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EVALUATION OF THE MECHANICAL PROPERTIES OF
CONCRETE MODIFIED WITH POLYMER

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NEAR EAST UNIVERSITY

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DEPARTMENT OF CIVIL ENGINEERING

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M.Sc. THESIS

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M.Sc.
THESIS

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Nicosia

February, 2022

Approval

We certify that we have read the thesis submitted by **MOATH ALHUSBAN** titled **"EVALUATION OF THE MECHANICAL PROPERTIES OF CONCRET MODIFIED WITH POLYMER**" and that in our combined opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Educational Sciences.

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Declaration

I hereby declare that all information, documents, analysis, and results in this thesis have been collected and presented according to the academic rules and ethical guidelines of the Institute of Graduate Studies, Near East University. I also declare that as required by these rules and conduct, I have fully cited and referenced information and data that are not original to this study

MOATH AL-HUSBAN

2/2/2022

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Moath Alhusban

Abstract

Evaluation of the mechanical properties of
concrete modified with polymer

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Polymer concrete is an epoxy-binder-based alternative to Portland cement that is used to bind a combination of aggregates together. It can be changed using a variety of resins and is used in construction projects to improve strength. Polymer concrete has excellent corrosion resistance and little chemical reactivity. Polymer concrete can be used to build new structures or to repair existing ones. This thesis is a practical application of using Structuro 520 as an additive to cement to know the extent of the effect of these materials on concrete structures. Different samples of Structuro 520 were used to modify the properties of cement concrete the results showed that there is a clear effect of the polymer on the strength and flow characteristics. One goal of this study to investigate the mechanical properties of concrete by obtaining the best components of modified concrete with polymer additives. The practice procedures of this thesis have been done to study the effect of using polymers on the enhancement of the concrete's mechanical and workability properties. The tests were done in the Modern Engineering Lab. A concrete mix design with and without polymer was performed. The samples have been tested for mechanical and durability properties. After conducting the practical trials, the results were analyzed. Structure 520 was used as an additive to concrete mixtures during different periods (7, 14, and 28) of time to perform different tests. The results proved the extent of the effects of polymer (structure 520) on concrete, with the best results for compressive strength (39.4 Mpa), workability (240 mm), flexural strength (13.6 Mpa), and water absorption (1.7%). Considering this, recommendations were given regarding the sample’s quantities, properties, and suitability of additive materials.

Key Words: Polymers, Workability, Compressive Strength, Flexural Strength, Water Absorption, Structuro 520.

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List Of Abberviations

PIC	polymer impregnated concrete.
PC	Polymer-concrete.
PPCC	Polymer Portland cement concrete.
MMA	Methyl methacrylate.
PCE	Polycarboxylate Ethers.

CHAPTER I

Introduction

Concrete is one of the best materials used in the construction industry due to its many characteristics such as strength, durability, and operability. It is also used in concrete roads, bridges, tunnels, and sewage systems. Although concrete has been used since ancient times in pavements and high buildings, and concrete at that time was considered a durable material that did not need maintenance or development, this concept did not develop until recently to understand its various properties. Recent studies have shown that concrete is affected by many factors that may lead to the deterioration of its structures. At the beginning of the 1920s, the idea of using polymers in concrete appeared, as a natural rubber polymer was used to modify the properties of concrete. One type of polymer concrete utilized as a binding material additive is polymer concrete. Its popularity is fast growing, and it is currently widely utilized as a construction material due to its high thermal stability, tensile and flexural strengths, high compressive strength, and chemical resistance (Keya, Habib, Akhter, Tamim & Akhter, 2019). One of the most important reasons for the development of concrete is the presence of weaknesses in ordinary Portland concrete, such as cracks, permeability, corrosion, and low resistance to weather fluctuations in summer and winter. The process of strengthening the cement mixture, reducing the porosity, and strengthening the interfacial transition zone leads to an improvement in the performance of concrete (Buyukozturk, 2004). Therefore, the term "high-strength concrete" became popular by adding polymer to the concrete (Zhutovsky, Kovler & Bentur, 2011). Therefore, the use of polymer concrete materials reduces pollution, extends the life of concrete, and protects the environment compared to traditional cement concrete. Polymers contain small components (called monomers) that are linked together by long chains, and some polymers sometimes consist of large numbers of monomers.

This thesis examines the diversity of concrete properties by varying the nature and concentration of polymer materials, and thus obtaining a multi-purpose modified concrete.

With the advancement of technology, it has become necessary to use modern polymers with high-quality components to meet the market's needs in the fields of construction and roads. Accordingly, some concrete additives were used, such as styrene rubber emulsion and polyvinyl acetate emulsion (Jiang, 2016; Konar, 2011). The use of polymer additives to cement mixtures leads to improved bonding strength, workability, and reduced permeability.

1.2 Problem Statement

Resistance to weather fluctuations requires high-strength concrete that contributes to maintaining quality and prolonging service life. On the contrary, dry concrete leads to cracks, shortening the life of the concrete structure and increasing the cost of maintenance (Sivakumar, 2011)**.** The lack of experience in the use of polymer materials, the increase in cost, and the failure to follow standard procedures in building construction lead to the presence of disadvantages in polymer mixtures compared to traditional cement mixtures.

1.3 Purpose of the Study

1- To investigate the mechanical properties of concrete by obtaining the best components of modified concrete with polymer additives.
2- To determine the best ratio polymer in cement
3- Studying the effect of curing age of concrete on the mechanical properties

1.4 Significant of Study

The study focuses on the behavior of the polymer with concrete, and it classifies the different effects of the polymer on concrete by conducting certain tests such as workability, compressive strength, flexural strength, and water absorption.

1.5 Thesis Organization

- Chapter one is explaining the introduction about the topic, problems statement as well as the objectives of the research.
- Chapter two is addressing the previous researches that were conducted on or related to the study area.
- Chapter three is providing in detail the methods and procedures that carried on to achieve the objectives of the study.
- Chapter for discusses the results of the research.
- Chapter five is about the conclusion, recommendation.

1.6 Limitations

Using varied quantities of polymer (Structuro520) without changing the proportions of cement and water to study the effect of polymer (Structuro520) on concrete.

CHAPTER II

Literature Review

2.1 Concrete Problems

Failure to follow the correct and standard methods in construction operations will lead to concrete failure, as it may change its color or limit cracks and fractures. Examining the problems and understanding their causes is the best way to solve them and develop strategies for developing the stages of work to avoid their occurrence in the future (Al-Hammoud, Soudki, & Topper et al., 2011).

A change in the color of concrete may occur for various reasons, such as weather conditions or the process of mixing concrete, but there must be ways to solve it. Concrete discoloration can be eliminated using detergents or cleaners, which will give a beautiful view of the concrete, or through concrete stains of different colors, or by researching how to avoid this problem by preventing air from penetrating large quantities into the concrete mix, as well as avoiding the use of salts and chemicals in concrete, especially in winter. One of the most important causes of curling is the occurrence of differences in temperature and humidity between the surface and the bottom of concrete, and distortion leads to irregular edges. Crazing is due to the small cracks not being extended. And crazy is considered a small problem that does not affect the concrete structure. Crazing usually occurs because of the lack of quality surfaces. The occurrence of crazing can be mitigated by making sure that it is repaired on time and that dry cement is not placed on top of water when it is present. In hot conditions, it is preferable to put water on the lower areas so that the water is not absorbed by the concrete. The surface cracks are not a cause for concern, as they do not affect the quality of concrete structures. One of the ways to treat cracks is to put in a concrete filling or use a penetrating concrete sealer to reduce water penetration. Various materials have been improved and offered in recent years. These materials contain monomers, resins, latexes, and polymers. They were originally employed in mortars, but they're now used in concrete as well. These materials can be used for interior and external floor coverings, repairing bridge decks, and other repair work (Marotta, 2019).

2.2 Polymers Classification

Polymers are classified according to their technical properties and scientific uses into the following categories:

1 - Thermoplastics

This category includes polymers that change their properties under the influence of heat, as they turn into fuses.

2- Thermoset Polymers

These polymers undergo chemical changes when heated, and the polymeric chains are cross-linked, and after heat treatment, they become insoluble, non-fusible, and poor conductors of heat and electricity.

3- Elastomers

This type of polymer is characterized by its flexible properties such as elongation and its ability to expand and contract.

4- Fibers

This class of polymers is characterized by special characteristics such as strength, durability, and ability to crystallize, and the polymeric chains must be able to be arranged in the direction of the fiber axis to gain strength and durability.

5- Adhesives and Coatings

A large proportion of these polymers are used as coating adhesives.

2.3 Benefits of adding polymer to concrete.

Adding polymer to concrete increases the bonding strength between concrete elements.

- The addition of polymer leads to an increase in the resistance to freezing and thawing by filling the gaps and reducing the volume of fluids inside these gaps by filling them with polymer.
- Increasing the resistance to friction and thus optimizing the use of methods implemented with concrete.
- Increasing the bending and tensile strength of concrete.
- Reduce the transmittance and modulus of elasticity.
- Some types of polymers when added to concrete lead to high sound absorption and high noise reduction, as in the use of Styrene-acrylics.

2.4 Polymeric concrete is divided into three types:

2.4.1 polymer impregnated concrete (PIC)

One of the most widely used polymer concrete compounds is It is ordinary pre-cast concrete that is treated and dried inside an oven, or by dielectric heating, where the air inside the concrete gaps is expelled by steam, and then the low-viscosity polymer is spread through the open gaps and then radiation is shed, or by adding a chemical agent (chemical initiation) that helps the polymer to reach and fill all the voids in the block. Through previous research, typical results were obtained for polymeric reinforced concrete beams soaked with polymer after loading the maximum load. After studying the flexural behavior, the variable adopted in this study is the flexural reinforcement, where the concrete beams soaked with polymer and reinforced with 5% and 7% developed the maximum torque by 37% and 92%, respectively, higher than ordinary concrete beams. The amount of torque that the polymer-soaked concrete could withstand was 50% higher than the standard concrete beams. The polymer-impregnated concrete beams were able to take advantage of the reinforcement ratios more effectively. Review and study were carried out to select the monomers, technique, PIC casting process, and influence on concrete for polymer impregnated concrete and ferrocement, as well as crack patterns in concrete. PIC is the most well-known polymer composition (polymer impregnated concrete (Kumar & Narayanan, 2020).

