Experimental Study on the effects of waste engine oil as superplasticizer on the properties of High strength concrete

Ashete Kafani Bulto

A thesis submitted to Department of Civil Engineering

School of Civil engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Construction engineering and Management

Office of Graduate Studies

Adama Science and Technology University

June, 2022

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Declaration

I hereby declare that this Master Thesis entitled **"Experimental study on the effects of waste engine oil as superplasticizer on properties of high strength concrete"** is my original work, That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation

Ashete Kafani Bulto

____________________ ____________ ___________

Name of the student Signature Date

Recommendation of Advisor

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled **"Experimental study on the effects of waste engine oil as superplasticizer on properties of High strength concrete"** prepared under my guidance by Ashete Kafani Bulto submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Construction engineering and Management. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Bahiru Bewket (PhD)

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Major Advisor/ Supervisor Signature Date

Approval page

I, the advisors of the thesis entitled **“Experimental Study on the effects of waste engine oil as superplasticizer on properties of high strength concrete”** and developed by Ashete Kafani hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Bahiru Bewket (PhD)

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We, the undersigned, members of the Board of Reviewers of thesis by Ashete Kafani Bulto have read and evaluated the thesis entitled **"Experimental Study on the effects of waste engine oil as superplasticizer on properties of high strength concrete"** and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Construction engineering and Management

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Abstract

Using industrial wastes or by-products as raw materials in cement and concrete is a common practice in modern building. This research was deals with the effects of waste engine oil as superplasticizer on properties of high strength concrete like workability, compaction factor, strength, durability and microstructure. Four mixes were used as 1% Superplasticizer, 1% of used engine oil, 2% superplasticizer and 2% used engine oil from weight of cement in kg. The test conducted were slump test, compaction factor, compressive strength test, split tensile strength test, water absorption, ultrasonic pulse velocity and scanning electron microscopy analysis. From total 72 concrete samples, 48 were cubes and 24 were cylindrical samples. The results of this research for workability tests show as the mix of used engine oil show less slump value when compared to control but it is in the range of 25-50mm which was designed value. Mix with addition of 1% of used engine perform higher compressive strength than control at 28 curing days, thus at 2% compressive strength decreased from control by 5%. The same things occurred for split tensile strength. At addition of 1%, the mix with used engine oil improves split tensile strength by 2.08%. From second control the mix perform less strength decreased by 15.5%.This due to different minerals in used engine which can affect the hydration of cement. Water absorption and UPV tests were prove that less water absorption and high UPV resulted for the higher compressive strength which is accepted by engineering properties of concrete. Used engine oil show the positive effect on the hydration products at optimum dosage of 1% from weight of cement in kg. Beyond optimum dosage, the sulphate and calcium sulphate in this by product would cause the expansive ettringite.

Key words: *Superplasticizer, Engine oil, hardened properties, microstructure, high strength, ettringite, ultrasonic pulse velocity*

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Lists of Acronyms

ACI	American Concrete Institute
ASTM	American Standard for Testing Material
DUEO	Diesel used Engine Oil
ITZ	Interfacial Tension Zone
OCS	Oil Contaminated Sand
OPC	Ordinary Portland cement
PUEO	Petrol Used Engine Oil
RHA	Rice Husk Ash
SEM	Scanning Electron Microscopy
SF	Silica Fume
SP	Superplasticizer
UEO	Used Engine Oil
XRD	X-ray Diffraction

CHAPTER ONE

1. INTRODUCTION

1.1 Background of the Study

The wide use of concrete in construction has significantly impacted energy use and environmental quality. Fortunately, finding alternatives like recycle waste materials would offer great opportunities for sustainability of concrete (Jin et al., 2015).Globally improper disposal of waste leads to environmental deprecation. Adding waste to concrete would make safe and cheap means of industrial waste disposal. In today world recycling and reusing waste materials is gaining attention. Because rapid increase in population and development has resulted in vast quantities of waste materials which are lead to continuous challenge to dispose such big wastes. Used engine Oil is one of industrial wastes which can be used as concrete admixture to improve the fresh and hardened properties of concrete (Okashah et al., 2020). It was reported that less than 45 % of used engine oil is collected and recycled worldwide while the other 55% is in environment which is goes to rivers, lakes and sea to pollute these natural resources (Varghes & sakaria, 2017). A gallon of used engine oil has the power to pollute a million gallons of water (Beddu et al., 2016).

Concrete industry has considered as recycling industrial products as concrete admixture in order to produce high quality and more sustainable construction material. Research conducted in India said that, addition of waste engine oil to concrete will give the same properties with adding air entraining admixture to concrete (Varghes & sakaria, 2017). As shown in this research result, used engine oil is a good alternatives material as superplasticizer without affecting workability and strength of concrete to solve the problem of the higher cost of superplasticizer and efficiently utilize engine oil waste to decrease the impact of environmental issues. Other research was conducted in Malaysia on the effects of recycle used engine oil on properties of fresh and hardened concrete (Shafiq et al., 2018). The result generalize as small dosage of used engine oil caused a substantial reduction in coefficient of oxygen permeability and porosity of all concrete mixes, which is an indicator of enhanced long term durability of concrete. But variations of compressive strength in the range of ±20% were caused compare to the control mix at 28, 56 and 180 curing days. Chemical composition of used engine oil showed the presence of 37% SO_3 content that may be the reason for the plasticizing effect on concrete property.

