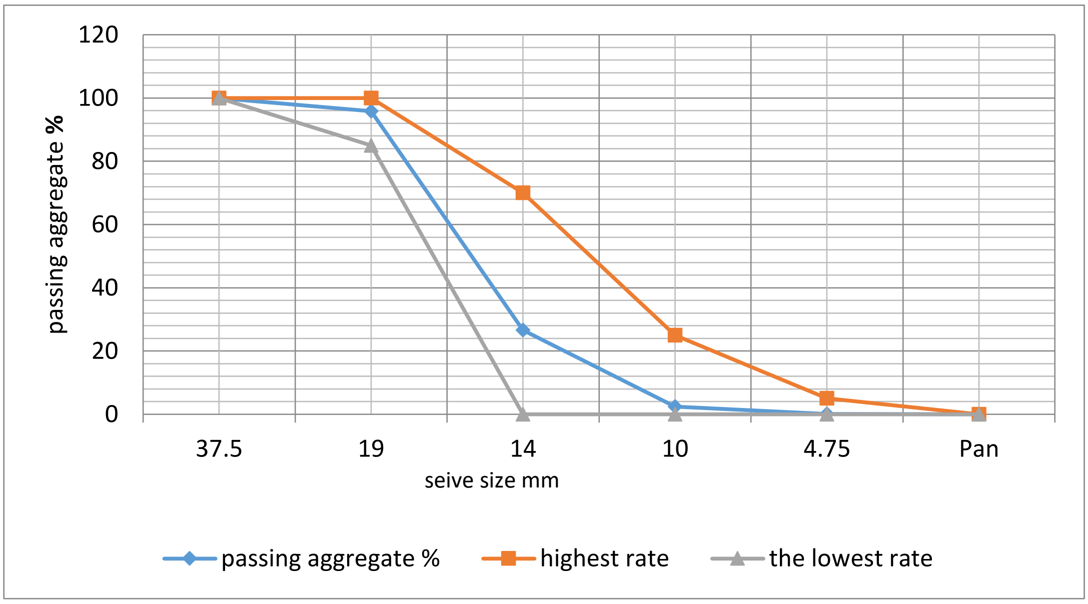

Figure 3.3: Gradual Gradation of Plowed Aggregate.

3.2.5 Waste Aggregate from Marble Factories

3.2.5.1 Coarse marble aggregate

Coarse marble aggregate was manufactured from the remnants of marble factories in the city of Misurata, The type used is Teresita-marble and the original homeland of this marble is Egypt, where it was crushed and sieved on standard sieves, and the sediment was collected on each sieve, and then it was mixed according to the granular gradation of the limits of British specifications (BS882:2002) [44]. Table (3.8) shows the results of the sieve analysis, and Figure (3.4) shows the lower and upper limits of the granular gradation according to British specifications .

Table 3.8: Sieve Analysis of Coarse Marble Aggregate According to British Specifications.

Sieve size (mm)	reserved weight (g)	Cumulative weight reserved (g)	Reserved Percentage (%)	Passing percentage (%)	Limitations of the specification (BS.882:2002)
37.5	0	0	0	100	100
19	583	583	11.66	88.34	100-85
14	2816	3399	67.98	32.02	70-0
10	1054	4453	89.06	10.94	25-0
4.75	512	4965	99.3	0.7	5-0
Pan	35	5000	100	0	-

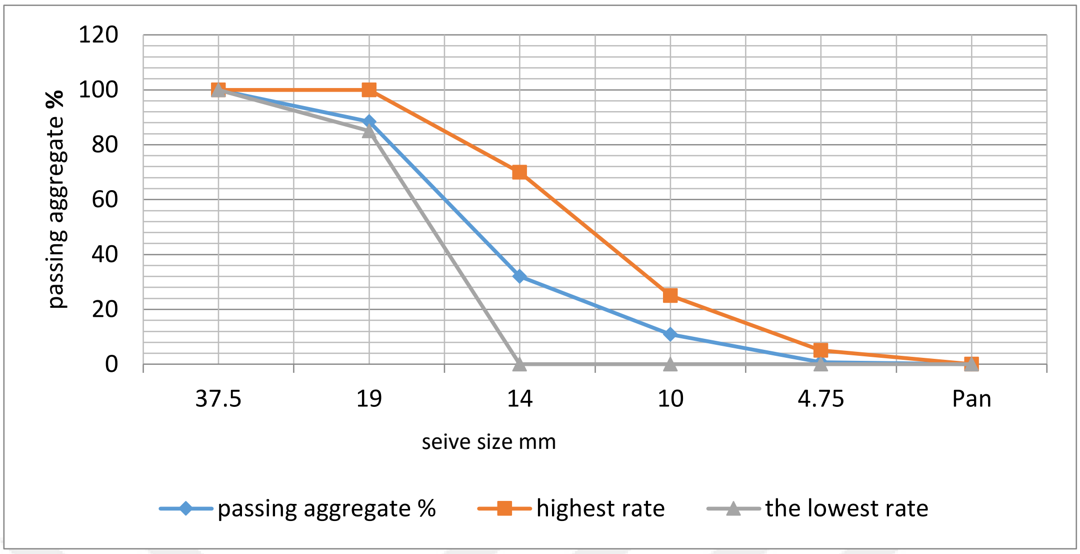

Figure 3.4: Gradual Gradation of Coarse Marble Aggregate.

3.2.5.2 Fine marble aggregate

Fine marble aggregate was manufactured by crushing the wastes of marble factories and sieving them on standard sieves and collecting the sequestrate on each sieve, and then it was mixed in proportions according to the limits of British specifications (BS812:1992) [44]. Table (3.9) shows the results of the sieve analysis and Figure (3.5) shows the lower and upper limits for granular gradation .and figure (3.6) shows Mechanical vibrators and standard sieves used in the determination of the granular gradation of aggregates to all aggregates .

Table 3.9: Sieve Analysis of Fine Marble Aggregate According to British Specifications.

Sieve size (mm)	reserved weight (g)	Cumulative weight reserved (g)	Reserved Percentage (%)	Passing percentage (%)	Limitations of the specification (BS:812:1992).
2.36	0	0	0	100	80 - 100
1.18	0	0	0	100	70 - 100
0.6	83	83	16.6	83.4	55 - 100
0.3	176.3	259.3	51.86	48.14	5 - 70

Table 3.9: Sieve Analysis of Fine Marble Aggregate According to British Specifications "Table Contuned".

0.15	228.9	488.2	97.64	2.36	0 - 5
0.075	8.4	496.6	99.32	0.68	-
Pan	3.4	500	100	0	-

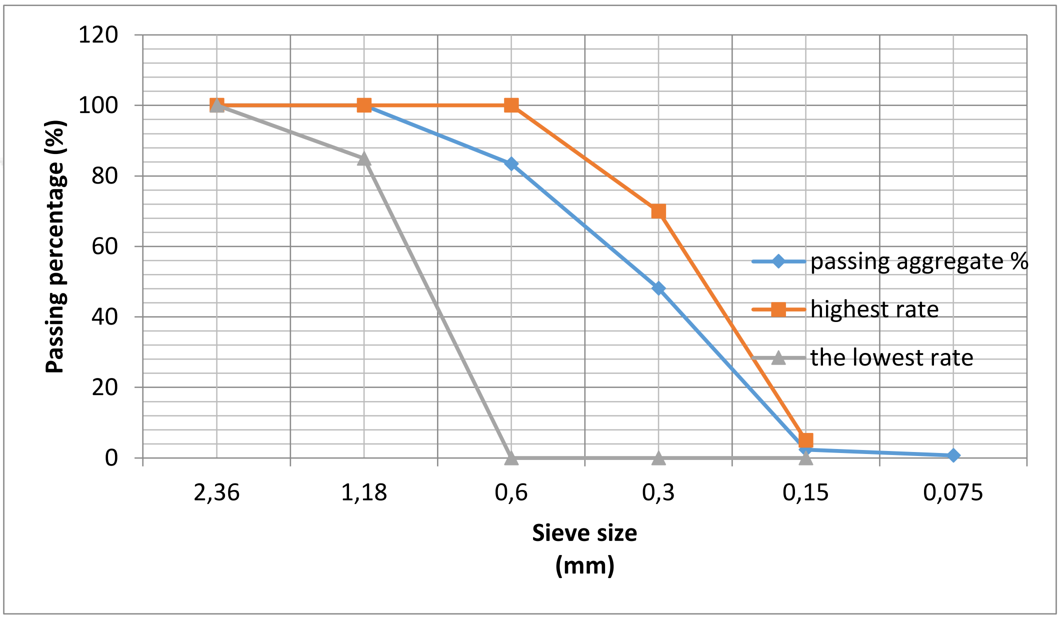

Figure 3.5: Gradual Gradation of Fine Marble Aggregate.

Figure 3.6: Mechanical Vibrators and Standard Sieves Used in The Determination of The Granular Gradation of Aggregates.