2.4.2 Polymer-concrete (PC)

It is a special concrete that can be obtained by treating ordinary concrete with polymer materials that act as a sealant or filler for the spaces between the aggregate grains, which represent 6–8 percent of the weight of concrete. One of its disadvantages is its high cost, as it represents (2–3) times the cost of traditional concrete, and its advantages are high- pressure resistance of 1000 kg/cm^2-tensile strength of 100 kg/cm^2 high resistance to shrinkage and external factors. The densities ranged from 1970 to 2350 kg/m3.Through previous research, some results were obtained, which can be summarized as follows:

- When comparing well-graded concrete with gradient-interrupted aggregate concrete, the latter gives higher mechanical specifications than the first.

- There are exponential linear relationships between the compressive modulus and the tensile strength by fission with the compressive strength of polymeric concrete.
- The behavior of concrete developed with epoxy and polyester systems was greatly affected by heat treatment methods, rate of change in strain, and temperature change during the examination.
- There is no direct relationship linking the aggregate distribution and its volume with the compressive strength. It should be noted that the main technique or method in the production of this type of concrete is to reduce the size of the gaps in the mass of aggregates to reduce the amount of polymer needed for the sanding process. This is done by obtaining the appropriate gradation and mixing the aggregates. One of the disadvantages of this type is that it is affected by solutions, including water, and this effect is to reduce the compressive strength depending on the type of pH and the concentration of the attacking solution. Studies have shown that the compressive strength of cylinders exposed to air decreased from 66 MPa to 45 MPa during a period from 1 -3 years.

2.4.3 Polymer Portland cement concrete (PPCC)

polymer. PPCC concrete mixes are Portland cement concrete mixes to which water-soluble emulsified polymers are added during the mixing process or emulsified polymers are added during the mixing process. The polymer has an effect in addition to the effect of the Portland cement hydration process on the formation of a continuous polymeric network through the concrete structure. Many polymers have been investigated for use in polymeric Portland cement concrete through many studies and research conducted on this type of concrete. Many types of research rely on adding epoxy resin to cement mortar and concrete mixtures to raise the tensile strength. The tests of compressive and tensile strength at the time showed a clear increase in both when adding 15% of the weight of the mortar to concrete with a decrease in the mixing water content while maintaining the suitable value for the strength of concrete (obtained by precipitation test). The decrease in mixing water in general in the concrete mixture is one of the reasons for the increase in concrete resistance. The experiments also showed that the addition of mesh polymers that are in the form of powders leads, in general, to increasing the bonding strength between the components of concrete, reducing permeability, increasing fracture resistance, and making concrete more durable, especially in concrete that is exposed to freezing and melting waves. The characteristics that have been developed for concrete and cement mortar vary depending on the type of mesh polymeric. The relative distribution of the elements and the mixing steps for this type of concrete are like those for ordinary concrete, but the method of treating this type of concrete is different from ordinary concrete, as it is in the form of one to two days of wet treatment followed by dry air treatment. Applications of this type of material include tile adhesive, grouting, surface leveling, and bridge floor covering.

2.5 Polymer Concrete

Polymer concrete (PC) contains the following materials: aggregate, filler, and polymeric binder. It is made by using hydraulic cement instead of conventional concrete. Polymer concrete is characterized by rapid hardening, high mechanical strengths, improved resistance to chemicals, etc. The concrete-polymer materials can be divided into polymer concrete, polymer cement concrete, and polymer-impregnated concrete, of which polymer concrete is well known for its many-sided structural applications (Van Gemert, Knapen, Czarnecki, & Lukowski, 2006). In polymer concrete, thermoplastic polymers are used, but normally thermosetting resins are used as the principal polymer component due to their high thermal stability and resistance to a broad diversity of chemicals (Figovsky & Beilin, 2013). Polymer concrete is also composed of aggregates that contain silica, quartz, granite, and limestone. The aggregate must be of the highest quality, free of dust, and dry. It is important to meet these criteria to increase the bond strength between the polymer binder and the aggregate.

The adhesive properties of polymer concrete permit the mending of polymer and conventional cement-based concrete. The corrosion resistance and low permeability of polymer concrete permit it to be used in swimming pools, sewer structure applications, drainage channels, electrolytic cells for base metal recovery, and other structures that contain liquids or corrosive chemicals.No need for painting or welding of PVC protected seams when using polymer concrete. It can also be used in asphalt pavement, for higher durability and higher strength on a concrete substrate, and in skate parks, as it is a very smooth surface. With the advancement of technology, polymer concrete has become less expensive, and fly ash as a filler in polymer concrete is attractive to enhance the mechanical features of PC. (Harja 2009: Bărbuţă ,2010)

Polymer mortars and concrete are widely used due to their ease of preparation and formulation, in addition to their durability, mechanical properties, resistance to chemicals and erosion, low permeability, and ease of mixing, and therefore they can be used in bridges, artificial marble, and mend materials for concrete structures (Heidarnezhad, Jafari, & Ozbakkaloglu, 2020).

The specifications and performance requirements of concrete are related to its quality, which can be determined in several ways. High-performance concrete is made from suitable materials and mixed according to standard proportions before being transported and treated properly, thus improving the performance and structure of concrete. In essence, high-performance concrete performs well throughout its design life. In 1953, the first research was written on polymer-modified mortars and concrete in Japan. It was interested in polyvinyl acetate–modified concrete. PC has received the greatest attention from researchers. Implementations involve the fixing of concrete, pipes, and usefulness components. PPCC has been used mostly in overlays but has not received many declarations as to the other two materials since the addition of monomers to the new concrete has not been successful in improving the properties of concrete. However, the concept of PPCC continues to have large repetition because of the similarity to the process technology for traditional concrete.

Polymer concrete, which uses monomer and resin extensively, is suitable for lightweight engineering materials. A lot of studies have been done on polymeric concrete using epoxy, polyester, and more recently, methylmethacrylate (MMA). Both scientific and engineering research on PCs has been limited in scope, with a notable exception in the development of PCs for geothermal applications (Ramdas, 2021). In polymer concrete (PC), the polymer is used to supersede Portland cement as a binder in the concrete mix. The polymer which formulates the ongoing stage and whose properties are dependent on time and temperature determines the behavior of the composite. In addition to its ease of handling and low cost, the most important characteristics of PPCC concrete are its rapid development in the commercial markets and the studies that have been conducted on it on a large scale.

2.6 Structuro 520

Based on Polycarboxylate Ethers (PCE), Structuro can produce concrete that flows silently and with less friction and can be placed within the most complex formwork and/or heavily congested reinforcement without the aid of any vibration or compaction. Structuro 520 is a carboxylic ether polymer with long lateral chains. This will enhance the cement stampede. An electrostatic stampede occurs at the beginning of the mixing, but the existence of the lateral chains causes the cement particle’s capacity to split up and disperse. This process will reduce the amount of water required for flow able concrete. Moreover, Structuro 520 is characterized by reducing water absorption and maintaining high workability, in addition to helping to produce concrete with durability and high workability. Structuro 520 is a solid hyperplastic that allows the production of consistent concrete properties around the required dosage.Structuro technology offers the following advantages:

- The possibility to create zero-defect concrete.
- Ability to maintain high slump flow values for two hours or more.
- Self-compacting concrete can significantly reduce staffing for placing.
- Good compaction and low voids improve steel protection against corrosion.

2.7Related Research

Recent years have witnessed a remarkable development in polymeric concrete. And that's through the excellent results in improving the strength and durability of concrete. Polymers are used to change the properties of materials and are called additives when used in small quantities in concrete.

Changing of Portland cement mortars and concretes by adding polymers, findings in mixed materials with improved engineering properties. Some of these materials have higher tensile and compressive strength, tensile and impact strength, scraping resistance, lower drying retraction, chemical resistance, and minimized permeability. The main feature of these materials is the reason for the continuous interest shown in these materials by various design, research, and production organization.

Several materials have been improved and marketed in recent years. These materials involve monomers, resins, latexes, and polymers. Firstly, they were used in mortars, but their use has been extended to concrete. Implementations for these materials include

interior and exterior floor covering, resurfacing of bridge decks, and other repair work (Marotta, 2019). The pozzolanic materials, such as slag, fly ash, palm oil fuel ash, metakaolin, etc., as partial replacement in cement, to have evidence on the improvement of sustainable bond materials (Hossain & Zain, 2016). The use of additives with Portland cement leads to the development of the properties of mortar and concrete in various cases (Zongjin, 2011).
The acrylic polymer is one of the active materials that effecting the mechanical properties of concrete and increasing the adhesion strength between materials (Bulut & Şahin, 2017).

The properties of cement mix can be improved by a small amount of polymer (Bhikshma, Jagannadha & Balaji et al., 2010). Using a minor amount (2%) of polyvinyl alcohol will decrease the water permeability of polymer-modified concrete compared with traditional concrete (Zhan, 2021).

Cement components are developed when an additive is used instead of cement. Duchesne and Be, 1995**.** The study results showed that the Furan based polymer has a good effect on the mechanical and chemical properties and the cost of the materials that are used in the construction field (Muthukumar & Mohan, 2005)

The polymer types (saturated, polymer concrete, and polymer-modified polymer concrete) on the permanence properties including compressive, flexural, tensile strength, and the reduction of water absorption**.** Using the epoxy and acrylic emulsion as an additive on concrete will increase strength properties and chemical resistance (Aggarwal, Thapliyal,. & Karade, et al., 2007).

Focused on the main reasons which made the cracks and how to avoid and amend them by using polymers technology (Tofail, 2018). The study results showed that the metakaolin and recycled erfiber have a negative effect on water absorption and mechanical properties after 28 days (Al Menhosh, 2016)**.**

The polymers contain small components (called monomers) that are linked together by long chains, and some polymers sometimes consist of large numbers of monomers. The polymer can be used in the form of oils, tars, and others (Masuelli, 2013).

The study examined the effect of different additives on the mechanical properties of concrete. The results confirmed that the use of these additives reduces the pores and increases the size of the distribution of these pores, and accordingly, the permeability, porosity, and shrinkage are reduced (Ayub, Khan, & Memon et al., 2014). Enhancing mechanical properties and reducing corrosion will be achieved by using Portland limestone cements (Yang, Che & Shi., 2021).