One of the important characteristics of concrete is excellent flowability for easier handling and placing which facilitates the removal of unwanted air voids by introducing superplasticizer (SP). But, the waste during production of SP results in environmental problems. Consequently used engine oil was initiated as an alternative that has the same as superplasticizer. Research has shown that while improving concrete properties UEO can mitigate the problems of higher production and direct cost of superplasticizer (Beddu et al., 2016).This research investigation reveals, used engine oil decreases the concrete porosity and comparable with SP. Concrete durability could be improved as chloride penetration test results illustrate.

A study was conducted in Libya by Alsadey, (2018) to evaluate the workability and strength properties of concrete using waste motor oil as an admixture for concrete structures. The cost of safe disposal of industrial waste is significantly higher and strict environmental regulations apply, which has a positive impact on the environment. However, the tests investigated are the slump test and the compressive strength test. Finally, the researchers found that as workability was improved. The compressive strength of concrete decreased with increasing used motor oil in the composition. To improve the workability of concrete compositions, used motor oil is a good additive to the composition.

Research conducted in Ethiopia has displayed, high performance water reducing agents play an important role in achieving better physical properties and quality of concrete and solving problems under undesired conditions during concrete work. Despite these facts, overdose of SP has been shown to degrade concrete properties, suggesting a decrease in compressive strength and an increase in porosity due to bleeding and segregation (Mamo, 2020). Ethiopia is one of developing countries in which number of vehicles increase yearly. The increment of vehicles and other machines lead to high quantity of used motor oil in environment which absolutely causes the heath problem and environmental disturbance if not recycled. Researches show as waste engine oil can be used as a superplasticizer for concrete production in their investigation. This paper was conducted a detailed investigation on the effects of using waste motor oil as a superplasticizer on properties of concrete. Quantities of waste engine oil is became increase with the increments of vehicles number yearly.

1.2 Statement of Problem

Waste generation is one of the main problems facing the modern world (Bast et al., 2021). A large amount of this waste can be used for concrete production. It is common to see that huge amount of used engine oil is simply drained to the ground in Ethiopian towns and cities. The experiences of the researcher indicate that used engine oils are drained on road which results in environmental pollution and loss of benefit (Tilahun et al., 2019). According to the ministry of transport report at last fiscal year on july,2020 the total 1,200,110 number of vehicles have been registered nationally. The last report of this ministry shows as the number of cars increase annually. From these numbers of existing vehicles 60% of vehicles are light automobiles which consume four liters of oil per each service. The next 25% are middle size which consume in average seven liters of oil per each service. The others are trucks, machines and gensets which take fifteen liters of oil on average per service (Tilahun et al., 2019). From these data average consumptions is six liters per service per vehicle. In average each vehicles serviced ones in three month. Therefore the annual oil consumption is 28,802,640 liters which annually disposed from vehicles engine. The chemical composition of used engine oil like sulfide (SO_3) (Shafiq et al., 2018),initiate the researcher to use as superplasticizer for concrete production. The effects of others compounds like calcium oxide and iron oxide in used engine oil need investigation. In foreign country research was conducted by (Noori Hussein Alhashimi, 2015; D. Singh & Kansal, 2016; Varghes & sakaria, 2017; Yaphary et al., 2020), investigate the effects of used engine oil on workability, air content, setting times, strengths, drying shrinkage, and durability of concrete. Similar study revealed the effects of waste engine oil on compressive, flexural and tensile strength of concrete by replacing various percentage of water by used engine oil (Satyaprakash et al., 2021). There is a gap on investigation of microstructure of concrete when used engine oil used as high range water reducer.

1.3 Objectives of the Study

1.3.1 General Objective of the Study

To evaluate the effect of used engine oil as superplasticizer on the properties of high strength concrete

1.3.2 Specific objectives of the Study

1. To Evaluate the effects of used engine oil on workability and compaction factor of concrete compared to commercial superplasticizer
2. To analyze the effects of used engine oil on Strength and durability of concrete
3. To analyses the hydration products of concrete mixed with used engine oil after 28 curing days by scanning electron microscopy

1.4 Research Questions

The research will answer the questions raised as follow:

1. What are the effects of using waste engine oil as commercial superplasticizer on workability and compaction factor of concrete?
2. What are the changes on strength and durability of concrete when UEO utilized as concrete admixture?
3. Does internal structure of concrete affected when waste engine oil used as superplasticizer?

1.5 Significance of the Study

This paper was provided the results of the experimental investigation on the characteristic properties of concrete in its fresh and hardened state using UEO as superplasticizer. This experimental program would help to identify the main differences, similarities and behavior of fresh and hardened properties of concrete made with UEO and with that made of commercial superplasticizer. Research study was done to support and prove that the used engine oil can be used as an alternative to superplasticizer. Thus solving the problems of higher cost of superplasticizer, leading to the efficient utilization of hazardous waste like used engine oil which causes severe environmental issues.

1.6 Scope of the Study

The scope of this research is experimental investigation on the effects of waste engine oil as superplasticizer on properties of concrete. Materials are ordinary Portland cement; class 42.5N. High range water reducer type F and waste engine oil from car service house was used for this research. Aggregates and water was taken as the standards and concrete mix was prepared as per ACI standards. Three samples were taken from each test. Tests conducted for this research are Slump test, compaction factor, compressive strength test, split tensile test and after 28 curing days the chemical analysis was done by SEM machine, water absorption test, Ultrasonic pulse velocity test was conducted

1.7 Limitation of the study

This research have limitations in terms of the laboratory instruments like XRF (x ray fluorescence) which is used for characterization of the liquid by illustrating the oxide type and percentages available in the sample. SEM-EDX for microstructure of concrete to identify the quantities of hydration products in percentage is more preferred than SEM. Absence of both instruments limit the depth of investigations.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Introduction

Building and infrastructure construction plays a central role in this historical of urbanization and industrialization by creating living and working spaces and contributing to the national economy. However, construction activities such as the manufacture of related building materials can have significant ecological implications (Yaphary et al., 2020). Waste materials with big fractions have been carried out in the road or building tasks (Toghroli et al., 2018).