3.2.6 Mixing Water

The water used in the mixing available in the concrete plant is free of organic matter and according to the limits of the Libyan specifications (QS 294) [45], which shows that the limits of chlorides allowed for mixing and curing concrete are less than 500 parts per million, and for sulfates, carbonates and bicarbonates, they are less than 1000 ppm.

3.3 CONCRETE MIX DESIGNE

The experimental study involved the use of different concrete mixtures, and their composition and quantities were recorded in Table (3.10). These mixtures were produced in varying percentages of coarse aggregate (33.33%, 50%, and 100%). In addition, fine marble aggregates were introduced to the mix in different ratios, which were 10%, 30%, and 50% of the weight of fine aggregate to concrete. The study aimed to investigate the effect of varying the percentage of coarse aggregate and the use of fine marble aggregates on the properties of concrete, It should also be noted that 32 concrete cubes were made, divided into 9 basic sections, in order to conduct all the necessary tests .

The quantities of materials used to produce one cubic meter of concrete mixture were carefully measured and recorded in Table (3.10).

Table 3.10: The Proportions of The Components of Each Mixture.

MIXURES	CEMENT Kg/m^3	WATER Lit/m^3	COARSE MARBLE AGGREGATE Kg/m^3	FINE MARBLE AGGREGATE Kg/m^3	BLASTING COARSE AGGREGATE Kg/m^3	PLOWED COARSE AGGREGATE Kg/m^3	FINE AGGREGATE Kg/m^3
M0	450	198	0	0	898	0	898
M1	450	198	449	0	449	0	898
M2	450	198	898	0	0	0	898
M3	450	198	0	0	0	898	898
M4	450	198	449	0	0	449	898
M5	450	198	299.33	0	299.33	299.33	898
M6	450	198	0	89.8	898	0	808.2
M7	450	198	0	269.5	898	0	628.6
M8	450	198	0	449	898	0	449

The varying percentages of coarse aggregate in the mixture were intended to study their impact on the properties of concrete. The use of fine marble aggregates in different ratios was another parameter studied in the experiment. Table (3.11) shows the ratios of fine marble aggregates used in the mixtures.

Table 3.11: The Percentage of Replacing Marble from Aggregate.

	M0	M1	M2	M3	M4	M5	M6	M7	M8
FINE MARBLE AGGREGATE	0%	0%	0%	0%	0%	0%	10%	30%	50%
FINE AGGREGATE	100%	100%	100%	100%	100%	100%	90%	70%	50%
COARSE MARBLE AGGREGATE	0	50%	100%	0%	50%	33.33%	0%	0%	0%
BLASTING COARSE AGGREGATE	100%	50%	0%	0%	0%	33.33%	100%	100%	100%
PLOWED COARSE AGGREGATE	0%	0%	0%	100%	50%	33.33%	0%	0%	0%

3.4 PREPARATION OF CONCRETE MIXES

The mixing process was carried out using a mixer with a capacity of 0.15 m^3. Figure (3.7) shows the mixer used for mixing. The following steps show the method of mixing and sample preparation:

a. The aggregates were immersed in water for 24 hours, then the outer surface was dried to obtain a saturated dry-surface aggregate.

b. Standard molds with dimensions of 150 x 150 x 150 mm and cylinders with dimensions of 150 x 300 mm have been prepared. The inner surface of the molds must be cleaned well to prevent concrete adhesion.
c. The components of the concrete mix required for the preparation of concrete samples were weighed.
d. The concrete mix materials were placed in the mechanical mixer and mixed dry for one minute.
e. Add the mixing water gradually until the mixture is homogeneous and ready to be poured into standard moulds, in a time of approximately four minutes.
f. Fresh concrete was poured directly into the moulds, and the concrete was compacted well to get rid of the air trapped inside the concrete, to a level higher than the surface of the mould, 2 mm.
g. After half an hour, the outer surface of the samples was leveled and placed inside the laboratory for 24 hours before removing the molds and numbering the samples according to the concrete mixture.
h. The molds were removed and numbered, and the samples were treated by immersion in water until the test date. Figure (3.8) shows the samples in the treatment basin.

Figure 3.7: Automatic Concrete Mixer.

Figure 3.8: Concrete Moulds Curing Basin With Water.

3.5 CONCRETE MOULDS

The pressure and density resistance test, as well as the ultrasound velocity test, utilized concrete cubes. On the other hand, cylinders were employed for the indirect tensile test. The molds that were utilized for these tests are displayed in Figure (3.9) .

Figure 3.9: Used Concrete Moulds.

3.6 TESTS AND SPECIFICATION

3.6.1 Aggregate Tests

3.6.1.1 Specific weight and adsorption ratio of coarse aggregate

This test aims to determine the specific weight of the aggregate that is used in the design of concrete mixtures. Figure (3.10) shows the tools used in this test. The test is performed according to British specifications [46]. The specific weight and absorption ratio are calculated through according to the British specifications [46] with three main equations as Apparent Specific Gravity (G_{sa}) , Bulk Specific Gravity (Bulk Dry Specific Gravity) (G_{sb}) and Absorption rate A (%) .

$$G_{sb} = \frac{A}{B-C} \tag{3.1}$$

$$G_{sa} = \frac{A}{A-C} \tag{3.2}$$

$$A\ (\%) = \frac{B-A}{A} \times 100 \tag{3.3}$$

Where:

A : Mass of oven-dry sample in air.

B : Mass of SSD sample in air.

C: Mass of SSD sample in water.

SSD : Saturated Surface Dry.

G_{sb} : Bulk specific gravity (Total specific weight).

G_{sa} : Apparent specific gravity of aggregates

A (%) : Absorption rate.

Figure 3.10: Tools Used to Determine The Specific Weight of Coarse Aggregate.

3.6.1.2 Crushing test for coarse aggregates

This test aims to determine the resistance of coarse aggregate to crushing, which is important in concrete subject to wear, wear and friction. Figure (3.11) shows the device used in this test. The test is carried out according to British specifications [47]. Calculation is calculated the according to British specifications [47] with two main equations as sample wight (C) and crushing coefficient A_{cv} (%) .

$$C = M_1 - M_0 \tag{3.4}$$

$$A_{CV}(\%) = \frac{C - M2}{C} \times 100 \tag{3.5}$$

Where:

M_0: pan weight only .

M_1:pan and sample weight .

C: sample weight .

A_{CV} (%): crushing coefficient.

Figure 3.11: The Template Used to Set The Crushing Coefficient.

3.6.1.3 Wild coefficient (Los Angeles) test for coarse aggregates

This test was conducted within the American specifications [48] ASTM C131. This test aims to measure the wear resistance of medium and large-grained aggregates when subjected to impact. Figure (3.12) shows the device used in this test, and the wild coefficient (los angeles) AB (%) is calculated according to American specifications [48] ASTM C131 from the following equation:

$$AB(\%) = \frac{m_1 - m_2}{m_1} \times 100 \tag{3.6}$$

Where:

m_1: Weigh the sample before testing.

m_2: The weight of the impoundment on the sieve is (2.36 mm).

AB (%): wild (Los Angeles) coefficient .

Figure 3.12: The Device Used in The Wear Coefficient Test.

3.6.1.4 Impact test of coarse aggregate

This test aims to determine the impact coefficient of the aggregate, and Figure (3.13) shows the device used in this test. The test is conducted according to British specifications [47]. The impact coefficient K(%) is calculated according to British specifications [47]. from the following equation:

$$K(\%) = \frac{m_1 - m_2}{m_1} \times 100 \tag{3.7}$$

Where:

m1: Weigh the sample before testing.

m2: The weight of the impoundment on the sieve is (2.36 mm).

K(%): impact coefficient.

Figure 3.13: The Device Used to Determine The Impact Coefficient of Coarse Aggregate.

3.6.2 Concrete Tests

3.6.2.1 Slump test for fresh concrete

This test aims to determine the strength of the concrete by knowing the amount of slump. Figure (3.14) shows the devices used in this test. The test is carried out according to British specifications. [49].

Figure 3.14: The Slump Test for Fresh Concrete.

3.6.2.2 Compressive strength test of hardened concrete

Cubes measuring 150 x 150 x 150 mm were used, and Figure (3.15) shows the pressure tester.

The test was carried out according to the British specifications [50], and according to the study plan, 3 samples were tested after 7 days and 3 other samples after 28 days, in order to know the pressure hardened concrete resistance.

Figure 3.15: Compression Resistance Test Device.

3.6.2.3 Indirect tensile test (Brazilian method)

This test was carried out in accordance with British Standards [51][52]. A cylinder with dimensions of 150×300 mm was used. The cylinder was placed in the testing machine as shown in Figure (3.16), where the loading was carried out gradually and at a regular rate until reaching the final value of the load in a period of approximately one minute.