Polymer-modified concrete normally enhanced the mechanical properties of concrete. the polymers improved tensile and flexural strength, struggle with physical damage, and increased chemical resistance (Islam, Rahman, & Ahmed, 2011).

CHAPTER III

Methodology

3.1 Introduction

The practice procedures of this thesis have been done to study the effect of using polymers on the enhancement of the concrete's mechanical and workability properties. determining the convenient ratio of polymer in cement and studying the effect of the curing age of concrete on the mechanical properties.

The materials from the Jordan market were selected and tested in the Modern Engineering Lab. A concrete mix design with and without polymer was performed. The samples have been tested for mechanical and durability properties. Structure 520 was used as an additive to concrete mixtures during different periods (7, 14, and 28) of time to perform different tests as listed in Table 1.

Table 1.

Types of Tests

Type	**Specifications**
Workability (Slump Test).	(BS EN 12350-2: 2019)
Compressive Strength	(BS EN 12390-3: 2019)
Flexural Strength	(ASTMC293/C293-2016)
Water Absorption	(BS 1881-122:2020)

3.2 Materials

3.2.1 Cement

Portland cement is the most common cement around the world. Lafarge Cement (Alraskh). Ordinary Portland Cement (OPC) Type CEM I; Grade 52.5 N. From Northern Cement Company/ Jordan. Conforms to Jordanian Standard Specifications 2007:1-30 JS. Table 2.

Table 2.

Chemical and Physical Properties for cement

Chemical Requirements	Results %		Standard Values	
	Min	Mix	Min	Max
Loss on ignition (LOI)	0.89	1.94	-	5.00
Insoluble Residue	0.49	1.70	-	5.00
Mgo	1.83	3.83	-	-
SO_3	2.67	3.5	-	4.0
Chloride Content	0.01	0.03	-	0.10
Cao	60.89	64.90	-	-
Sio_2	17.81	20.77	-	-
AI_2O_3	4.12	6.02	-	-
Fe_2O_3	2.97	5.44	-	-
K_2o	.60	1.02	-	-
Free Lime	.75	2.56	-	-
Physical Requirement	Results %		Standard Values	
	Min	Max	Min	Max
Fineness (Blaine) cm^3/g	4188	5020		
Soundness (Expansion) mm	1.50	2.50	10.0	
Initial Setting Time	120	180	45	
Compressive Strength	Results (MPa)		Standard Values (MPa)	
	Min	Max	Min	Max
2DAYS	29.20	35.00	20	
28DAYS	55.00	61.00	52.50	

3.2.2 Aggregate

Aggregates are small rock fragments of mineral origin, and mixing aggregates with water and cement is a necessary process for concrete production. The aggregates available in the Jordanian local market were used.

The tests were performed on aggregates according to the relevant of ASTM C 295 – 03; “Standard Guide for Petrographic Examination of Aggregates for Concrete”.

Table 3.

presents the applicable standards for these tests.

Aggregate Identification	**Coarse Agg. 20mm**	**Med. Agg. 12mm**	**Med. - Fine Agg. 8mm**	**Silica Sand 2mm**	**Concrete Aggregates**		
Test Name	Test Result				Test Standard	**JAS**	
- Sieve Analysis: -	% Passing by Weight						
- Sieve Number: 1"	100	100	100	100			
3/4"	100	100	100	100			
1/2"	70	100	100	100			
3/8"	1	55	100	100	ASTM C 136/C136M-14, ASTM C 117-17	□	
No. 4	1	9	63	100			
No. 8	1	2	4	100			
No. 16	1	1	2	97			
No. 30	1	1	2	87			
No. 50	1	1	2	37			
No. 100	1	1	2	9			
No. 200	0.4	0.8	1.2	2.8			
- Specific Gravity (SG): Bulk SG. (Oven Dry)	2.64	2.64	2.62	2.62			
Bulk SG. (SSD)	2.67	2.67	2.65	2.63	ASTM C127-15, ASTM C128-15	□	
Apparent SG.	2.71	2.70	2.71	2.65			
- Water Absorption, %	0.9	0.8	1.3	0.5			
- Moisture Content (as received), %	0.4	0.5	0.7	1.9	ASTM D2216-19	□	
- Flakiness Index	5	11	--	--	BS 812 (BS EN 933-3:1997)	□	
- Elongation Index	22	21	--	--	BS 812: Part 105.2, 1990	□	
- Abrasion Loss (500 cycles), %	23		--	--	ASTM C 131/C131M-14	□	
- Ratio of wear loss (100/500)	0.21		--	--			
- Clay Lumps, %	0.06	0.25	0.20	--	ASTM C 142/C142M-17		--
- Sand Equivalent	--		88		ASTM D 2419-14		--
- Sulphate Content (SO3), %	0.078	0.085	0.064	0.001	EN 1744-1: 2012	□	
- Chloride Content (Cl), %	0.007	0.005	0.008	0.007	EN 1744-1: 2012	□	

- Soundness Loss *(MgSO4)* , %	1.64	3.13	4.64	2.32	ASTM C 88/C88M-18	--
- Lightweight Particles, %	Nil	0.05	0.01	0.08	ASTM C 123/C123M-14	□
- Shell Content, %	Nil	Nil	Nil	--	By Inspection	--
- Organic Impurities (For Fine)	Lighter Than Standard Color				ASTM C40/C40M-19	--
- Potential Alkali-Silica Reactivity	Aggregates Considered Innocuous					
- Dissolved Silica (Gravimetric/ Photometric Method), mmol/L	64.6/60.0		47.3/40.0		ASTM C 289 – 07	--
- Reduction in alkalinity, mmol/L	130		95			
- Chert & Flint Content, %	Nil	Nil	--	--	IHM/EAS 003 - 2019 **(*)**	□
- Drying Shrinkage, %	0.032				BS EN 1367-4:1998	--

Table 3(continued)

3.2.3 Aggregate Testing Results:

The results of these tests at the specified depths are as provided in Table 4

Table 4.

Physical and Chemical Properties for Aggregate

Aggregate Identification		**Coarse Agg.**	**Med. Agg.**	**Med. - Fine Agg.**	**Silica Sand**
Test Name		Test Results			
Gradation					
Sieve No.	Size, mm	Passing by Weight, %			
”1.5	37.5	100.0	100.0	100.0	100.0
”1.15	28	100.0	100.0	100.0	100.0
”1	25	100.0	100.0	100.0	100.0
”4\3	20	81.0	100.0	100.0	100.0
”2\1	14	3.0	99.0	100.0	100.0
”8\3	10	1.0	47.0	100.0	100.0
No. 4	4.75	1.0	5.0	99.0	99.0
No. 8	2.36	1.0	0.3	99.0	44.0
No.16	1.18	1.0	0.3	96.0	3.0
No.30	0.6	1.0	0.3	85.0	3.0
No.50	0.3	1.0	0.3	46.0	2.0

No.100	0.15	1.0	0.3	12.0	2.0
No. 200	0.075	0.3	0.2	4.2	1.9

Table 4(continued)

Mentioning that the involved aggregates are regional and being in use for long in concrete mixes, the simplified petrographic examination was carried out on the mix aggregates in general accordance with ASTM C 295 – 03; "Standard Guide for Petrographic Examination of Aggregates for Concrete".

The crushed limestone aggregate is composed of grey, strong, angular with some subangular, mostly fine-textured, particles. No Chert or Certifying particles exist. Flaky and elongated particles, as defined by ASTM D 4791, are noticeably low. No Significant heterogeneities, coatings or incrustations, or suspicious constituents were noticeably revealed in the crushed limestone aggregate. Silica sand is composed of quartzite light rosy, rounded to subrounded, gap-graded particles. No Significant heterogeneities, coatings or incrustations, or suspicious (unusual) constituents were noticeably revealed in the silica sand.

3.2.4 Water

The following determinations were carried out on the delivered water sample according to the stipulated corresponding standard procedures, and the results of the test were as shown below Table (5).

Table 5.
Water Tests Results

Test Type	Water Sample	Maximum BS EN 1008-2002
PH	7.4	>4
Chloride Contant, CI(p.p.m)	85	1000
Sulphate Content, SO_3(p.p.m)	35	2000

3.2.5 Structuro 520

Structuro 520 differs from other superplasticizers in that it is made up of a single carboxylic ether polymer with lengthy lateral chains. Cement dispersion is substantially improved as a result of this. An electrostatic dispersion occurs at the start of the mixing process, but the existence of the lateral chains, which are attached to the polymer backbone, creates a steric barrier that stabilizes the cement particle's ability to split and disperse. The water requirement in flowable concrete is significantly reduced by this technique.

Water reduction and workability retention are combined in structuro 520. It enables the creation of high-performance and/or high-workability concrete. Structuro 520 is a highly strong hyperplasticiser that allows for consistent concrete quality around the dosage required. It was obtained from Fosroc Company in Jordan.

The optimum dosage of Structuro 520 to meet specific requirements has been determined by trials using the materials and conditions experienced in use. Table(6). The sample range was between(0.5% to 2.0%) as shown in and Figure 1.

Table 6.