Environmental problems associated with the disposal of various wastes have risen to a level of concern. Local industries generate large amounts of different types of waste each year. Therefore, the demand for more sustainable development makes green buildings even more significant. In recent years, extensive research has been conducted to recycle waste for use in the manufacture of concrete products (Meng et al., 2018).

Recently, there has been a growing interest in using more environmentally friendly technologies. Much waste is used instead of commercial materials. Solid or liquid based industrial waste and by products are available in large quantities worldwide. Environmental agencies in most countries have laws and regulations regarding the safe handling or disposal of waste. However, such waste is illegally disposed of in large quantities and can cause serious environmental problems. Some waste can be used as chemical admixtures and additives that can change the freshness and hardening properties of concrete (Satyaprakash et al., 2021). Engine oil is a need for every engine operating, and after a period of time this oil needs to be changed so we have a waste product called used engine oil (Khatib et al., 2021).

2.2 Concrete Admixture

Admixture is material added during the mixing process of concrete in small quantities related to the mass of cementitious binder to modify the properties of fresh or hardened concrete. American standards for testing material classify the chemical admixture of concrete in to seven types. These are type A (water-reducing admixtures), type B (retarding admixtures), type C (Accelerating admixtures), type D (water-reducing and retarding admixtures), type E (water-reducing and accelerating admixtures), type F (water-reducing, high range admixtures), and type G (water-reducing, high range, and retarding). Currently, the ready mix concrete industry produces more than 70% of all in-situ concrete in the globe. Chemical additive (Superplasticizer) is used by these concrete producers, and it is easily available from a variety of suppliers. This additive is always used to improve the workability of concrete and reduce the amount of water added to the mix. As a result, its strength has increased. This is a sort of water reducer that reduces the amount of water used in the concrete mix significantly. When superplasticizer is used in concrete, it improves the workability of the concrete while maintaining the cement content; it improves the placement and compacting of the concrete; it reduces the amount of water used in the concrete mix, increasing its strength; and it also designs a normal strength and workability with less cement content (Dawood, 2020). Additionally, the application of superplasticizer has a good impact on both the fresh and hardened qualities of concrete.

The research was conducted on two chemically different poly carboxylate-based superplasticizer by Govin et al., (2019) to improve concrete properties. It became proven that the rheological residences are strongly modified by the addition of the two forms of admixtures. Despite the advent of the hydroxypropyl guars, the relative viscosity of the cement pastes reduced whilst the dosage in polycarboxylate-based superplasticizer increases. However, the residual viscosity is higher than with polycarboxylate-based superplasticizer on my own. This may be the result of the boom in awareness of the non-adsorbed HPG coils in the aqueous phase due to the reduction in adsorption. The aggregate of polycarboxylate-based superplasticizer with hydroxypropyl guars allows maintaining a sizeable yield pressure to the cement paste in evaluation to polycarboxylate-based superplasticizer.

2.3 Dosage of Concrete admixtures

Research by Ma, (2020) in Hubei, China was conducted on effect of aliphatic-based superplasticizer on rheological performance of cement paste plasticized by polycarboxylate superplasticizer. In real exercise, the addition of aliphatic superplasticizer has been advanced as a not unusual manner to alleviate the bleeding and segregation of concrete plasticized by way of PCE, even as the main reason for this phenomenon isn't always clear. In the studies, the effect of aliphatic superplasticizer on dispersion of Polycarboxylate superplasticizer was investigated. Adsorption conduct of aliphatic superplasticizer and Polycarboxylate superplasticizer and conformation of those polymers in liquid section had been analyzed with total organic carbon (TOC), conductivity, and dynamic mild scattering. Finally, molecular dynamics modeling was used to confirm the experimental results, and dispersion models were proposed to better understand the mechanism. The results revealed that the effects of aliphatic superplasticizer on the rheological performance of cement paste containing Polycarboxylate superplasticizer were closely related to the additional dosage, and that three stages were divided in accordance with the aliphatic superplasticizer dosage. The primary reason for this alteration was due to competing adsorption between aliphatic and polycarboxylate superplasticizer. Furthermore, Polycarboxylate superplasticizer molecules that existed inside the liquid section due to aggressive adsorption would be cross linked via calcium ions in pore solution, resulting in an increase in cement paste plastic viscosity despite the lower yield strain. These results demonstrated why aliphatic superplasticizer should be added to the Polycarboxylate superplasticizer system to improve bleeding and segregation resistance. These results could be beneficial in the application of a few superplasticizer systems in practical engineering.

2.4 Types of concrete

2.4.1 Normal Strength Concrete

The concrete that is obtained by mixing the basic ingredients cement, water and aggregate will give normal strength concrete. The strength of this type of concrete varies from 10MPa to 40MPa. The normal strength concrete has an initial setting time of 30 to 90 min that depend on the cement properties and the weather conditions of the construction site (Jimma, 2014).

2.4.2 Plain Concrete

The plain concrete will have no reinforcement in it. The main constituents are the cement, aggregates, and water. Most commonly used mix design is 1:2:4 which is the normal mix design. The density of the plain concrete will vary between 2200 and 2500 Kg/m^3. The compressive strength is 200 to 500 kg/cm^2. These types of concrete are mainly used in the construction of the pavements and the buildings, especially in areas where there is less demand of high tensile strength. The durability given by this type of concrete is satisfactory to high extent (Çomak, 2018).