The indirect tensile strength f_t was calculated acoording to British Standards [51][52] from the following equation:

$$f_t = \frac{2p}{\pi l d} \tag{3.8}$$

Where:

p: precipitation that leads to sample collapse .

l: Cylinder net length .

d: cylinder diameter .

f_t: Indirect tensile value .

Figure 3.16: Indirect Tensile Strength Test Device.

3.6.2.4 Ultrasound test

The test aims to detect cracks, gaps, and in homogeneities in the density of concrete. The idea of this test depends on the fact that the pulses (ultrasonic waves) do not flow in a vacuum, so the wave takes a longer path if it encounters a crack or a gap, and accordingly the speed varies and the transmission time of the pulses increases. This test uses the same samples used to find the compressive strength. To measure the speed of ultrasound, the V-Metric Mark III device shown in Figure (3.17) was used.

The direct method of measurement was used, that is, placing the transmitter and the receiver on two opposite sides, according to the British specifications [53]. After measuring the ultrasonic velocity, the mold is left for the purpose of performing a pressure test. The number is an expression of the time (T) for the flow of the pulses through the tested part, and the speed of the pulses (V), is as follows :

$$V = \frac{L}{T}\left(\frac{Km}{sec}\right) \tag{3.9}$$

Where:

L: Measured track length.

T: wave travel time.

V: The speed of the pulses.

Figure 3.17: Ultrasound Test Device.

4. RESULTS AND DISCUTIONS

4.1 ANALYZE AND DISCUSS THE RESULTS OBTAINED

This chapter deals with the analysis and discussion of the results of this study, which was conducted on all samples in the form of tables and figures. We will also show during this chapter some comparisons of these results.

4.2 AGGREGATES TESTS RESULTS

4.2.1 Crush Coefficient Tests Results for Coarse Aggregates

The calculation and results of this test are shown in Table (4.1), and Figure (4.1) shows the crushing coefficient for all types of aggregates used .

Table 4.1: Laboratory Crushing Test Results for Used Aggregates.

Aggregate type	Plowing Aggregate	Blasting Aggregate	Marble Aggregate	Standard limits
Crushing coefficient %	28.8	19.77	28.3	Less than 30%

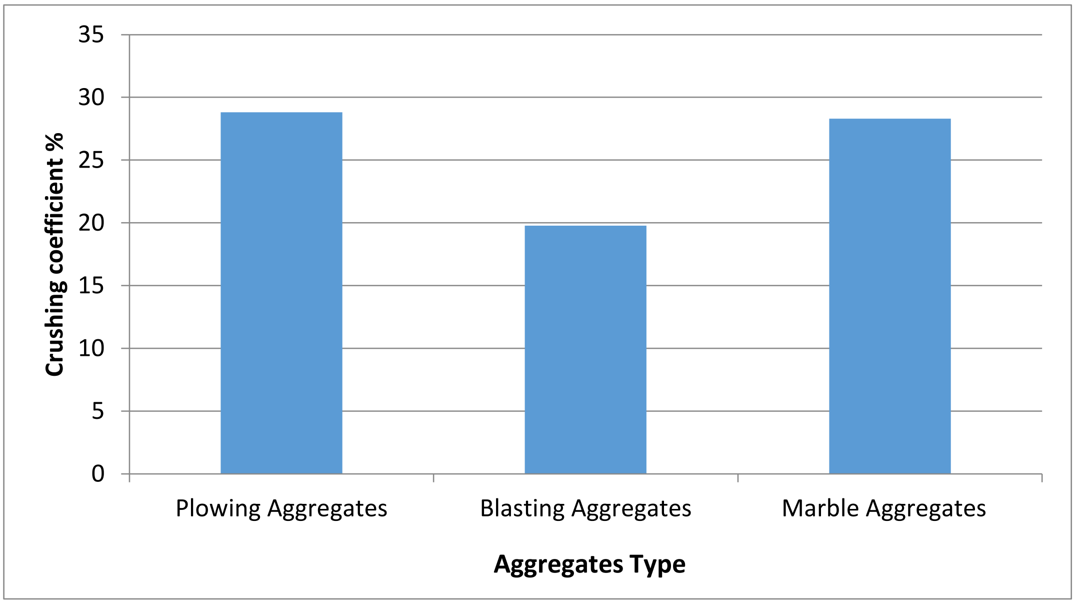

Figure 4.1: Crushing Coefficient of Used Aggregate.

Through the results of the crushing coefficient of aggregates, it was found that the crushing coefficient of marble aggregates is less than the crushing coefficient of plowing aggregate by 0.5% and higher than the crushing coefficient of blasting aggregates by 8.53%.

4.2.2 Wear Coefficient (Los Angeles) for Coarse Aggregates

The calculation and results of this test are shown in Table (4.2), and Figure (4.2) shows the wear coefficient for all types of aggregates used.

Table 4.2: Results of Wear Coefficient Test for Used Aggregates.

Aggregate type	Plowing Aggregate	Blasting Aggregate	Marble Aggregate	Standard limits
Wear coefficient %	27.54	17.64	28.9	Less than 30%

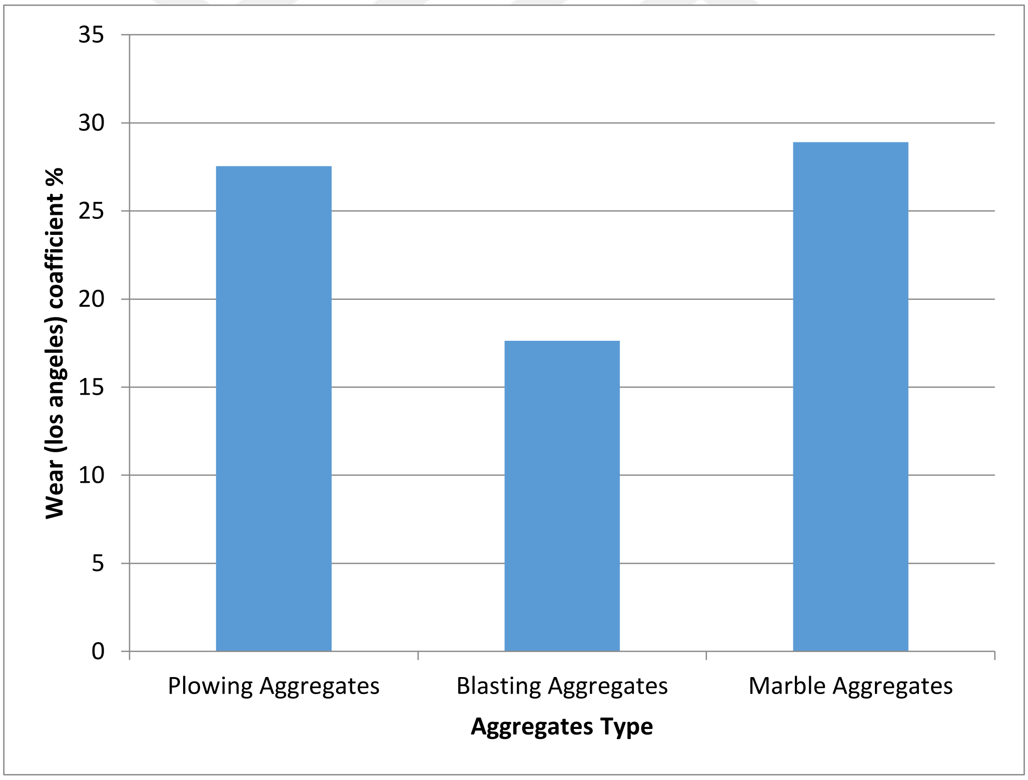

Figure 4.2: Wear (Los Angeles) Coefficient of Used Aggregates.

By measuring the wear coefficient for all types of aggregates, it was found that the marble aggregates have a wear coefficient higher than the plowing aggregates by 1.36% and also higher than the blasting aggregates by 11.26%.

4.2.3 Impact Test Results for Coarse Aggregates

The calculation and results of this test are shown in Table (4.3), and Figure (4.3) shows the impact coefficient for all types of aggregates used.

Table 4.3: Impact Lab Test Results for Used Aggregates.