Structuro 520 Typical Properties

Appearance	Light brown colored liquid
Chloride content	Nil
Specific gravity	1.1 @ 20°C
pH value	6.5
Alkali content	Typically, less than 1.5 gm Na_2O equivalent per liter of admixture

Figure 1

Structuro 520 dosage range

3.3 Equipment

Tools and equipment employed in this experimental work include:

a) Portable Concrete mixer.

b) Balance to measure the mass of concrete components

c) Plastic bottle for water volume

d) Cube and beam molds.

e) A plastering tube

f) Curing box

g) Oven for drying the samples

h) Sieves

i) Slump Cone

j) Hydraulic compressive strength machine

k) Blackhawk flexural strength testing machine

3.6 Job Mixes Formulas

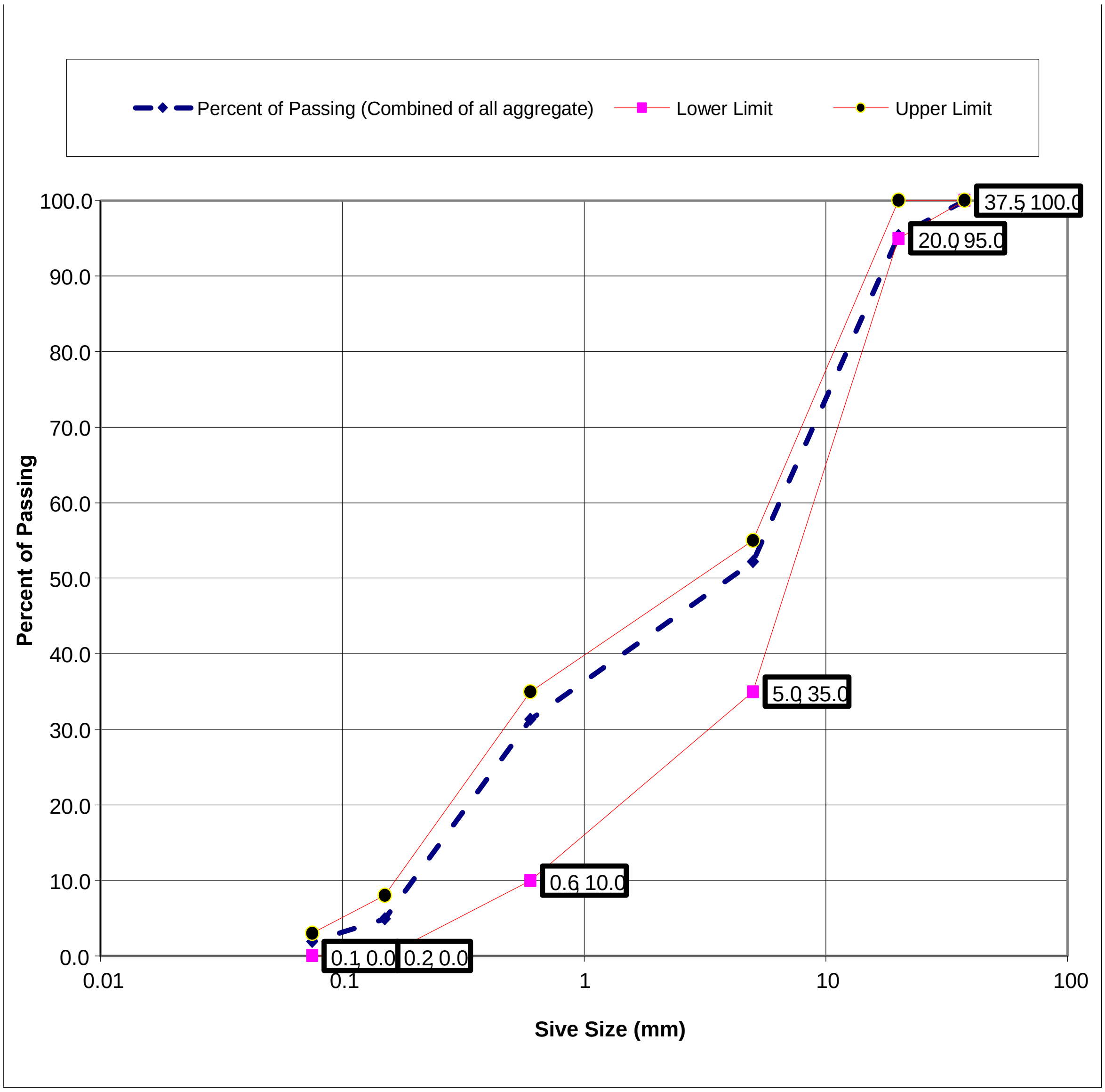
The most suitable proportions by weight to satisfy the grading limits and mixes properties were as follow in Table (7), and Figure (2)

Table 7.
Combined Aggregate Grading

%		24.4	24.4	15.4	35.8	100	Specifications Grading Limits JS 2065: 2016	
Sieve Number:		Coarse Agg.	Med. Agg.	Med. - Fine Agg.	Silica Sand	Combined Grading		
1 ½”	37.5	100	100	100	100	100.0	-	-
1”	25	100	100	100	100	100.0	98	100
¾”	20	81	100	100	100	95.4	90	100
½”	12.5	3	99	100	100	76.1	-	-
3/8”	9.5	1	47	100	100	62.9	50	90
No.4	4.75	1	5	99	99	52.1	-	-
No.8	2.36	1	0.3	44	99	42.6	23	63
No.16	1.18	1	0.3	3	96	35.2	-	-
No.30	0.6	1	0.3	3	85	31.2	-	-
No.50	0.3	1	0.3	2	46	17.1	-	-
No.100	0.15	1	0.3	2	12	4.9	-	-
No.200	0.075	0.3	0.2	1.9	4.2	1.9	0	5

Figure 2

Combined Grading Curve



3.7 Mixing Design

Cement, Water, Coarse Aggregate, and Fine Aggregate are the four primary components in varying proportions of a combination . Additional ingredients, like polymers and chemical additives, can be added to the mix to give it a desired wear pattern. The mixture is designed to have a 30 MPa breaking strength.

The mix ratio of control mix was 1:2:3 (cement: fine aggregate: coarse aggregate) with water- cement ratio of 0.57. The volume of polymer (Structruro 520) was 0.5%, 1.0%, 1.5% and 2.0%, of cementitious materials, respectively. The coarse aggregate could be calculated by multiplying The specific gravity of each coarse aggregate sample by the percentage of each gradient. As for the fine aggregate, it's all about trial and error till completion of 1 cubic meter, Cement is constant in this equation. Water-cement ratio could be used to get the amount of water, and to get the total water; simply by adding absorption of aggregate.

1. Different trial mixes were conducted according to the requirements of ACI 211.2 and ASTM C94 for design and inspection of standard concrete mixes:
2. Determine the trial mix design and proportioning study the reference standard is MPWH General Technical Specification for building, 1986 and Jordanian Standard Specification (JS/2065/2016) and change the percentage of plasticizer (0.5%, 1%, 1.5%, 2%) for each trial. Table (8) and Figure (3)

Table 8.

Mixing Design (Kg/m^3)

components	**sample1**	**sample 2**	**sample 3**	**sample 4**	**sample 5**
Coarse Agg.	485.6	485.6	485.6	485.6	485.6
Med. Agg.	485.6	485.6	485.6	485.6	485.6
Med. -Fine Agg	306.5	305.6	304.8	303.9	303.0
Silica Snad	715.3	713.2	711.1	709.0	706.9
Cement	261	261	261	261	261
Water (Net)	148.8	148.8	148.8	148.8	148.8
Water (Total)	180.0	179.0	178.0	177.9	177.3
Structuro 520 (%)	0	0.5	1.0	1.5	2
W/C	0.57	0.57	0.57	0.57	0.57

Figure 3

mixing procedures

3.8 Procedures

The fresh concrete after mixing was casted in steel moulds .The moulds were lightly oiled and filled with mixes in three layers, and compacted using hand vibrator, then the surface was finished level. After 24 hours, the specimens were removed from the moulds . Cube specimens of 150 x 150 x 150 mm and beams 600 x150 x150 mm.

1. 12 cure cubes prepared for (150 mm x 150 mm) for each trial as shown in Figure 3 and listed in Table 7.
2. Five cure beams prepared with dominations of 600 mm*150 mm Crush three Cubes at seven days, three at 14 Days, and three at 28 days' ages. We are doing the flexure strength test at 28 days. Figure (4)

Figure 4
Procedures

3.9 Workability (Slump Test)

The workability of concrete means the extent of mixing concrete easily and homogeneously, which is positively reflected in the mechanical properties, quality, appearance, and cost. The workability test was carried out based on the (BS EN 12350-2: 2019) standard.

The main factors affecting Concrete workability can be summarized as follows:

- Mixing water content and water/cement ratio
- Properties of cement
- Characteristics of aggregates
- Use of additives
- Effect of time, temperature, and wind

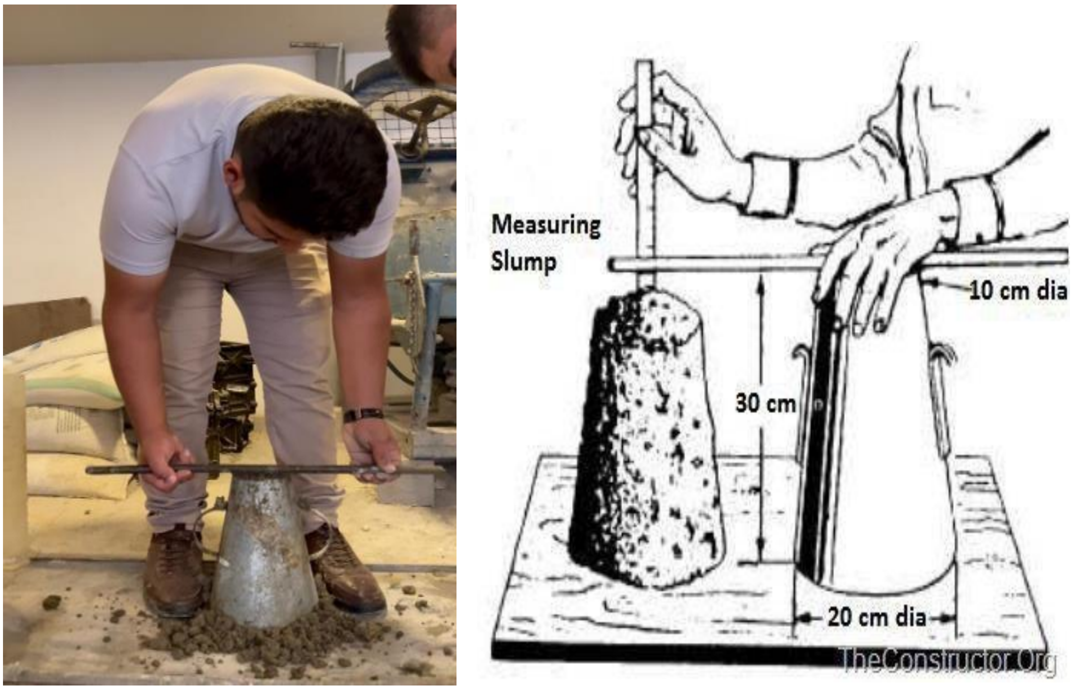
Consistency is one of the most important factors that measure the homogeneity of concrete and ensure that all its components have been mixed well without any separation or dispersal. To measure the level of consistency, the slump test is adopted using a metal cone Figure (5) with the following dimensions:

- Bottom diameter 20 cm

- Top diameter: 10 cm
- Height30 cm

Figure 5

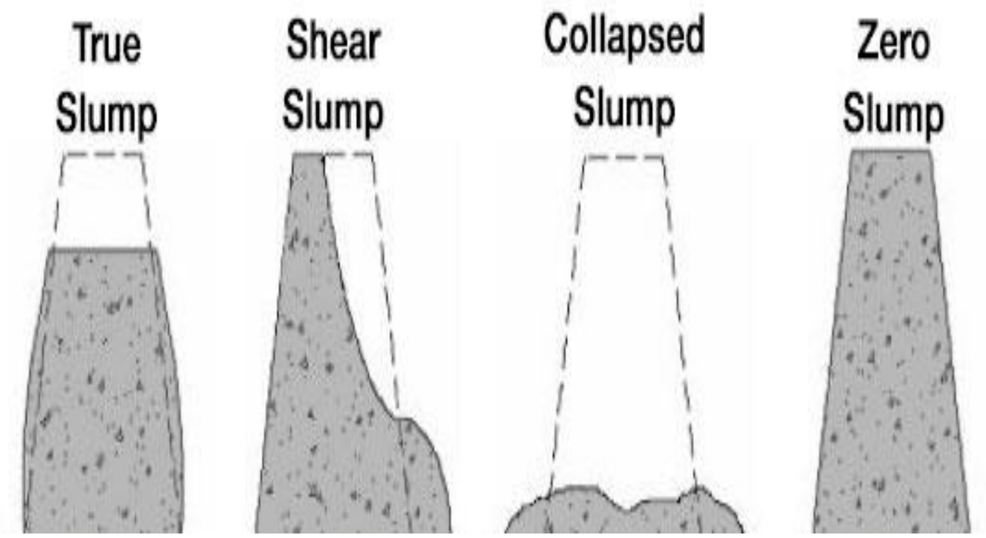
Slump Cone



Slump normally appears on three types (true, shear, collapse) Figure (6). In a true slump, the edges of concrete slide equally from both ends, while in a shear slump concrete slip is uneven on both sides. The slump value is calculated here by the cone height and the average height between the two parties. The occurrence of this type is evidence that a Heterogeneous mix of concrete. And in the slump of the collapse, there is no cohesion in the concrete, and therefore there is no height on both sides .

Figure 6

Slump types



3.6.1 Slump Test

The following steps have been taken to perform the slump test:

1. The constituents of the concrete dry state have been weighed. The components of the concrete are mixed to obtain a uniform color and then continue to mix slowly.
2. After cleaning the internal surface and wiping it with a light layer of oil, the cone has been filled with four equal layers of fresh concrete.
3. In each layer, it must be tamped well 25 times, and it must be ensured that the tamping rod penetrates all layers each time.
4. Excess concrete was removed from the cone, and then the height of the cone was measured.

3.10 Compressive strength test

When stress is applied to hardened concrete, the properties and proportions of the materials used in the mixture, stress level, and curing methods must be taken into account, as all of them affect the concrete's response to pressure. In the compression test, an axial compressive force is applied to the molded cylinders, and it continues until the cylinder breaks. This test not only measures the endurance, but also the quality level of hard concrete, Figure (7) The compressive strength was gained on cubes of 150 x 15 0mm x 150 mm size. A sample testing was carried out at 7, 14, and 28days' age. Five samples of each mixture were tested and reported. The Compressive strength test was carried out based on the (BS EN 12390-3: 2019) standard.

Figure 7

Compressive test

3.11 Flexural Strength

A flexural strength test is performed by applying a force to the concrete beam with a length of not less than three times the depth, where the flexural force is expressed as the rupture rate. flexural strength is an indicator of the resistance of the cylinder during bending.

A beam mold 600mm×150mm×500mm was filled with the concrete Figure (8). After 24 hours the samples were removed from the mold and left for 28 days before measuring the flexural strength of the concrete. Five beams were cast for this test. The center point loading method was used to conduct the concrete flexural test. The Flexural Strength test was carried out based on the (ASTMC2393/C293-2016) standard.

Figure 8

Flexural strength Test

3.12 Water Absorption

The level of water entering hardened concrete is a crucial step determination of the potential durability of a structure. The water absorption of a concrete surface depends on mixing ratio, chemical muddle and additional cement-based materials, the composition, and physical characteristics of the cement-based component, aggregates, type and duration of curing, the degree of hydration, or age, and the presence of microcracks. Water absorption is also strongly affected by the humidity condition of the concrete at the time of testing.

The samples were oven-dried at a temperature of 107 ◦C for 24 hours and then pliable to cool to room temperature for 30 min Figure (9). The samples were weighed then immersed in filtered water at 25 ◦C for 24 h. Thereafter, the samples were removed from the water and weighed to calculate the amount of absorbed water. The water absorption of each sample was calculated based on its absorbed water and oven-dried weight. The Water Absorption test was carried out based on the (BS 1881-122:2011) standard.

The percentage absorption of water was then calculated using the formula:

$$\text{Water Absorption } \% = \frac{W2-W1}{W1} * 100\%$$

Where W1 is the oven-dry mass of the test sample.

W_2 is the wet mass of the test sample.

Figure 9

Water Absorption test

CHAPTER VI

Results and Discussion

The results show for polymer-modified concrete that the performance and structural characteristics are outstanding compared to conventional concrete. It is noted not only in the hardened state but also in its new state. After conducting the practical trials, the results were analyzed and presented through tables and graphs.

4.1 Workability

The results are shown in Figure (10). Increasing Structuro 520 by more than **1%** will reduce the workability of the concrete. The reason is that the polymer will make the concrete viscous and its solid particles will fill the voids in the concrete, thus hindering the concrete mixture from slumping.

The results show that there is no slump value (collapse) at 1.5% and 2% of Structuro 520 because the concrete mix becomes too tough and slimy.

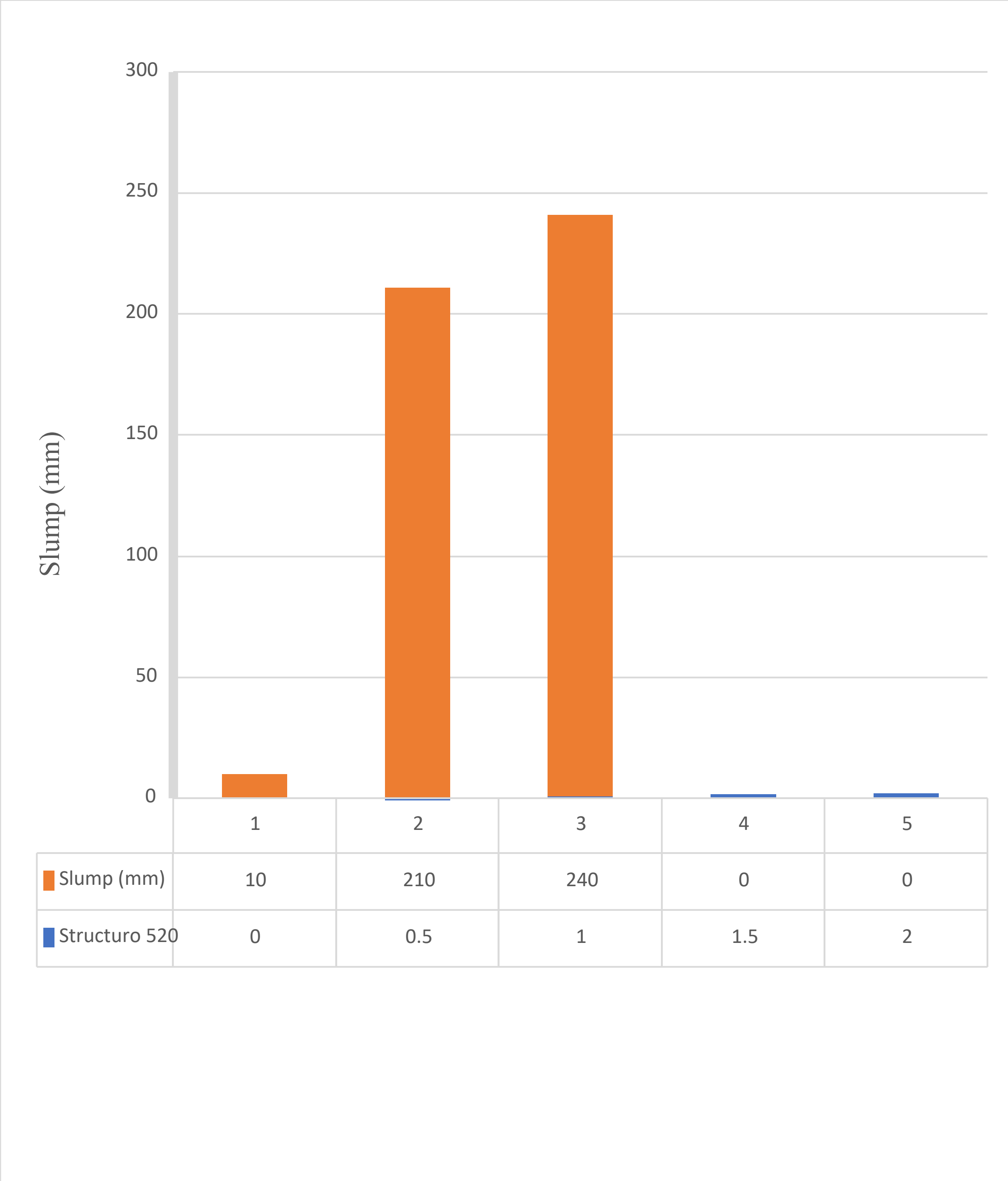
Table 9.