2.4.3 Reinforced Concrete

The reinforced cement concrete is defined as the concrete to which reinforcement is introduced to bear the tensile strength. Plain concrete is weak in tension and good in compression. Hence the placement of reinforcement will take up the responsibility of bearing the tensile stresses. R.C.C works with the combined action of the plain concrete and the reinforcement. The steel reinforcement used in the concrete can be in the form of rods, bars or in the form of meshes. Now fibers are also developed as reinforcement. Fiber reinforced concrete are concrete that use fibers (steel fibers) as reinforcement for the concrete. Use of meshes in concrete will give Ferro cement. Whatever be the type of reinforcement used in concrete, it is very necessary to ensure proper bond between the concrete and the reinforcement (Arooj et al., 2021). This bond will control the strength and the durability factors of the concrete

2.4.4 Pre-stressed Concrete

Most of the mega concrete projects are carried out through pre stressed concrete units. This is a special technique in which the bars or the tendons used in the concrete are stressed before the actual service load application. During the mixing and the placing of the concrete, these tensioned bars placed firmly and held from each end of the structural unit. Once the concrete sets and harden, the structural unit will be put in compression. This phenomenon of pre stressing will make the lower section of the concrete member to be stronger against the tension. The process of pre stressing will require heavy equipment and labor skill (jacks and equipment for tensioning). Hence the pre stressing units are made at site and assembled at site. These are used in the application of bridges, heavy loaded structures, and roof with longer spans(Kumbár et al., 2017)

2.4.5 Ready Mix Concrete

The concrete that mix and bathed in a central mixing plant is called as ready-mix concrete. The mixed concrete is brought to the site with the help of a truck-mounted transit mixer. This once reached in the site can be used directly without any further treatment. The ready-mix concrete is very precise and specialty concrete can be developed based on the specification with utmost quality. The manufacture of these concrete will require a centralized mixing plant. These plants will be located at an adjustable distance from the construction site. If the transportation is too long then it will result in setting of concrete. Such issues of time delay are copes up with the use retarding agents that delays the setting(S. B. Singh et al., 2015).

2.4.6 Lightweight Concrete

Concrete that have a density lesser than 1920kg/m^3 will be categorized as lightweight concrete. The use of lightweight aggregates in concrete design will give us lightweight aggregates. Aggregates are the important element that contributes to the density of the concrete. The examples of light weight aggregates are the pumice, perlites, and scoria. The light weight concrete is applied for the protection of the steel structures and also used for the construction of the long span bridge decks. These are also used for the construction of the building blocks(Jhatial et al., 2018)

2.4.7 Polymer Concrete

When compared with the conventional concrete, in polymer concrete the aggregates will be bound with the polymer instead of cement. The production of polymer concrete will help in the reduction of volume of voids in the aggregate. This will hence reduce the amount of polymer that is necessary to bind the aggregates used. Hence the aggregates are graded and mixed accordingly to achieve minimum voids hence maximum density. Polymer concrete used for repair of structure, under water and marine construction, rehabilitation of dams and other important hydraulic structures and has a great potential as a structural material(Joni et al., 2019).

2.4.8 High Strength Concrete

The concretes that have strength greater than 40MPa can be termed as high strength concrete. High strength concrete has been commonly used because most of the rheological, mechanical and durability properties of these materials are better than those of conventional concretes(Salem et al., 2016). The calcium hydroxide crystals that are the major concern product during hydration for the strength properties is reduced by the incorporation of silica fume. In terms of performance, the high strength concrete ought to be less performing in terms of workability which is an issue. High-strength concrete is achieved at low water to cement ratio which is obtained by adding water reducing plasticizer or high range water reducing plasticizer. It is also essential to select a high quality Portland cement, and optimize aggregates, then optimize the combination of materials by varying the proportions of cement, water, aggregates, and admixtures. Applications of high strength concrete are in high rise buildings, bridges with long spans, and high load carrying buildings built on weak soil.

2.4.9 High performance concrete

High-performance concrete is defined as a concrete that meets special combination of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practice. However, high strength concrete is defined as concrete that has a compressive strength of 55MPa or higher, as per ACI Code (Xue et al., 2020).

The use of high-performance concrete has overcome many problems observed in conventional concrete like less durability, weaker transition zone (aggregate-cement interface), low resistance to chemical attack and difficulty in repair and retrofitting works. High strength concrete has been used in the construction of many structures to decrease the size of members, reduce dead load, and decline cost and construction materials. Applications of high performance concrete are in high rise structures, bridge, highway pavement, hydro power structures. High performance concrete is produced by careful selection of raw materials such chemical admixtures and appropriate mix design to achieve the desired performance objectives (Azmee & Shafiq, 2018).

2.4.10 Self-Consolidated Concrete

Self-consolidating concrete is an exciting technology that has found many successful applications (F. Yang, 2004). The concrete mix when placed will compact by its own weight is regarded as self-consolidated concrete. No vibration must be provided for the same separately. This mix has a higher workability. The slump value will be between 650mm and 750mm. This concrete due to its higher workability is also called as flowing concrete. The areas where there is thick reinforcement, self-consolidating concrete works best. The additions of fibers were improved hardened properties and observed to be more in self-consolidated concrete (Ahmad, 2018).