Aggregate type	Plowing Aggregate	Blasting Aggregate	Marble Aggregate	Standard limits
Impact coefficient %	11.55	12.6	15.38	Less than 30%

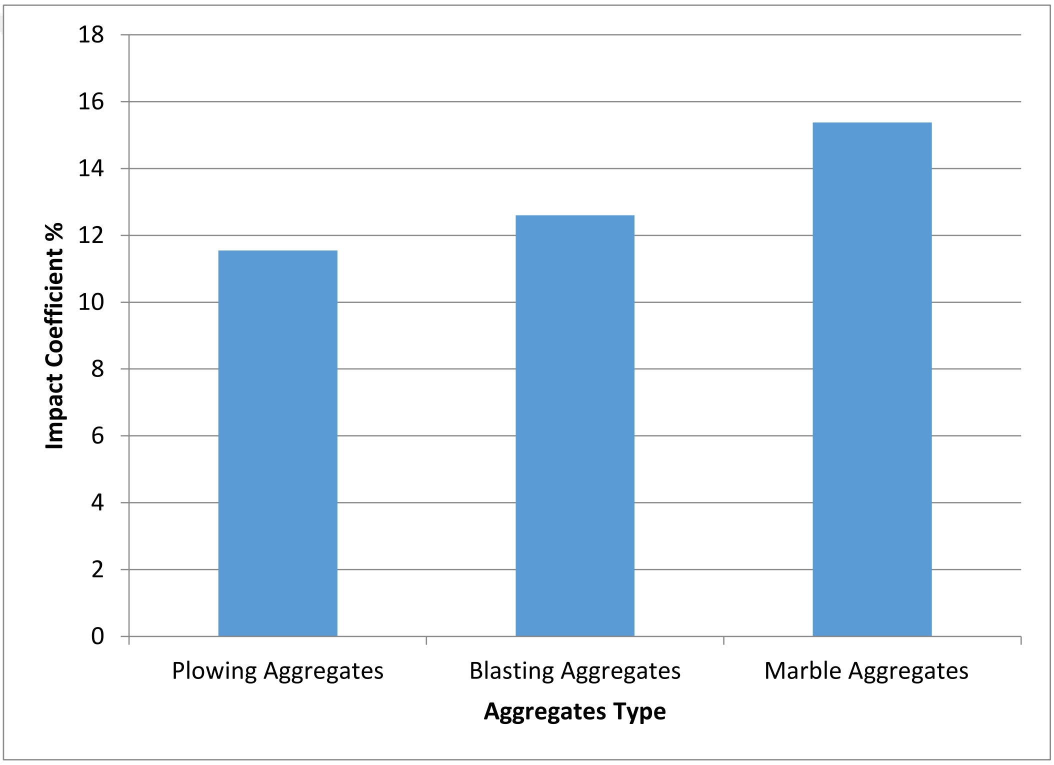

Figure 4.3: Impact Modulus of Used Aggregate.

Through the results of the impact coefficient test of the aggregates, it was found that the impact coefficient of marble aggregates is higher than the impact coefficient of plowing aggregates by 3.83% and higher than the impact coefficient of blasting aggregates by 2.78% .

4.2.4 Results of The Specific Weight and Absorption Ratio of Coarse Aggregates

The calculation and results of this test are shown in Table (4.4) and Figure (4.4).

Table 4.4: Specific Weight Test Results for Used Aggregates.

Aggregate type	Plowing Aggregate	Blasting Aggregate	Marble Aggregate	Standard limits
Specific weight	2.52	2.63	2.51	2.5-2.75%
Absorption rate	2.8	2.63	0.4	Less than 3%

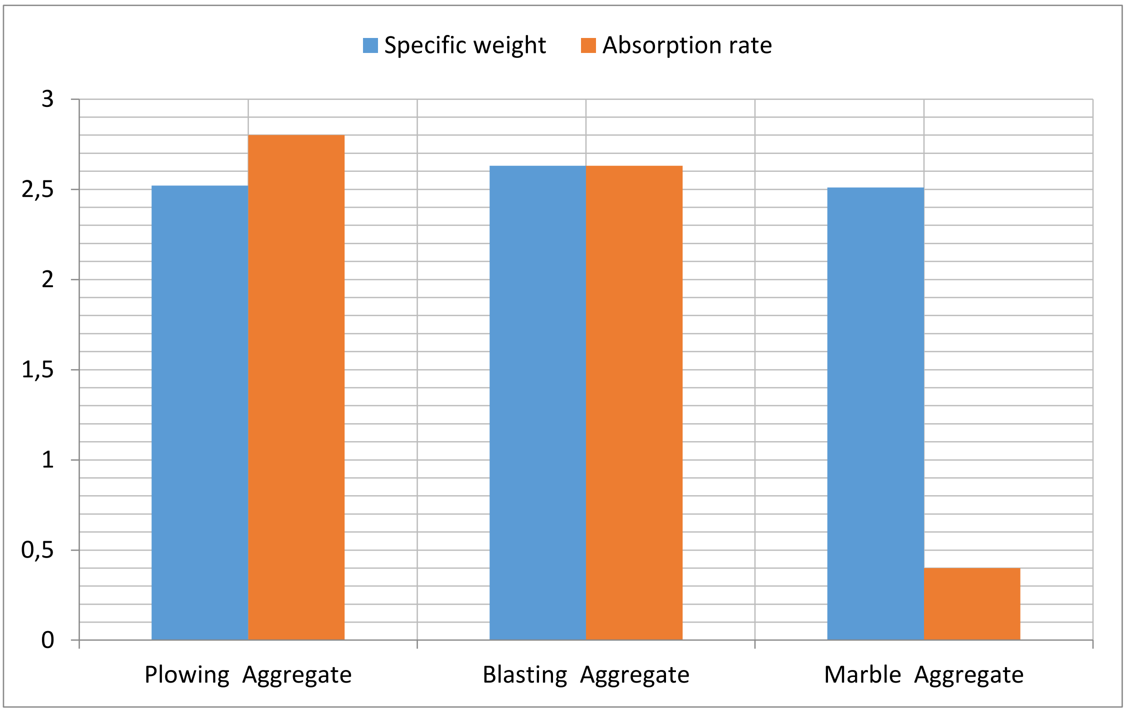

Figure 4.4: Specific Weight and Absorption Percentage of The Used Aggregate.

In the results, we note that marble aggregates, blasting aggregates, and plowing aggregates fall within the standard limits of the specific weight of aggregates (2.5-2.75), but we note that the specific weight of marble aggregates is 0.12% less compared to blasting aggregates and 0.01% less than plowing aggregates.

We note that the absorption rate of marble is 2.4% lower than that of plowing aggregate and 2.23% that of blasting aggregate.

4.3 RESULTS OF SOFT CONCRETE

4.3.1 Slump Test Results

Figure (4.5)and table (4.5) shows the slump of soft concrete for all admixtures.

Table 4.5: The Slump of Soft Concrete for All Admixtures.

Sample	M0	M1	M2	M3	M4	M5	M6	M7	M8
Slump amount (mm)	36	42	45	34.5	24	35	41.5	39	43

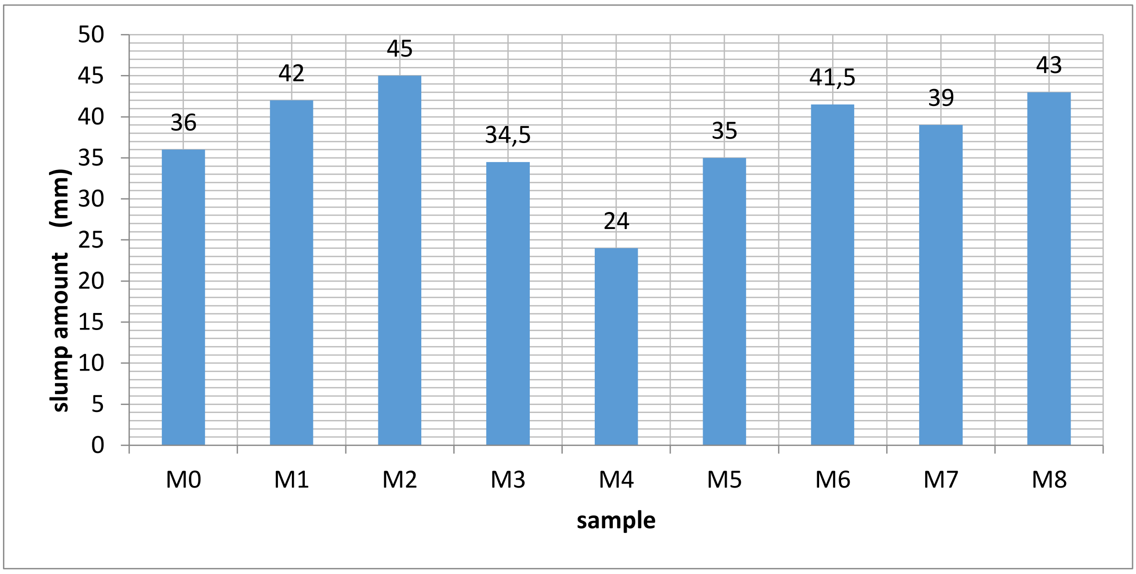

Figure 4.5: The Slump of Soft Concrete for All Admixtures.

Where it is noted that the drop value ranges between 24 and 45 mm As M0, which contains 100% blasting aggregate and 100% fine aggregate (sand), and compared with M1, M2, and M5, which contain coarse marble aggregate, it can be noted that M1 increased by 16.66%, M2 increased by 25%, and M5 decreased by 2.77% when compared with the reference mixture M0. It is known also that M3, which contains 100% plowed aggregate and 100% fine aggregate (sand), and when compared with M5, M4 and M2, it can be noted that M2 increased by 30.43%, M4 decreased by 30.43%, and M5 increased by 1.45% compared to M3 reference mix. As for the mixtures M8, M7, and M6, which contain 100% blasting aggregates and varying proportions of fine marble aggregates and fine aggregates (sand), it can be seen that M6 increased by 15.27%, M7 increased by 8.33%, and M8 increased by 19.44%.