Slump test results

Structuro 520 (%)	**Slump (mm)**
0	10
0.5	210
1	240
1.5	Collapse
2	Collapse

Figure 10

Workability Results



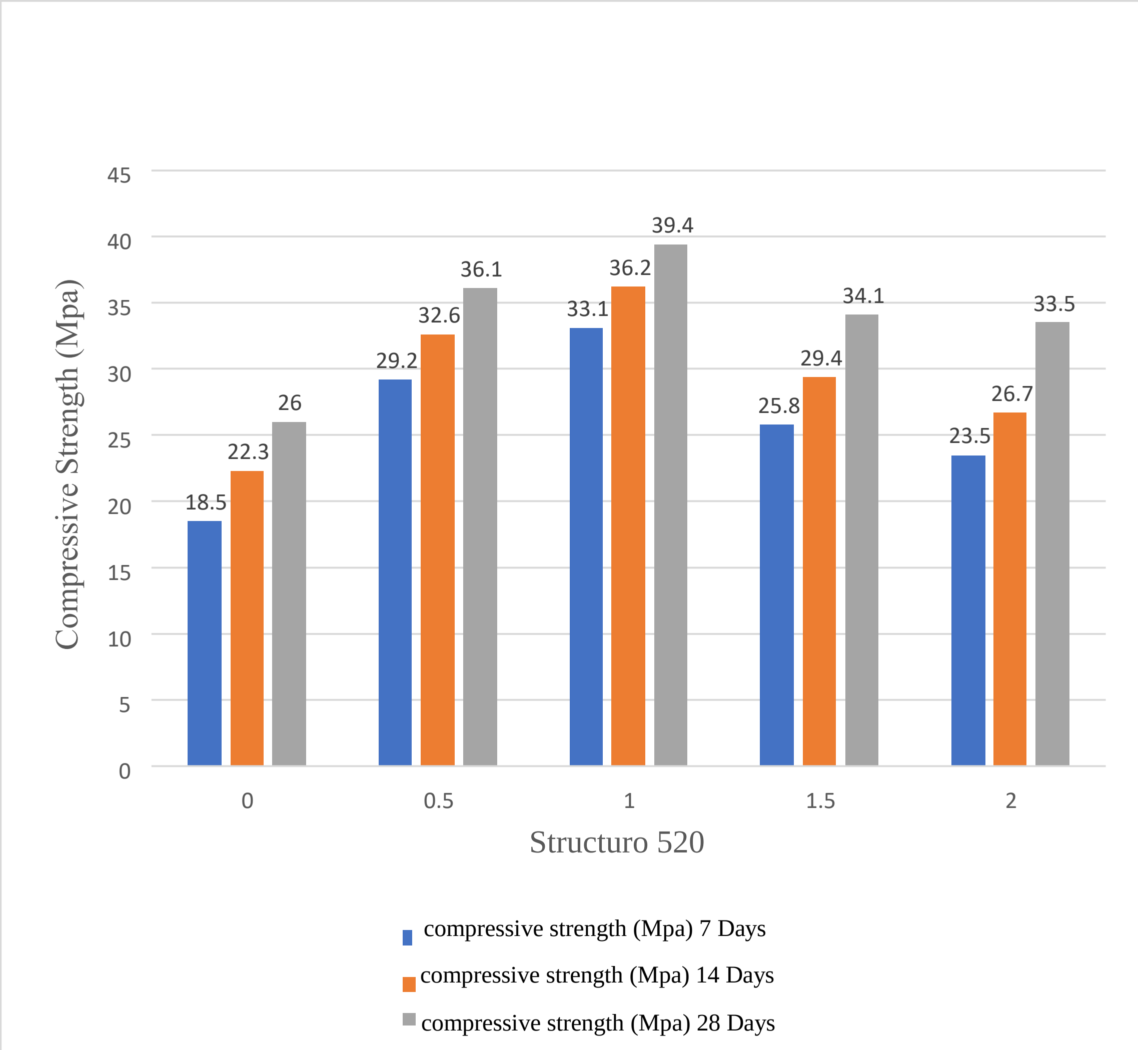
4.2 Compressive Strength

Figure (11) shows that the compressive strength increased linearly with the incorporation of polymer up to 1%, and then decreased after this point. Structuro 520 does not help in enhancing the concrete compressive strength when the ratio exceeds 1% at different ages (7, 14, and 28 days). This causes a weakness in the cohesion of concrete bonds. Concrete containing 1% of the polymer is considered the best compared to the other ratios, as the compressive strength at this point was 39 Mpa.

Table 10.
Compressive Strength Results

	Compressive Strength(Mpa)		
Structuro 520 %	7 Days	14 Days	28 Days
0	18.5	22.3	26.0
0.5	29.2	32.6	36.1
1	33.1	36.2	39.4
1.5	25.8	29.4	34.1
2	23.5	26.7	33.5

Figure11
Compressive Strength Results



4.3 Flexural Strength

The flexural strength of concrete with different dosages of structure 520 was tested for 28 days. The maximum recorded value was 13.6 Mpa at 1% of the Structuro 520 dosage Figure (12). After this curing point, the flexural strength decreased with increasing the percentage of Structuo 520. This is due to the lubricating property present in the polymer particles. The polymer particles must be well combined with the concrete during mixing; otherwise, this will lead to a weak bond between the concrete particles.

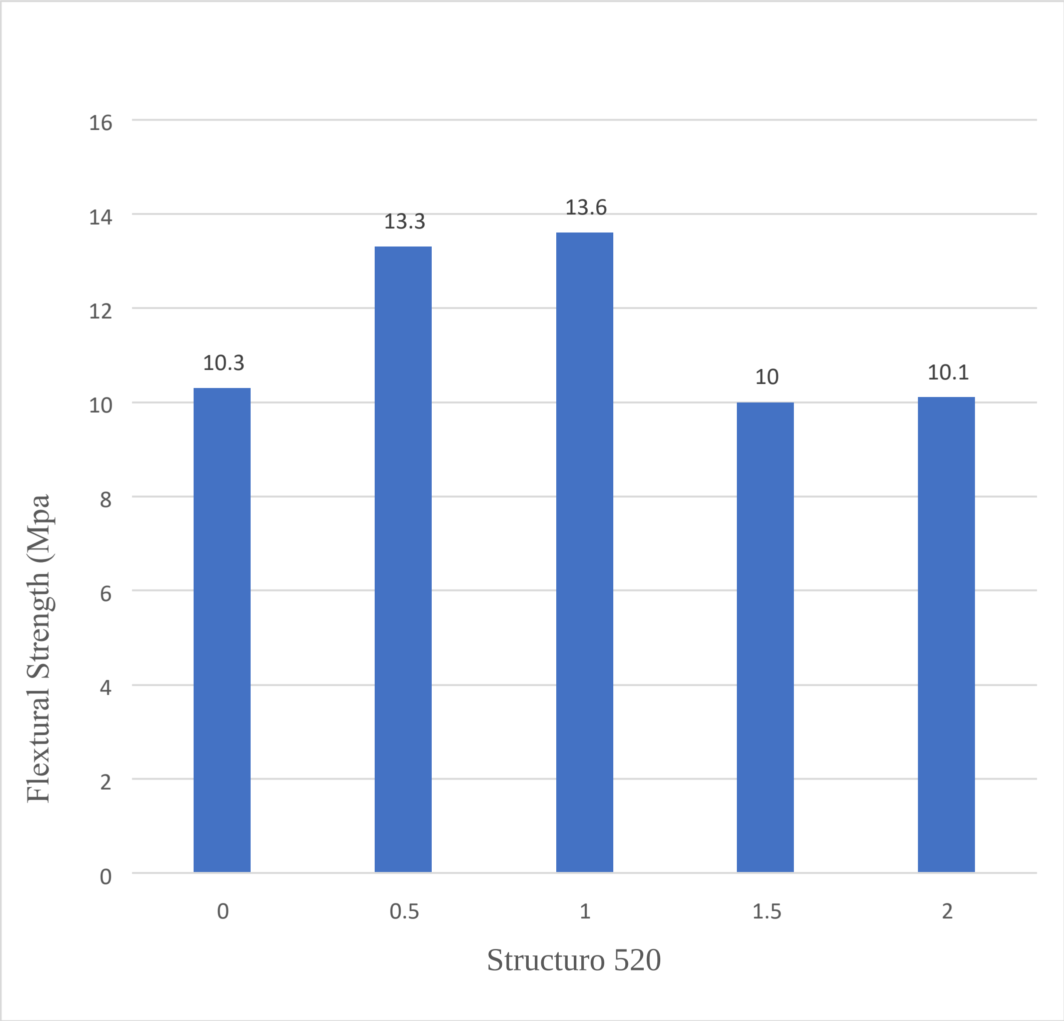
Table 11

Flexural Strength Results

Structuro 520 %	**Flexural strength (MPa) 28 Days**
0	10.3
0.5	13.3
1	13.6
1.5	10.0
2	10.1

Figure12

Flexural Strength Test



4.4 Water absorption

The results show that with an increase in the Structuro 520 percentage, the percentage of water absorption also increases. We noted that the control sample absorbed the largest proportion of water (2.4%).

When adding 0.5 and 1% of Structuro 520, the amount of water absorbed was 1.7%, which means the cohesion of polymeric concrete and the absence of permeability or void in it, Figure (13). When the percentage of Structuro 520 is increased to 1.5%, the water absorption percentage increases to 1.8%, and then this percentage rises to 1.9% when the ratio of Structuro 520 is at 2%. This means that the increase in the water absorption rate indicates the lack of homogeneity and bonding between the concrete components and Structuro 520 with an increase in the percentage of Structuro 520.