2.5 Effects of Admixture on Fresh and hardened properties of concrete

The concrete industry is considering recycling industrial by products as a concrete additive to produce higher quality and more sustainable building materials. In the previous studies, several methods have been proposed to improve the sustainability and durability performance of concrete. Water reducing agents are the most widely used admixtures in the concrete industry, especially in ready mix concrete. The effectiveness and outcome of the use of additives depends on the type of cement, the brand of cement, the particle size of the aggregate, the mixing ratio and the concentration of the mixture. The mixture can affect multiple properties of concrete. Multiple mixtures may be used in the same mixture, or the mixture may adversely affect the desired properties of concrete. Therefore, the choice of admixture should be made carefully (Varghes & sakaria, 2017).

By means of Abousnina et al., (2020), the use of oil contaminated sand (OCS) in concrete is considered a very sustainable solution and cost effective recycling method for minimizing its negative effect to the environment. The study investigated mechanical properties, strength development, hydration, and microstructure of cement mortar containing oil contaminated sand. Parameters examined in the study were degree of oil contamination, mixing method, water cement ratio (w/c), and hardening age. The microstructural, physical and mechanical properties of the cured sample and the strength development pattern of cement mortar containing oil contaminated sand were assessed up to 365 days. The results show that the presence of crude oil up to 4%, improves the properties of the mortar compared to the uncontaminated sample. The strength of cement mortar containing sand contaminated with 2% light crude oil similar to cement mortar containing uncontaminated sand after a year. However, the winning percentage is highly contaminated cement mortar with light crude oil (4-10%) is perceived to be slow in strength. The ultrastructure of the mortar, including fine sand contaminated with up to 2% oil, appeared to be very dense and it has a finer pore structure.

2.5.1 Workability of concrete

Workability means ability to quickly mix and discharge from the truck, easy flow from chute and paste stability that will reduce the drain down. Similarly, is the ability to spread, compact and finish easily (Jimma, 2014). It is measured by means of the "slump test. Many elements influence the workability of concrete, including the initial slump, cement type and amount, temperature, relative humidity, mixing requirements (total mixing time, mixer type, and mixer speed), and the presence of chemical and mineral admixtures.. The slump value increase when superplasticizer used up to 2% of weight of cement (Lateef, 2016).The results of the research by (Yaphary et al., 2020) show that as used engine oil can be used as concrete admixture. Concrete remained workable for longer duration when the dosage of admixture was increased (Mohammed et al., 2017).

When UEO up to 2% of the cement weight was utilized, the slump value increased from 100 mm to 125 mm. Effect of inducing used engine oil (UEO) into OPC mixes, as an admixture, on their initial slump and air content are illustrated by (Abdelaziz, 2015). A comparison between the effects of traditional chemical admixtures, namely, water reducer and air entraining, and UEO on these parameters was also shown. As seen from the research result the initial slump of OPC concrete increases with increasing the dosage of UEO induced in OPC mixes. The amount of increase reaches 25, 75 and 110%, compared to the corresponding of OPC made without admixture (control mix). The effect of UEO on initial slump seems to be nearly close to that obtained when a water reducing admixture was used. Thus, utilization of UEO has a beneficial role on improving the consistency of concrete.

Research conducted by Goh & Job, (2021), using replacement of cement by 20% of Metakaolin and use the different percentage of used engine oil from 0.2% to 1% of weight of cement. The workability result shows as optimum was 18mm which is greater than that of control mix recorded the slump of 10mm. This is due to the motor oil serving as a lubricant, hence reducing friction between the concrete particles. Air was also generated by the engine oil. Bubble that act as a ball bearing between the particles, allowing them to slide past one other and giving the aggregates more mobility, thus increasing the fluidity of the concrete.

In Malaysia research by Shafiq et al., (2018b), the effects of used engine oil were easily examined. Addition of 0.15% content of UEO caused an increment in the slump of all concrete mixes as compared to the measured slump of the related control mix. In case of 100% cement concrete, UEO caused about 53% increase in the slump whereas the commercially produced water reducer caused an increment of about 35%.

2.5.2 Setting time of concrete

Setting time is determined in terms of initial set and final set. These are arbitrary points between initial water-cement contact and the beginning of strength gain. The initial setting time is the time elapsed from the addition of water until the paste behaves like a liquid or plasticizer. While the final setting time refers to the time it takes for the cement paste to reach a certain hardness state and withstand a certain load(Mamo, 2020b). The vicat needle test is used for measuring setting times. The primary purpose of determining set-ting time is for quality control(Lateef, 2016). The results of Abdelaziz, (2015) affirms that UEO has a significant effect on reducing the value of setting time, where the initial setting time of OPC mixes made with 0.15, 0.30 and 0.60% UEO reach 120, 110 and 90 minutes, respectively, while the corresponding of that mix made without superplasticizer reaches 150 minutes.

2.5.3 Compactability of Concrete

Concrete with super plasticizer showed increase in compacting factor with increase in dosage. Concrete with used engine oil showed a steady increase in compacting factor with increase in dosage. Considering the compressive strength, split tensile strength, and slump value of the varying dosage of used engine oil to concrete, 0.3% of addition by weight of cement can be taken as the optimum percentage addition of used engine oil to concrete(Varghes & sakaria, 2017).

2.5.4 Compressive Strength of concrete

The compressive strength of concrete is an essential specification for any mix design procedure. Investigating the effect of UEO on the compressive strength of concrete was included in the study of Shafiq et al., (2018b). Fly ash and rice husk ash were used as partially replacement for cement. For 100% cement concrete; used engine oil caused an increase of 1.5% and 14% in the compressive strength at the age of three and seven days respectively. Whereas at 28, 90 and 180 days UEO caused an average reduction of 18% in the compressive strength as compared to the control concrete mix due to the mineral available in used engine oil.