4.4 RESULTS OF HARDNED CONCRETE TESTS

4.4.1 Effect of Coarse Marble Aggregates Ratio on Compressive Strength of Concrete

Figure (4.6) shows the effect of the ratio of coarse marble aggregates with blasting aggregates on the compressive strength of the concrete. Through the figure, we notice that the compressive strength increased by 5.78%, 10.2%, and 4.08%, after 7 days for samples that contain aggregates. Marble with a substitution ratio of 33.33%, 50%, and 100%, respectively, when compared to the reference samples. At 28 days, the resistance increased by 7.6%, 1.84%, and 0.69% for the samples that contained a replacement percentage of 33.33%, 50%, and 100%, respectively, compared to the reference samples. Through these results, we note the possibility of using marble aggregates with high substitution rates without any decrease in the resistance of the excess moisture content, and thus it works to reduce the water percentage of the cement, which results in an increase in the resistance. pressure, especially with the increase in the age of the samples, and this may be due to the improvement in the absorption resistance of the marble .

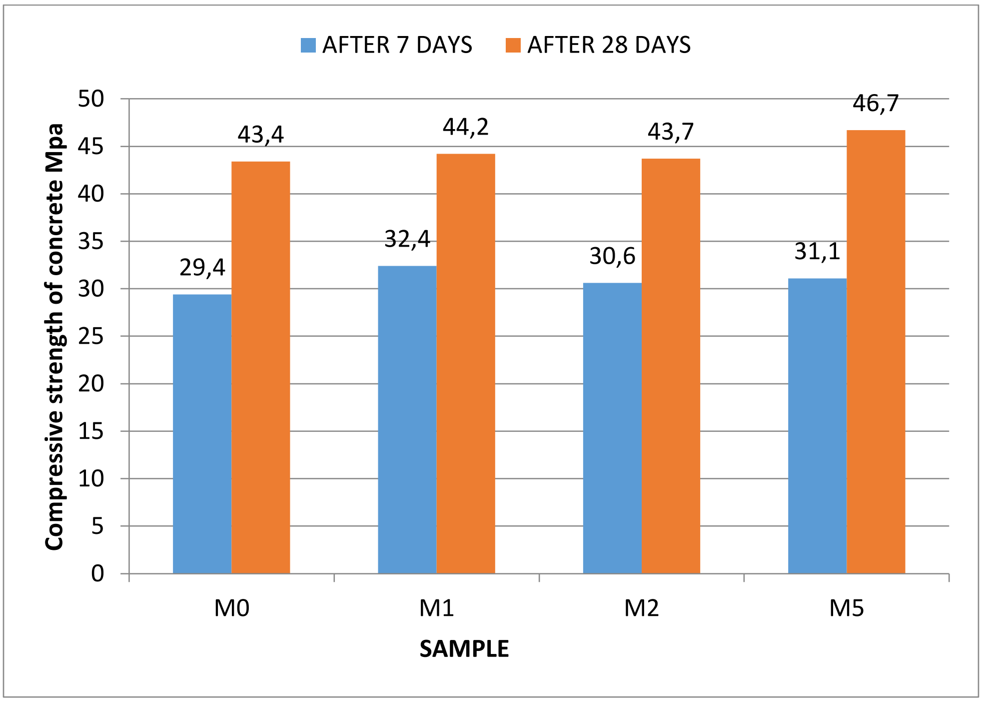

Figure 4.6: Concrete Compressive Strength When Adding Marble As Coarse Aggregate With Blasting Aggregate.

Figure (4.7) shows the effect of the ratio of coarse marble aggregates with plowing aggregates on the compressive strength of the concrete. Through the figure, we notice that the compressive strength decreased by 4.6%, 3.98%, and 6.13% after 7 days for samples that contain a percentage of marble aggregates by Substitution of 33.33%, 50%, and 100%, respectively, when compared to the reference samples. At 28 days, the resistance increased by 8.35%, 5.57%, and 1.39% for the samples that contained a replacement percentage of 33.33%, 50%, and 100%, respectively, compared to the reference samples. Through these results, we note the possibility of using marble aggregates with the used substitution ratios.

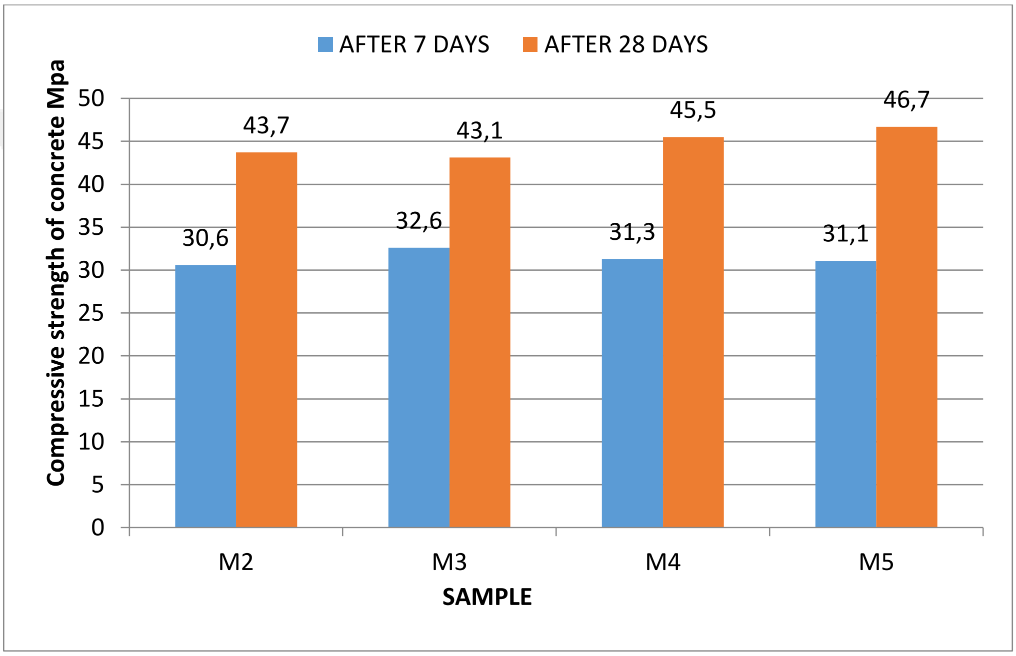

Figure 4.7: Compressive Strength of Concrete When Marble is Added As Coarse Aggregate With Plowed Aggregate.

4.4.2 Effect of Fine Marble Aggregates Ratio on Compressive Strength of Concrete

Figure (4.8) shows the effect of the percentage of fine marble aggregates on the pressure resistance, and through the figure we notice that the pressure resistance after 7 days decreased by adding fine marble aggregates, as it decreased by 0.68% of the resistance of the standard mixture for 10% marble and increased by 26.19% for 30% marble, while The compressive strength of 50% marble decreased 2.72% to that of the standard mixture, and at 28 days it decreased by 2.53% of the strength of the standard mixture of 10% marble, while it increased by 20,96% for 30% marble and increased by 12.21% for 50% marble. We also note that the pressure resistance of the mixtures containing fine marble aggregates increases significantly with time, as observed at the age of 28 days. This indicates the delay in obtaining the early pressure resistance of the mixtures containing fine marble, given that the soft marble contains fine soft particles that fill the voids between the cement particles. Roughness and acting as pozzolanic materials slow down the hydration process, and this was confirmed by previous studies.