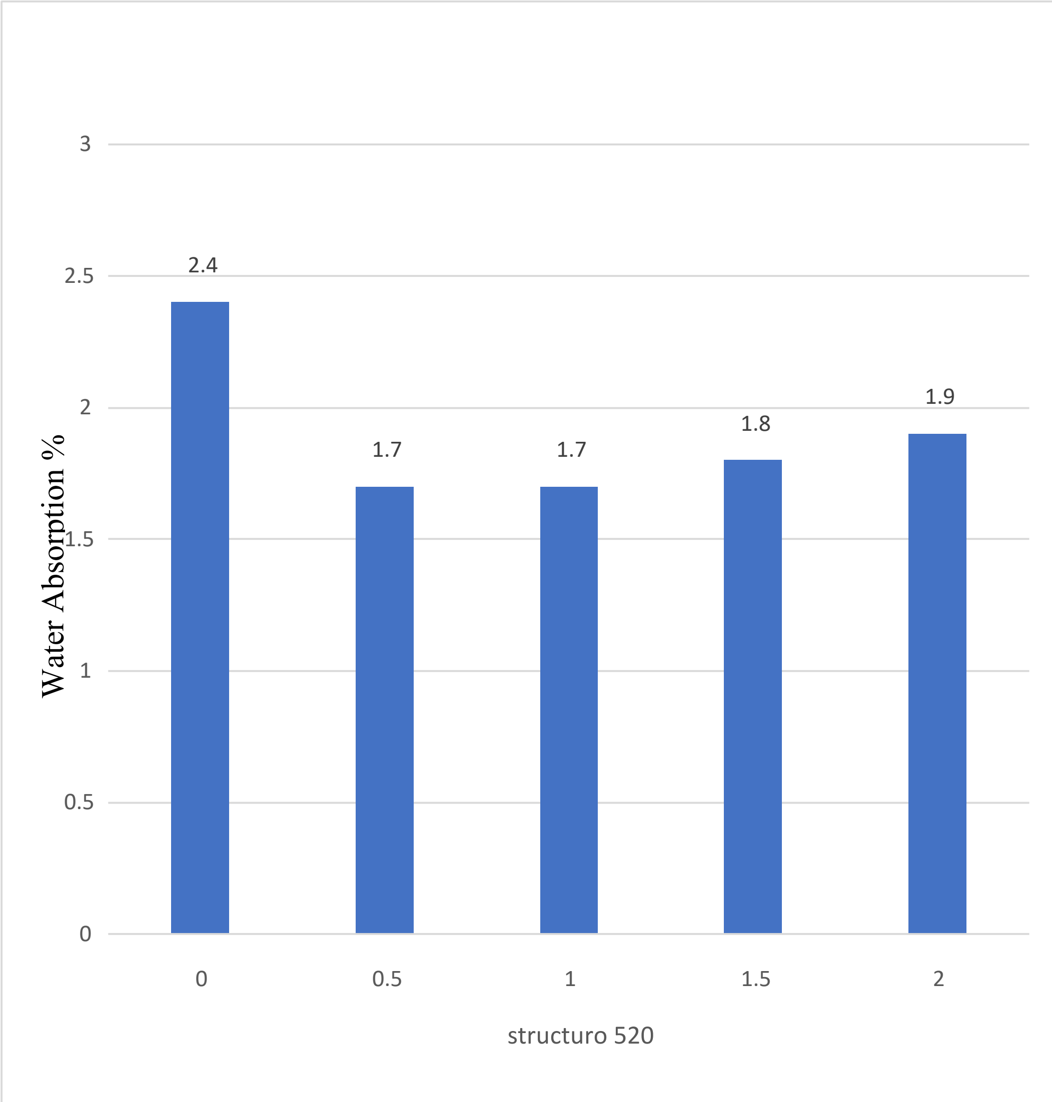
Table 12

Water Absorption Results

Structuro 520 %	**water absorption %**
0	2.4
0.5	1.7
1	1.7
1.5	1.8
2	1.9

Figure13

Water Absorption Test



CHAPTER V

Conclusions and Recommendations

5.1 Results Summary

All results have been summarized in Table (13).

Table 13.
Results Summary

Results	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Coarse Agg.	485.6	485.6	485.6	485.6	485.6
Med. Agg.	485.6	485.6	485.6	485.6	485.6
Med. -Fine Agg	306.5	305.6	304.8	303.9	303.0
Silica Sand	715.3	713.2	711.1	709.0	706.9
Cement	261	261	261	261	261
Water (Net)	148.8	148.8	148.8	148.8	148.8
Water (Total)	180.0	179.0	178.0	177.9	177.3
Structuro 520 (%)	0	0.5	1.0	1.5	2
W/C	0.57	0.57	0.57	0.57	0.57
		Concrete Properties			
Slump (mm)	10	210	240	collapse	collapse
Compressive strength (Mpa)					
7 Days (Avg.)	18.5	29.2	33.1	25.8	23.5
14 Days (Avg.)	22.3	32.6	36.2	29.4	26.7
28 Days (Avg.)	26.0	36.1	39.4	34.1	33.5
Flexture Strength (Mpa)	10.3	13.3	13.6	10.0	10.1
Water Absorption (%)	2.4	1.7	1.7	1.8	1.9

5.2 Conclusions

This thesis was conducted to identify the mechanical properties and performance of polymeric concrete by conducting practical experiments during varying periods, where the optimal mixture was identified, which positively affects the mechanical and structural properties of polymeric concrete. The results proved that Structuro 520 modified concrete gives better results than Conventional concrete, both hardened and new, and accordingly, the following points were concluded:

- The higher the percentage of polymer structure 520 in concrete than 1%, the lower the workability, as shown in the slump test.
- The optimum sample that achieved the best compressive strength contained 1% of Structure 520, which means that complete polymerization occurred at this percentage, which led to filling the voids with polymer and thus obtaining a strong resistance network and improving the properties and performance of polymeric concrete.
- When the percentage of Structuro 520 is added to (0.5% - 1%), the flexural strength of polymeric concrete increases accordingly. The reason is that the use of Structuro 520 leads to the creation of three-dimensional networks of polymer particles in concrete, where the bonding strength increases because of the strong polymer properties.
- According to the water absorption results, it was found that an increase in Structuro 520 up to 1% has resulted in a considerable reduction in porosity and water absorption in polymer-modified concert.
- The best ratio of structuro 520 has been observed at 1 %. It was found that the compressive and flexural strength recorded the maximum values at this point was 39.4 MPa and 13.6 MPa respectively.
- The effect of structuro 520 on the 7 curing days mechanical strength was weaker than that on the 28 days strength. This reason can be ascribed to the low hydration degree of polymer at the early age.

5.3 Recommendations

This thesis recommends conducting more future studies to research:

1. Studying the effect of different types of modern polymers on the mechanical properties of concrete.
2. Studying the effectiveness of Structuro 520 on repairing faults affecting concrete such as cracks and pores.
3. During the practical experiments in this thesis, some weaknesses were identified when adding polymer to concrete, so it is recommended to conduct studies to research how to treat it to increase its effectiveness and popularize contractors to use it in a wide range.

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APPENDICES

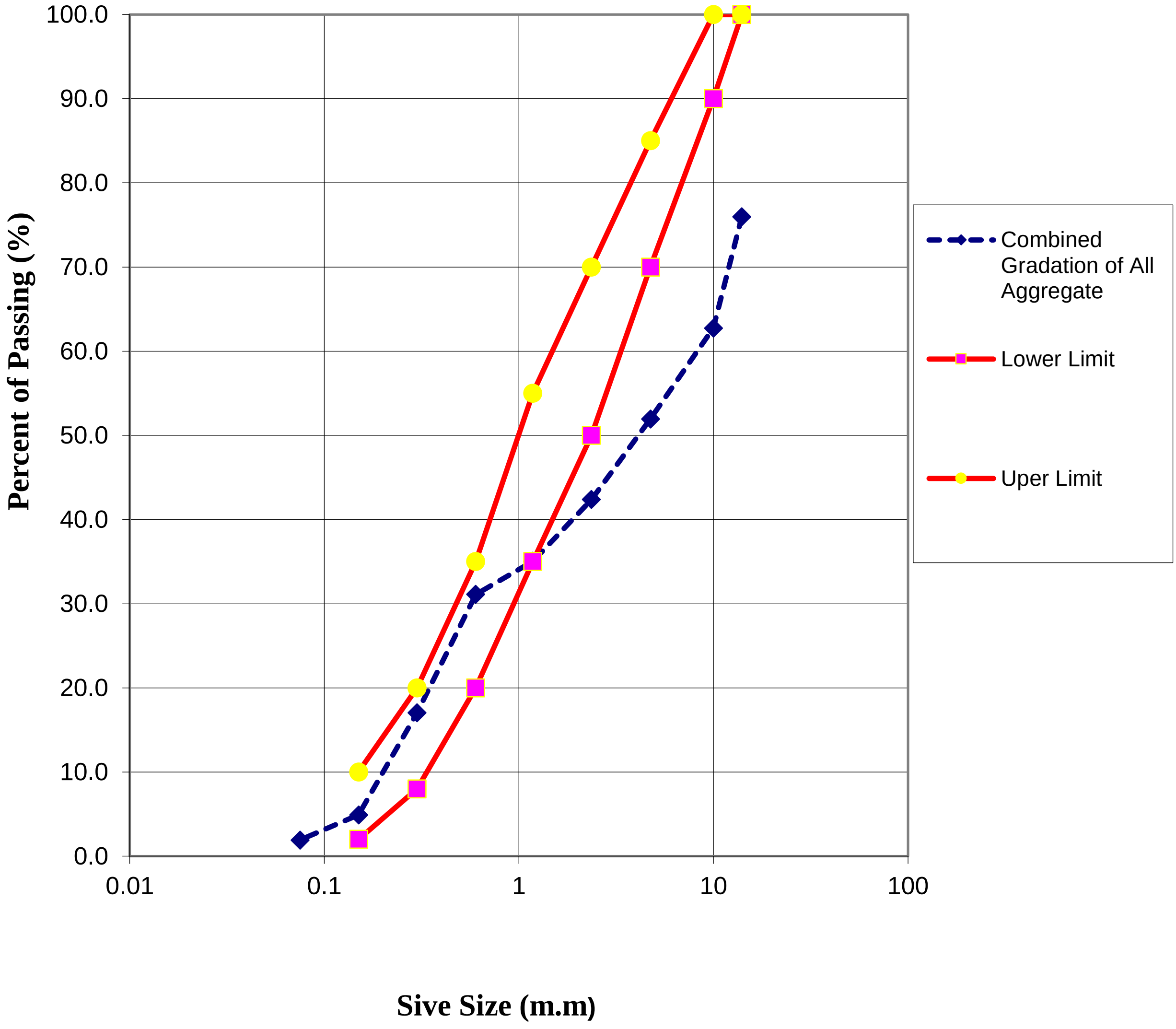
Appendix 1: Mixed Materials according to American Society for Testing and Materials (ASTM)

sieve size mm	% PASSING BY WEIGHT							
	Coarse 1	Coarse 2	Coarse 3	Med 1	Med 2	Med 1	Fine 2	Fine 3
37.5	100	100.0	100.0	100.0	100.0	100.0	100.0	100
28	100	100.0	100.0	100.0	100.0	100.0	100.0	100
25	100	100.0	100.0	100.0	100.0	100.0	100.0	100
20	69	81.0	100.0	100.0	100.0	100.0	100.0	100
14	22	3.0	99.0	100.0	100.0	100.0	100.0	100
10	13	1.0	47.0	99.4	100.0	100.0	100.0	100
4.75	13	1.0	5.0	63.2	99.9	99.0	99.0	99
2.36	13	1.0	0.3	14.9	99.8	44.0	99.0	98
1.18	13	1.0	0.3	10.2	99.6	3.0	96.0	98
0.6	12	1.0	0.3	9.2	87.7	3.0	85.0	92
0.3	12	1.0	0.3	8.8	28.5	2.0	46.0	66
0.15	12	1.0	0.3	8.2	5.1	2.0	12.0	16
0.075	46	0.3	0.2	7.4	2.1	1.9	4.2	7.7