(Zeyad & Almalki, 2020) conduct research on influence of mixing time and dosage of superplasticizer on properties of self-compacting concrete. Evidently, long mixing times decreased the compressive strength of SCC at an early test age of 7 days at 25.5, 24.9, 23, and 21.9MPa and at the sub-sequent test age of 90 days at 38.1, 37.1, 36.5, and 35.1MPa when the mixing times were 15, 30, 60, and 90 min. Thus, workability decreased, and the filling and self-compacting capabilities of self-compacting concrete were affected. Therefore, the reduced compressive strength can be due to delayed mixing and casting times, which reduces the self-compacting capacity of the concrete and thereby increases the trapped voids

2.5.5 Durability of Concrete

The durability of a concrete structure is closely associated to the permeability of the surface layer, the one that should limit the ingress of substances that can initiate or propagate possible deleterious actions (carbon dioxide, chloride, sulphate, water, oxygen, alkalis, acids, etc.).In practice, durability is determined by material choice, concrete composition, and the level of monitoring provided during placement, compaction, finishing, and curing.(Goh & Job, 2021) use Metakaolin as cement replacement and used engine oil as concrete admixture, then investigate the porosity. Two blended samples showed lower porosity in comparison with the control sample at 28 days of curing age which is 23% for using 1% of used engine from weight of cement and 20% of cement replacement by Metakaolin which is less porous than control of 27% porosity. Total porosity of concrete is an essential characteristic that affects the short and long term performance of concrete. It governs the compressive strength, establishes fluid and ion transport mechanism in concrete and most importantly the concrete durability. Low porosity of concrete indicates that it will perform better during the service life, whereas high porosity concrete usually performs poorly. Fly ash concrete and Rice Husk ash concrete was used for the research of (Shafiq et al., 2018b) by adopting used engine oil as concrete admixture. The end result of porosity check shows nice consequences for all sorts of concrete. Although at higher age, fly ash concrete confirmed higher porosity than the a 100% cement concrete, results of the UEO at the porosity of fly ash concrete are determined useful, that brought about a reduction of about 15% inside the porosity of concrete at the age of 90 and 180 days. In case of rice husk ash concrete, used engine oil dosage did now not make any extremely good exchange within the porosity of concrete at every age .The pore shape traits definitely impact the permeability of cement paste(Liu et al., 2018).

Water permeability tests can be accomplished with several strategies which include percentage of water absorption, rate of water absorption and coefficient of water absorption(Balta, 2020).

2.6 Used Engine Oil as Superplasticizer

Study in Hong Kong by Yaphary et al.,(2020), was conducted on coupling effects of admixing a used engine oil (UEO) and reducing the cement paste content on the properties of a normal strength concrete. Different tests like workability, air content, setting times, strengths, drying shrinkage, and freezing and thawing (F–T) durability) were performed. The admixed UEO can facilitate the production of concrete with 9.4% less cement content than that in the reference concrete. The study provides a basis for realizing a more economical and eco-friendly production of concrete by both reducing its cement content and admixing UEO. Similar study by Noori Hussein Alhashimi, (2015) deal on the effects of used and New engine oil on properties of concrete. Used engine oil improve concrete strength than the new one because the viscosity of new engine oil is higher than the viscosity of used engine oil, but the use of both new and used engine oil gives lower compressive strength compared with the control sample and that because engine oil will effect on the bonding of the aggregate in the concrete. But decreasing water cement ratio from 0.54 to 0.48 achieves concrete strength than control mix at 28 curing days. Compressive strength of control was 31.1Mpa, while for new and used engine oil is 32Mpa and 32.8Mpa respectively. Additionally the result of this research identified using new and used engine oil up to 0.75% by weight of cement improve the workability of concrete than control mix which is without adding engine oils. However, concrete with both oils have lower compacting factor compared to control sample and concrete. Goh & Job, (2021), investigate the effects Combination of used engine oil and Metakaolin in fresh and hardened concrete properties. This researcher prepares 36 numbers of cube samples for porosity and permeability tests. Using one percent of UEO and 20% replacement cement by Metakaolin, the lowest porosity was recorded against control sample. This is 23% porosity when the porosity of control mix is 27%.

According to Research conducted in Malaysia by (Obeta & Ohwoganohwo, 2014), two types of UEO (Petrol engine and diesel engine) and silica fume (SF) have been incorporated into the concrete to improve its properties. The two UEOs are used because they have different chemical compositions and different processes. The study includes determining the optimal amount of UEO in consideration of workability and compressive strength for 28 days. Next, 10% SF and 15% cement substitutes were added to the concrete using optimal UEO and the properties were evaluated. As a result, it was found that UEO and SF can be discarded by adding them to concrete to change or improve their properties. The results showed that the optimal DUEO and PUEO were 0.8% and 0.6% at compressive strengths of 32N/mm2 and 31N/mm2, respectively. Adding SF reduced workability by up to 17.6%, but did not significantly affect the compression factor. In addition, 10% and 15% of SF showed that the compressive strength of concrete with optimal UEO increased by 37%.