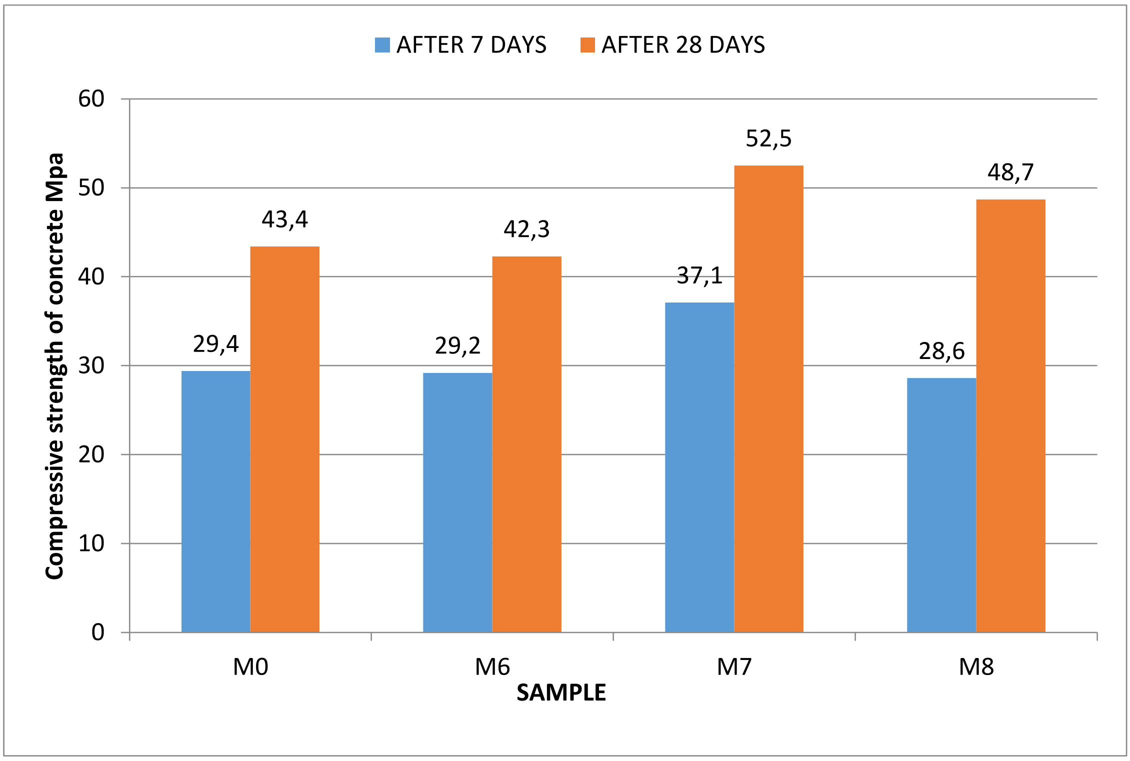

Figure 4.8: Compressive Strength of Concrete When Marble is Added As Fine Aggregate.

4.5 RESULTS OF THE INDIRECT TENSILE STRENGHT TEST

4.5.1 Effect of Coarse Marble Aggregates Ratio on Indirect Tensile Strength of Concrete

Figure (4.9) shows the effect of the ratio of coarse marble aggregates with blasting aggregates on the indirect tensile strength, and through the figure we notice that the tensile strength after 7 days gave similar results by adding coarse marble aggregate for 50% marble and decreased by 5.55% for 100% marble, and decreased by 11.11% for 33.33% marble. And at 28 days it increased by 8.69% from the resistance of the standard mixture of 50% marble, and increased by 7.69% for 100% marble, while it decreased by 13.64% from the resistance of the standard mixture of 33.33% marble.

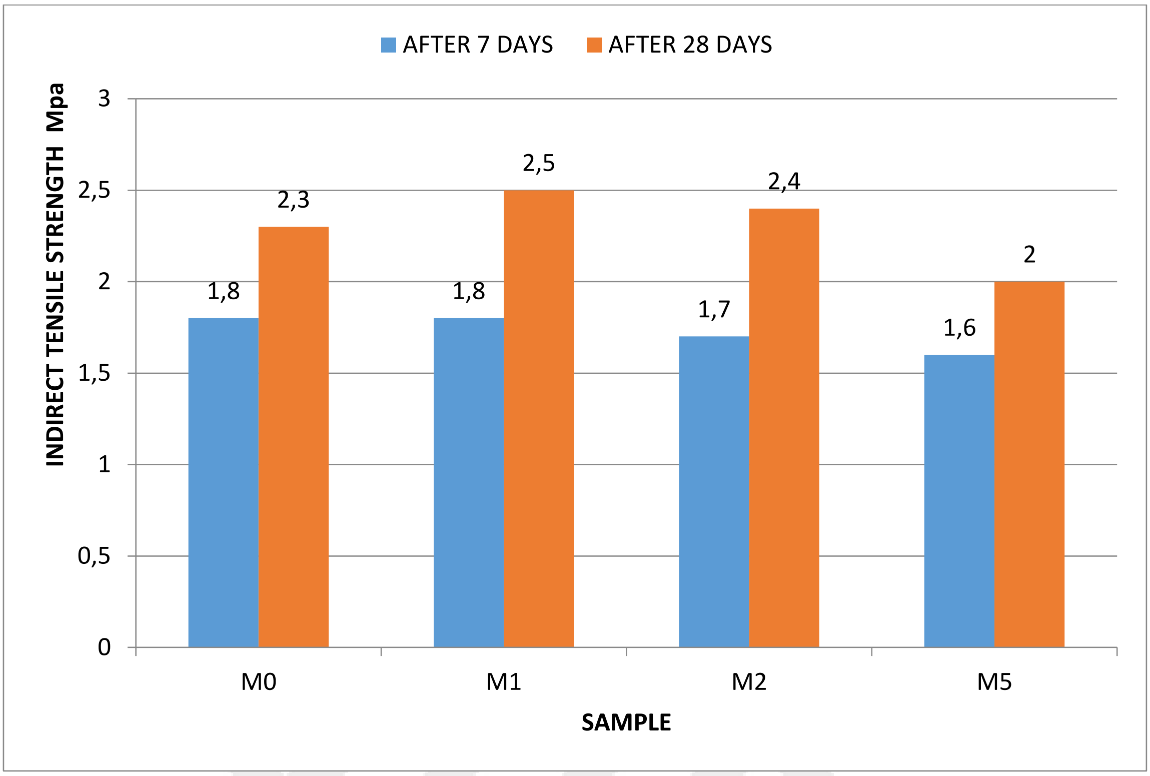

Figure 4.9: Concrete Indirect Tensile Strength When Adding Marble As Coarse Aggregate With Blasting Aggregate.

And in Figure (4.10) shows the effect of the ratio of coarse marble aggregates with plowed aggregates on the indirect tensile strength, and through the figure we notice that the tensile strength after 7 days gave similar results by adding coarse marble aggregate for 100% marble and decreased by 5.88% for 50% marble, and decreased by 5.88% for 33.33% marble. And at 28 days it increased by 20% from the resistance of the standard mixture of 100% marble, and decreased by 5% for 50% marble, while it gave similar results by adding coarse marble aggregate for 33.33% .

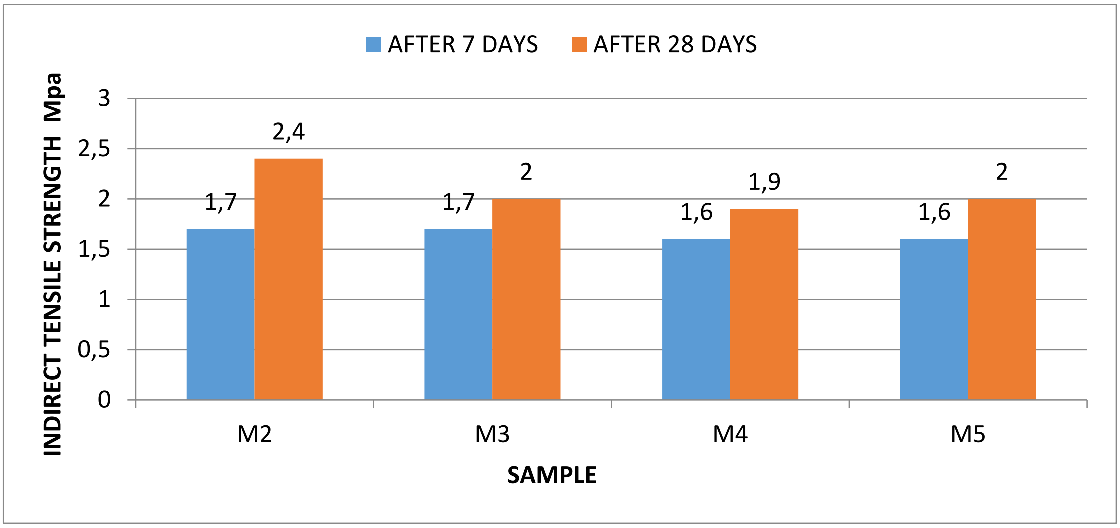

Figure 4.10: Concrete Indirect Tensile Strength When Adding Marble As Coarse Aggregate With Plowed Aggregate.

4.5.2 Effect of Fine Marble Aggregates Ratio on Indirect Tensile Strength of Concrete

Figure (4.11) shows the effect of the percentage of fine marble aggregate on the indirect tensile strength, and through the figure we notice that the indirect tensile strength after 7 days changes with the addition of fine marble aggregate, as it decreased by 11.11% of the strength of the standard mixture for marble 10% and increased by 5.55% for marble 30 %, while it decreased by 11.11% for 50% marble, and at 28 days the indirect tensile strength decreased by 4.35% for 10% marble and increased by 4.35% for 30% marble, while equaled the resistance of the standard mixture for 50% marble.