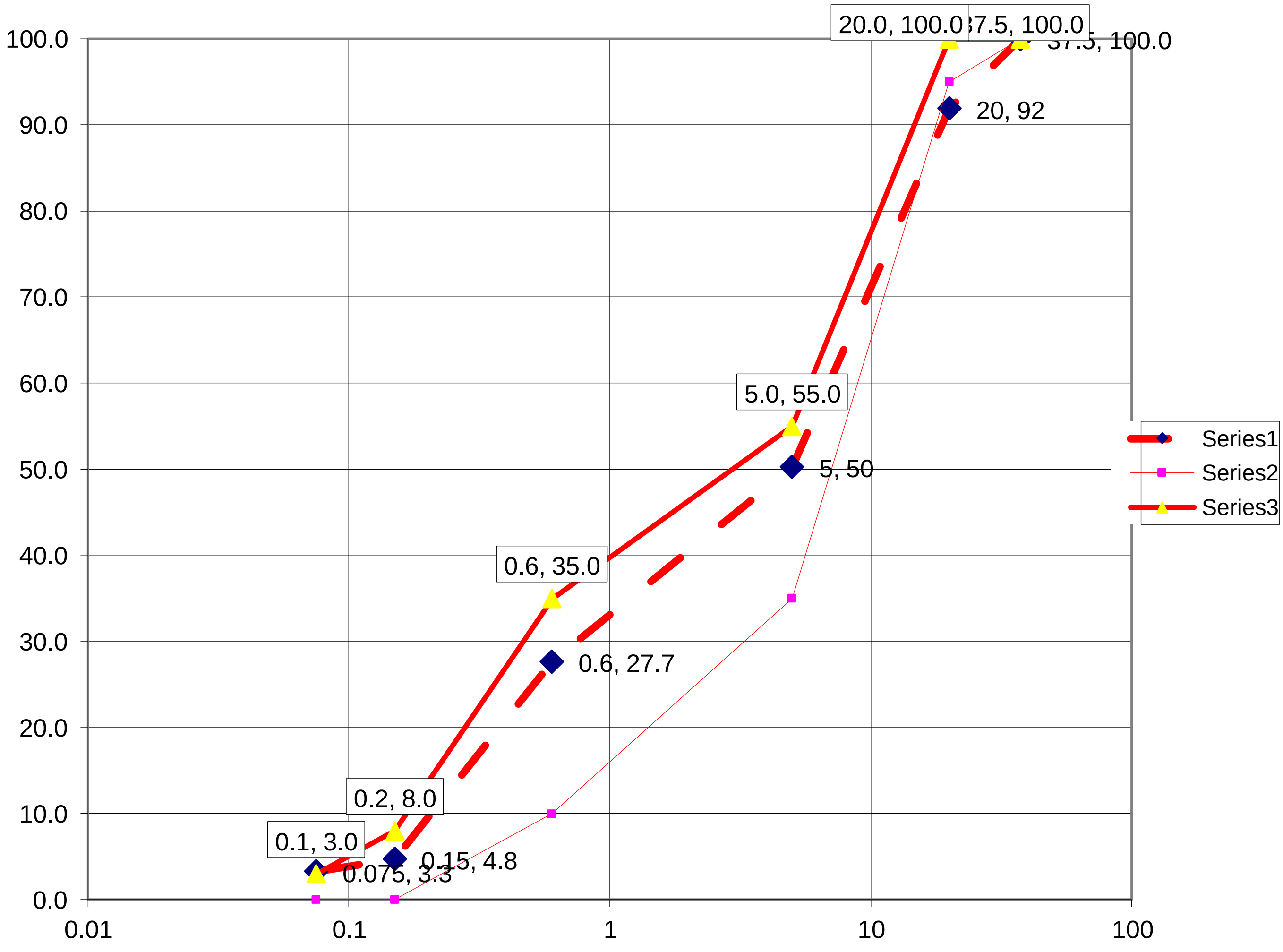
Material Name Size	Jozeh Coarse	Fouleyha Coarse	Hemseah Coarse	Retained Commulative Adaseyah Med	Adaseyah Med	White Sand Fine	Semsemyha Fine	Silica Sand Fine
	1	2	3	1	2	1	2	3
				TOTAL WEIGHT				
	7000	6170.6	8000	5031.1	250	2626.2	83	48
sieve size mm				Retained Commulative				
37.5	0	0	0	0	0	0	0	0
28	1000	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
20	2193.6	2193.6	13.2	13.2	0	0	0	0
14	5473.3	5473.3	152.3	152.3	0	6.6	0	0
10	6109.8	6109.8	2552.1	2552.1	50	22	0	0
4.75	6124	6124	4800.1	4800.1	200	276.6	2	0
2.36	6124.3	6124.3	4946.6	4946.6	230	712.5	10	25
1.18	6124.8	6124.8	4948.1	4948.1	230	980.8	30	30
0.6	6125.4	6125.4	4948.9	4948.9	250	1325.7	40	35
0.3	6126.7	6126.7	4956.5	4956.5	250	2119.1	60	40
0.15	6128.8	6128.8	4962.2	4962.2	250	2420.3	77	45
0.075	6130.8	6130.8	4966.9	4966.9	250	2489.7	80	45

Components	**sample1**	**sample 2**	**sample 3**	**sample 4**	**sample 5**
Coarse Agg.	485.6	485.6	485.6	485.6	485.6
Med. Agg.	485.6	485.6	485.6	485.6	485.6
Med. -Fine Agg	306.5	305.6	304.8	303.9	303.0
Silica Snad	715.3	713.2	711.1	709.0	706.9
Cement	261	261	261	261	261
Water (Net)	148.8	148.8	148.8	148.8	148.8
Water (Total)	180.0	179.0	178.0	177.9	177.3
Structuro 520 (%)	0	0.5	1.0	1.5	2
W/C	0.57	0.57	0.57	0.57	0.57

JS 96 Requirements for Gradation of Aggregaate for concrete mixes



Aggregates from natural sources for concrete BS 882



Results summarize

Results	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Fouleyha	485.6	485.6	485.6	485.6	485.6
Adaseyah	485.6	485.6	485.6	485.6	485.6
Semsemyha	306.5	305.6	304.8	303.9	303.0
Silica Sand	715.3	713.2	711.1	709.0	706.9
Cement	261	261	261	261	261
Water (Net)	148.8	148.8	148.8	148.8	148.8
Water (Total)	180.0	179.0	178.0	177.9	177.3
Structuro 520 (%)	0	0.5	1.0	1.5	2
W/C	0.57	0.57	0.57	0.57	0.57
		Concrete Properties			
Slump (mm)	10	210	240	collapse	collapse
		Compressive strength (Mpa)			
7 Days (Avg.)	18.5	29.2	33.1	25.8	23.5
14 Days (Avg.)	22.3	32.6	36.2	29.4	26.7
28 Days (Avg.)	26.0	36.1	39.4	34.1	33.5
Flexture Strength (Mpa)	10.3	13.3	13.6	10.0	10.1
Water Absorption (%)	2.4	1.7	1.7	1.8	1.9

Combined Aggregate Grading

%		24.4	24.4	15.4	35.8	100	Specifications Grading Limits	
Sieve Number:		**Fouleyh**	**Adaseyeh**	**Crushed sand**	**Natural Sand**	**Combined Grading**	**JS 2065 : 2016**	
1 ½"	37.5	100	100	100	100	100.0	-	-
1"	25	100	100	100	100	100.0	98	100
¾"	20	81	100	100	100	95.4	90	100
½"	12.5	3	99	100	100	76.1	-	-
3/8"	9.5	1	47	100	100	62.9	50	90
No.4	4.75	1	5	99	99	52.1	-	-
No.8	2.36	1	0.3	44	99	42.6	23	63
No.16	1.18	1	0.3	3	96	35.2	-	-
No.30	0.6	1	0.3	3	85	31.2	-	-
No.50	0.3	1	0.3	2	46	17.1	-	-
No.100	0.15	1	0.3	2	12	4.9	-	-
No.200	0.075	0.3	0.2	1.9	4.2	1.9	0	5

NEAR EAST UNIVERSITY YAKIN DOĞU ÜNİVERSİTESİ

REF: 3/2022

ETHICS LETTER

TO GRADUATE SCHOOL OF APPLIED SCIENCES

REFERENCE: **MOATH ALHUSBAN *(*20194240*)***

I would like to inform you that the above candidate is one of our postgraduate students in the Civil Engineering department he is taking a thesis under my supervision and the thesis entailed: **EVALUATION OF THE MECHANICAL PROPERTIES OF CONCRETE MODIFIED WITH POLYMER**. The data used in his study was our data obtained from experimental work conducted by a student in Jordan.

Please do not hesitate to contact me if you have any further queries or questions.

Thank you very much indeed.

Best Regards,

Assoc. Prof. Dr. Shaban Ismael Albrka Ali

Student's Supervisor & Head of Transportation Unit
Civil Engineering Department,
Faculty of Civil and Environmental Engineering,
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