2.7 Effects of water to cement ratio on concrete properties

Water is often added to the concrete site to aid workability and finish on the job site. Additional mixing water can aid mixing and workability, but increases porosity, resulting in reduced strength and structural performance (Kim et al., 2014). L. Yang et al., (2018) concluded that due to the change in the water-cement ratio at the same age, the change in the recovery index increased significantly and thus the compressive strength of the concrete. This implies that as the cement content increases, more of the slurry hydration products fill in the voids. This results in increased concrete density contributing to higher surface hardness and compressive strength of concrete as well. The concrete strength for w/c ratio of 0.36, 0.40, and 0.45 reduced by 8.11%, 12.78%, and 17.56% respectively, at an average age when compared to the concrete strength for w/c ratio of 0.3 (Kumavat & Chandak, 2021).

Hydration positively affects the formation of porous structure in cement pastes and porous structures structural properties that positively affect the permeability of the cement paste. The resulting effect of Nano silicon oxide in refining the pore structure and improving the impermeability of cement paste is more visible, especially when the w/c ratio is lower (Liu et al., 2018). The application of internal curing to concrete is made with a low water to cement ratio, especially with w/c less than 0.30, which reduces the possibility of cracking and reduces shrinkage due to drying. With the reduction of the water/cement ratio, the efficiency of the internal curing process reduces the possibility of concrete cracking increase. This can be explained by the fact that the contribution of unplanned shrinkage to the total shrinkage increases as the w/c ratio decreases.

2.8 Microstructure of concrete contains admixture

Accepting and modeling the microstructure of concrete is essential for the development of advanced concrete science and technology. The work of Monteiro et al., (2019) provides an overview of existing experimental micro scale probes for characterizing hydrated cementitious materials, with an emphasis on new methods and their pioneering applications. Analysis of concrete microstructure, fly ash and slag addition can mitigate the adverse effects of low humidity and large temperature fluctuations on concrete microstructure and cement hydration (Guo et al., 2021). Compressive strength, fracture characteristics, SEM images, pore characteristics, and X-ray diffraction characteristics were investigated in the early stages of curing 28 days before. Result shown that the addition of fly ash and slag can improve compressive strength and fracture properties of concrete in an environment with low humidity and large temperature fluctuations.

Mechanical properties and internal microstructures of rice husk ash (RHA) concrete at five different temperatures and with different compositions were investigated by Wang et al., (2017). The phase composition and microstructure of cement at different temperatures were examined using differential scanning calorimetric analysis, X-ray diffraction, and scanning electron microscopy. The result shows the compressive strength of concrete with 20 % cement replaced by RHA is 50 % greater than that of normal concrete. This helps to apply RHA to the development of high performance concrete. Incorporating $CaCO_3$ nanoparticles into OWC mixtures enhances their mechanical properties and performance by yielding higher compressive strengths than the control mixture exhibiting relatively high early strengths and resisting the acidity (Dawood Salman et al., 2020). The results supported the notion that the $CaCO_3$ nanoparticles act not only as filler, but also as an activator to support the hydration process. The presence of $CaCO_3$ nanoparticles increases the reaction rate of tri calcium aluminate (C_3A) to form carbon aluminate complex there by increases the total hydration products and delays the formation of micro cracks, and the hydration products and consequently the compressive strength.

2.9 Literature Summary and Research gap

2.9.1 Literature summary

Different scholars are conduct investigation on the effects of used engine oil as chemical admixture on properties of concrete by using various percentage of UEO.

Table 2.1.Summary of Literature

Authors	UEO from weight of cement in (%)	Parameters studied
(Noori Hussein Alhashimi, 2015)	0.75	Workability
		Compressive strength
(D. Singh & Kansal, 2016)	0.6	Workability
		Compressive strength
		Flexural strength
(Shafiq et al., 2018)	0.15	Workability
		Compressive strength
		Durability
(Beddu et al., 2016)	0.5	Workability
		Compressive strength
		Durability
(Alsadey, 2018)	1.2	Workability
		Compressive strength
(Varghes & sakaria, 2017)	0.3	Workability
		Compressive strength
		Flexural strength
(Okashah et al., 2020)	0.8	Workability
		Compressive strength

Previous studies have revealed some properties of UEO that function as a chemical mixture. Research by (Okashah et al., 2020) examine the effects of used engine oil on concrete workability and compressive strength partially substitution of cement by silica fume up to 15% have no negative effect on both properties of concrete. Similar study by (Varghes & sakaria, 2017) Analyses the impacts of using waste engine oil as superplasticizer on slump, compaction factor, compressive strength and split tensile strength of concrete. Both scholars (Okashah et al., 2020; Varghes & sakaria, 2017) did not investigate the effect of hydration products of concrete. Dosages of discarded engine oil acts as both superplasticizer and an air entraining agent(D. Singh & Kansal, 2016).The research conclude that, workability and strength of concrete was improved. But flexural strength slightly decreased at same dosage of used engine oil. Researcher not goes further for other properties of concrete. (Naik et al., 2016) investigate the effects of UEO on microstructure of fly ash concrete. This research focused on the effects of used motor oil on the workability, strength, quality, durability and chemical properties of high strength concrete without using other additives like fly ash and silica fume in the mix design. The statically relationship between parameters was analyzed; which was not considered by other researcher in this area of study.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Introduction

This chapter comprises the research methods and design used to address the research questions and objectives. Materials used for research was clearly identified under this section.