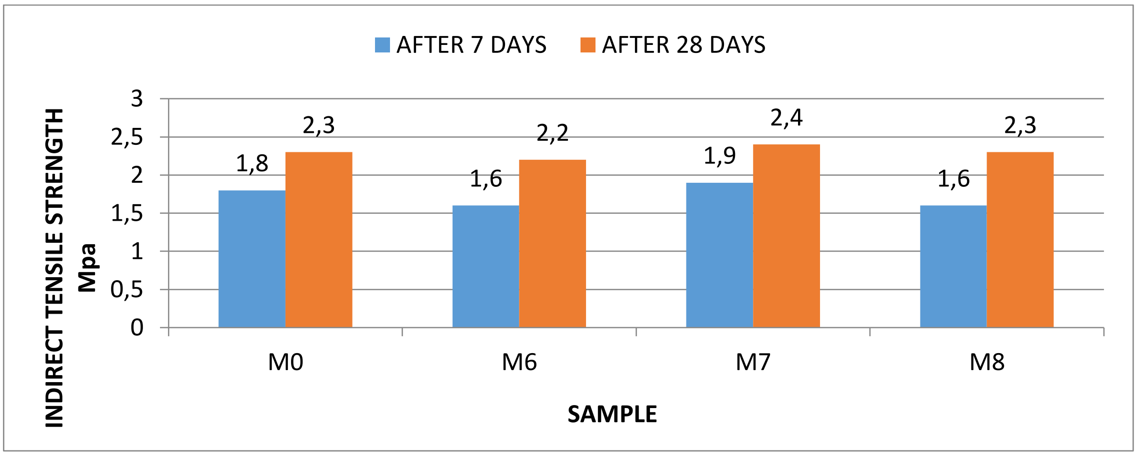

Figure 4.11: Indirect Tensile Strength When Adding Marble As A Fine Aggregate.

4.6 ULTRASOUND TEST RESULTS

The test was conducted by the direct method, where the distance between the transmitter and the receiver was 15 cm. figure (4.12) shows the results of the velocity of sound waves at 7 and 28 days. As shown in the figure, all samples that contain marble, whether they contain fine marble aggregate or coarse marble aggregate, gave good results according to the specifications. Unlike samples M4 and M5, which contain 50% and 33% coarse marble aggregate, all samples gave high results. Although these two samples also gave good results.

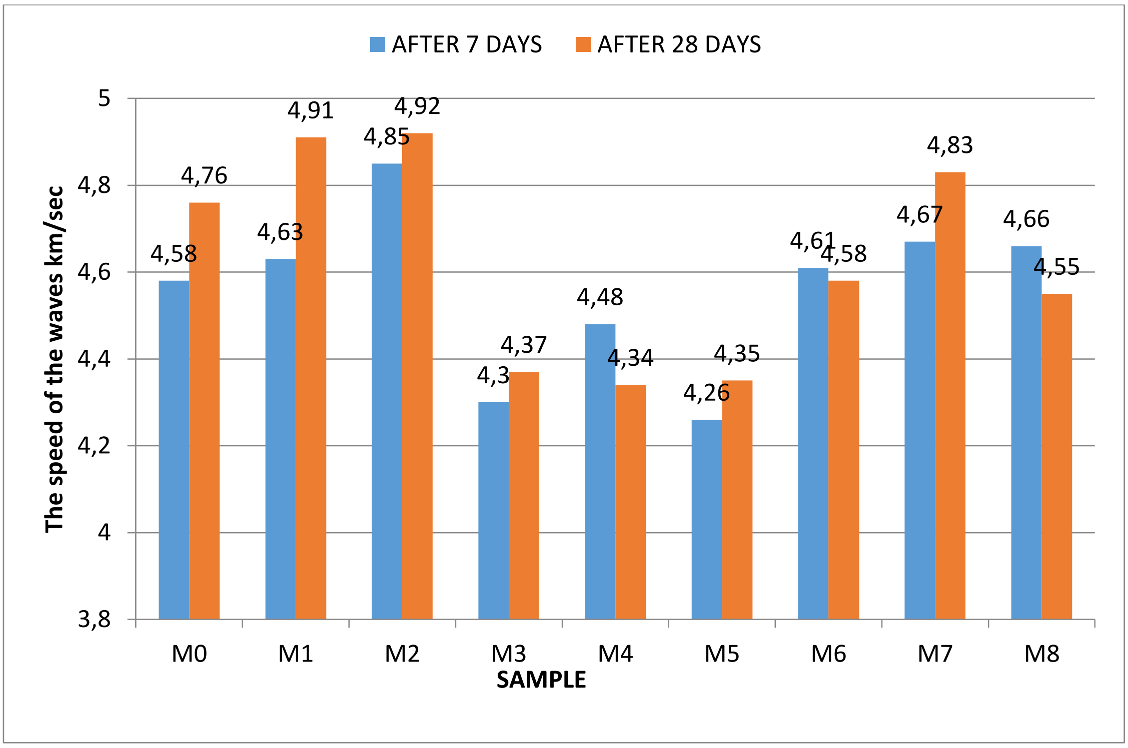

Figure 4.12: The Results of The Velocity of Sound Waves at 7 and 28 Days.

5. CONCLOTIONS AND RECOMMENDATIONS

5.1 CONCLOTIONS

Based on the laboratory results reached in this study, and after discussing these results, the following conclusions could be reached :

a. The results of laboratory tests related to the engineering properties of the studied aggregates showed the acceptance of marble waste aggregates for the formation of normal concrete mixtures, where it was found that the values of granular gradation, specific weight, absorption ratio, unit volume weight, crushing, impact and wear coefficients, had a positive effect compared to the aggregates available locally in the city of Zliten. This would increase the resistance of the concrete to the loads it is subjected to and improve its resistance to wear and various weather factors, and the bearing of concrete with time and the volumetric changes of concrete are all considered to be achieved with such characteristics that characterize the rubble of marble waste.
b. The processes of incorporating the aggregates of marble waste as one of the components of the normal concrete mixture lead to a noticeable increase in the strength, as a resistance of 44.2 and 45.5 MPa was obtained when mixing 50% with the local aggregate and 46.7 MPa when mixed with the local aggregate 33.33% after 28 days of curing. This resistance is very excellent compared to the reference mixture, which gave a resistance of 43.2 and 43.7 MPa under normal conditions.
c. The inclusion of marble powder in the concrete mix did not adversely affect the workability.
d. The best substitution percentage for marble powder instead of fine aggregate is 30% as this mixture has met all acceptance requirements in the British Standard Specifications.
e. The search results were also compared to the Turkish code, and the test results were within the Turkish code[54].

5.2 RECOMMENDATIONS

Through the tests carried out in this study, it was noted that there are a large number of ideas and suggestions that may be included in some future studies to complete this research in order to achieve more information and data that may contribute to the preparation of a guide for the use of marble waste in an economical and environmental way. Among these recommendations are the following:

a. We recommend studying the effect of acids on concrete to which coarse and fine marble aggregates are added.
b. We recommend studying the effect of adding marble aggregates on the reaction activity between active alkali produced from rehydration and active silica in natural aggregates.
c. We recommend studying the flexural strength when adding fine marble aggregates greater than 50%.
d. We recommend studying the compressive, tensile and bending resistance of concrete with marble aggregate added at advanced ages (90 and 180) days, because marble is considered as a pozzolanic material that slows down the hydration process and shows its effect at later ages.
e. We recommend an indirect tensile strength study for proportions greater than 50% of fine marble aggregates.
f. We recommend studying the effect of adding marble aggregates on modulus of elasticity of concrete.
g. We recommend studying the permeability of concrete with marble aggregate added.
h. Encouraging the use of waste from marble industry workshops as rubble in order to reduce the damage of marble waste to the environment.
i. We recommend working on benefiting from marble waste in the city of Zliten and other cities as an additive to concrete made from local materials in order to reduce the damage of marble waste to the environment.
j. We recommend working on benefiting from marble waste in the city of Zliten and other cities as an additive to concrete made from local materials in order to reduce the damage of marble waste to the environment.

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APPENDIX A

A.1 DESIGN CONCRETE MIXES AND DETERMINE THE QUANTITIES REQUIRED TO IMPLEMENT THE PROJECT

The design of concrete mixtures to determine the mixing ratios of their components is considered one of the most important factors that affect the quality and grade of concrete. Therefore, this aspect was taken into account as mentioned in the design of three types of concrete mixtures for this study, which differ among themselves according to their resistance to pressure. The absolute volume method was used, which assumes that the volume The absolute ratio of cement, coarse and fine aggregate and water is as follows:

$$\frac{C}{G_c} + \frac{S}{G_s} + \frac{CA}{G_d} + \frac{Ww}{1} = 1\ m^3 (1000\ lit) \qquad (A.1)$$

Where :

C : Cement weight (kg/m^3). G_c : Specific gravity of cement.

S : : Weight of sand (kg/m^3). G_s : Specific gravity of sand.

C_A : Aggregate weight (kg/m^3). G_d : Specific gravity of aggregate.

W_w : Water weight (kg/m^3).

A.2 VARIABLES THE USED IN THE EQUATION

a. The ratio of fine aggregate: coarse aggregate = 1:1 was used .

b. Water/cement ratio (W/C) for all mixtures = 0.44 .

c. Cement content used in concrete mixtures = 450 kg/m^3 .

d. Coarse marble aggregate was used in four mixtures (100%) (50% mixture with blasting) (50% mixture with plowed) .

e. Fine marble aggregate was replaced in proportions (10%, 30%, and 50%) with three mixtures (M6-M7-M8) .

f. In this method, it is also necessary, based on experience or from the scientific results of laboratory tests, to determine each of the following in accordance with the requirements required for the resistance of hardened concrete and the extent of operation required for plastic concrete:

   i. The amount of cement needed per cubic meter of concrete.

   ii. Water-cement ratio by weight (W/C) or the amount of water per cubic meter of concrete.

   iii. The ratio of fine to coarse aggregate of the aggregate used.

   iv. Specific gravity of cement and coarse and fine aggregate.

APPENDIX B

B.1 AGGREGATE TESTS

i. Sieve Analysis of Coarse and Fine Aggregate Samples

Steps to conduct the test:

a. The test sample is dried until its weight is stable and placed in an oven for 24 hours.
b. Prepare a known weight of the sample in an air-dry state of fine aggregate and coarse aggregate.
c. Sift the sample onto standard sieves using a mechanical vibrator, and sifting continues until it is confirmed that all the aggregate stones that can pass through the opening of any sieve have passed. In the case of coarse aggregate, the stones can be moved by hand, and the vibrator's operation time is usually 10 minutes.
d. The reserved aggregate is weighed on each sieve.
e. The results are manually recorded for the percentage passing through each sieve, and the gradation curve is drawn, indicating the graphical relationship between the openings of the different sieves and the percentage passing through these openings, and the values corresponding to the specifications are predicted on the same graph for the purpose of evaluating the gradation of the aggregate sample.

ii. Test to Determine The Specific Gravity and Absorption Percentage of Coarse Aggregate

Steps to conduct the test:

a. A sample of aggregate is weighed about (5000 grams) and the amount that passes through the sieve (14 mm) and the one that is trapped on the sieve (10 mm) are taken.
b. The aggregate sample is immersed in water for 24 hours.
c. After this period has elapsed, the surface of the aggregate is dried to obtain a saturated, dry-surface aggregate, and the saturated, dry-surface sample is weighed and is W_1.

d. The aggregate sample is placed in the basket, and the basket containing the aggregate is weighed while it is suspended in water. It is set as W_2.
e. The sample is dried in the oven for 24 hours.
f. It is weighed and the dry sample weight is recorded as W_3.
g. The specific gravity and absorption percentage are calculated through the following equations:

$$(G_{st} = \frac{\mathrm{w3}}{\mathrm{w1-w2}}) \tag{B.1}$$

$$A(\%) = \frac{w2-w1}{w1} \times 100 \tag{B.2}$$

$$G_s = \frac{\mathrm{w3}}{\mathrm{w3-w2}} \tag{B.3}$$

iii. Crushing Test for Coarse Aggregate

The crushing coefficient of the aggregate is the percentage by weight passing through the 2.36 mm sieve after subjecting the sample to a gradual pressure load of 400 kN.

Steps to conduct the test:

a. A sample of the aggregate is sieved on two sieves (10-14 mm), and the aggregate that passes through the first and is reserved for the second is used.
b. Weigh the container when it is empty, let it be (M0).
c. The cylindrical measure is filled in three layers, with each layer compacted 25 times. Then the surface is leveled and the sample and container are weighed (M1).
d. The open steel cylinder is placed in place on the base.
e. The test sample is placed in the cylinder in three layers, and each layer is compacted 25 times using a compaction rod, and a piston is placed on top of it.
f. The cylinder, base and piston are placed in the compression testing machine, then the piston is carried at a regular rate until the compression load reaches 400 kN in ten minutes, then the load is lifted after that.
g. The cylinder is emptied into a metal dish and the sample is sieved on a standard 2.36 mm sieve, then the seized item is weighed (M2).
h. The crushing coefficient is calculated from equations below :

$$C = M_1 - M_0 \tag{B.4}$$

$$A_{CV}(\%) = \frac{C - M2}{C} \times 100 \tag{B.5}$$

iv. Los Angeles Test for Coarse Aggregate

Devices used:

a. The Los Angeles device consists of a cylinder made of steel, closed on both sides, with an internal diameter of (70) cm and an internal length of (50) cm. It has an opening for inserting the sample to be tested and then removing it. Inside the cylinder is a steel rack that is the length of the cylinder and fixed to it. This cylinder rests on two pillars fixed at the end of the cylinder, so that the cylinder rotates between them, as shown in Figure (3-11).
b. Balls made of steel, the weight of each ranging between (390-445) grams, and the diameter of the ball (4.8) cm .
c. A set of sieves and a sensitive balance.

Steps to conduct the test:

a. We wash and dry the aggregate and perform a granular grading for the purpose of determining the type of aggregate and taking the appropriate weight, let it be (M1).
b. We place the sample in the cylinder and then add the balls (11 balls) according to the appropriate number.
c. Close the device tightly and run 500 revolutions at a speed of 30 to 33 revolutions per minute, then the materials are taken out and sieved on a 2.36 mm sieve.
d. We weigh the reserved aggregate on the 2.36 mm (M2) sieve.
e. The wild factor is calculated from equation bellow :

$$K(\%) = \frac{m_1 - m_2}{m_1} \times 100 \tag{B.6}$$

B.2 CONCRETE TESTS

Compressive Resistance Test

The compressive resistance of concrete cubes is calculated by means of the load applied to the samples and resulting from the testing device. Three concrete cubes were used for one mixture, then the average of these cubes is calculated. The compressive resistance is calculated as follows:

$$\sigma = \frac{P}{A} \tag{B.7}$$

Where :

σ: Compressive strength (Mpa).

P : Force (N) .

A: Cubic area (mm²).

$$\sigma_{\text{ave}} = \frac{\sigma_1+\sigma_2+\sigma_3}{3} \tag{B.8}$$

Where :

σ_{ave}: Average compressive strength (Mpa).

σ_1: Compressive strength of the cube 1 (MPA) .

σ_2: Compressive strength of the cube 2 (MPA) .

σ_3: Compressive strength of the cube 3 (MPA) .

B.3 ULTRASOUND TEST

In this test, the time value was determined by creating pulses, which are ultrasound waves, to pass through the tested cube. Three cubes were measured for each mixture. After that, the speed value was calculated in Km/sec for each cube and the average was taken for the three cubes, then the value of the compressive resistance in units (Kg/cm^2) is extracted from the curve that represents the relationship between wave speed and compression resistance, then the compressive resistance is converted into a unit (Mpa), which is applied in the following equation:

$$V = \frac{L}{T} \tag{B.9}$$

APPENDIX C

C.1 SOME PICTURES ATTACHED TO THE PROJECT

Marble Aggregate in The Concrete Mix.

Mixture of Marble and Plowed Aggregate.

APPENDIX D

D.1 GRAIN GRADIENT BOUNDARIES

Grain Gradation Limits for Coarse Aggregate According to British Standards (BS812:1992).

Sieve size	Percentage by mass passing BS sieves for nominal sizes							
	Graded aggregates			Single-sized aggregate				
mm	40 mm to 5 mm	20 mm to 5 mm	14 mm to 5 mm	40 mm	20 mm	14 mm	10 mm	5 mm[a]
50.0	100	—	—	100	—	—	—	—
37.5	90 to 100	100	—	85 to 100	100	—	—	—
20.0	35 to 70	90 to 100	100	0 to 25	85 to 100	100	—	—
14.0	25 to 55	40 to 80	90 to 100	—	0 to 70	85 to 100	100	—
10.0	10 to 40	30 to 60	50 to 85	0 to 5	0 to 25	0 to 50	85 to 100	100
5.0	0 to 5	0 to 10	0 to 10	—	0 to 5	0 to 10	0 to 25	45 to 100
2.36	—	—	—	—	—	—	0 to 5	0 to 30

Grain Gradation Limits for Fine Aggregate According to British Standards (BS812:2002).

Sieve size	Percentage by mass passing BS sieve			
	Overall limits	Additional limits for grading		
		C	M	F
10.00 mm	100	—	—	—
5.00 mm	89 to 100	—	—	—
2.36 mm	60 to 100	60 to 100	65 to 100	80 to 100
1.18 mm	30 to 100	30 to 90	45 to 100	70 to 100
600 μm	15 to 100	15 to 54	25 to 80	55 to 100
300 μm	5 to 70	5 to 40	5 to 48	5 to 70
150 μm	0 to 15[a]	—	—	—

APPENDIX E

E.1 ULTRASOUND SPEED

Wave Speed and Concrete Quality According to British Specifications (BS1881 part 203).

UPV(m/s)	Concrete quality
Above 4500	Excellent
3500 to 4500	Good
3000 to 3500	Medium
Below 3000	Doubtful