3.2 Research design

The research approach for this research is quantitative research for numerical data type. Experimental research type was used as the design and process present graphically in figure 3.1

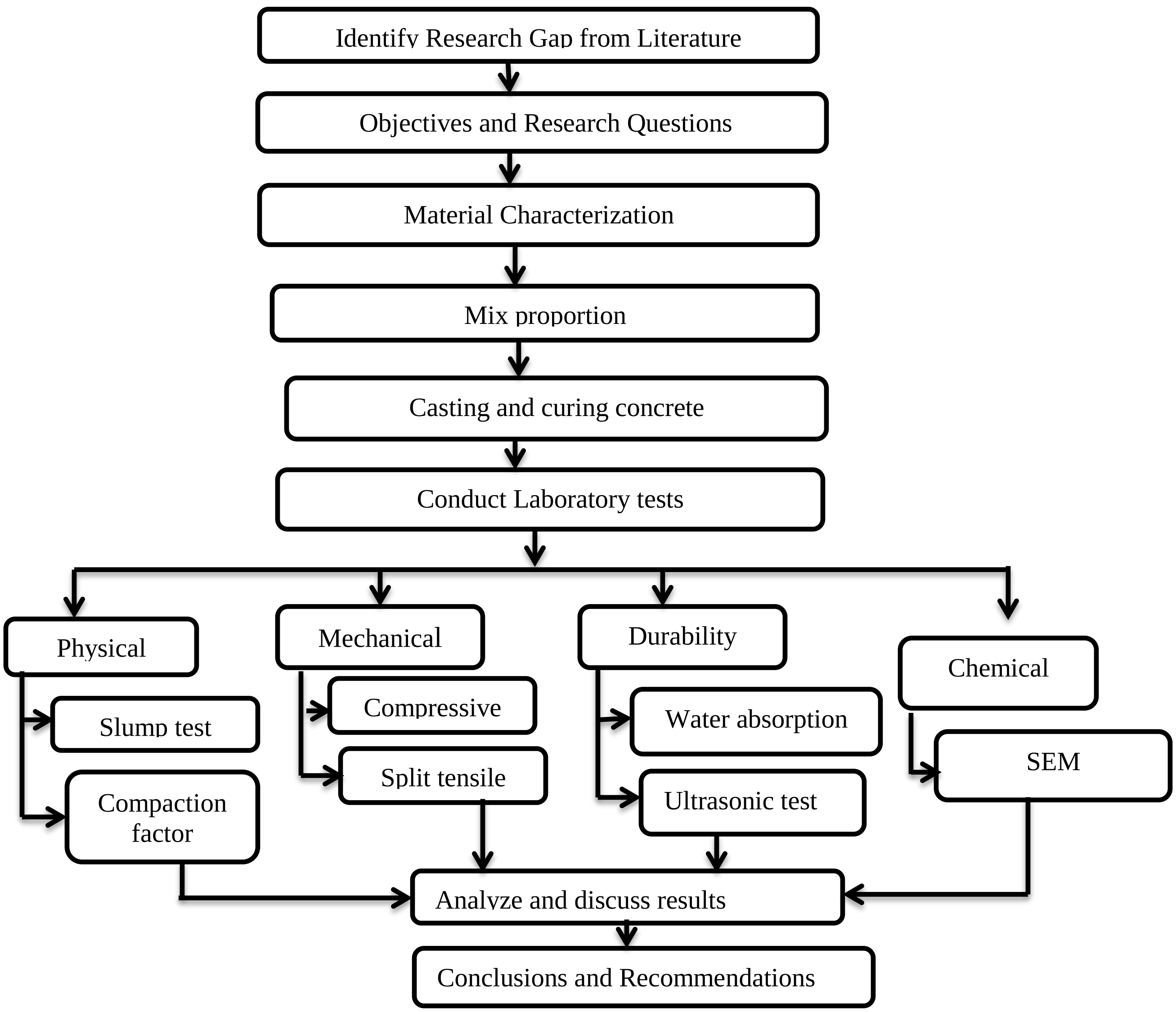


Figure 3.1 Research design skeleton

3.3 Materials Characterization

3.3.1 Cement

Ordinary Portland cement (OPC) normal hydration of grade 42.5N was used for this research. The tests conducted for cement are fineness, normal consistency, and setting time and cement soundness as per Ethiopian standards.

3.3.1.1 Fineness of cement

The fineness to which cement is ground during production can have considerable effect on behavior of cement during hydration. Rate of hydration increased with increasing fineness. Since hydration takes place at the surface of cement particles, and further hydration is hindered by formation of the reaction products, finer particle will be more completely hydrated than coarser particles. The test was taken by 50 g of sample on sieve no.100 (150micro) and the percentage of finer shall not be less than 90%.

3.3.1.2 Normal consistency of cement

The normal consistency of hydraulic cement refers to the amount of water required to make a neat paste of satisfactory workability. Cement is a finely ground powder of chemically combined argillaceous materials and calcareous materials with iron oxide, gypsum and small amount of other ingredients. When mixed with water, cement sets and hardens in to a solid mass upon hydration. It is determined by using vicat apparatus. The range of water to cement ration for normal consistency of cement is between 26% and 33%.

3.3.1.3 Soundness test of cement paste

Soundness refers to the ability of a hardened cement paste to retain its volume after setting. It is used to know the expansion of cement in mm. Unsoundness in cement result from excessive volume change after setting. The causes of unsoundness in cement are slow hydration of free lime and reaction of gypsum with tri calcium aluminate. The expansive reaction takes place slowly, and unsoundness will only appear after long time. According to Ethiopian standards, the expansion for Portland cement shall not exceed 10mm.

3.3.1.4 Setting time of cement

This test is used to determine the initial and final setting time of cement paste. The initial setting time is the duration of cement paste related to 25mm penetration of the vicat needle in to the paste in 30 seconds after it's released while the final setting time is that related to zero penetration of the vicat needle in to the paste. Ethiopian standard recommends that the initial setting time for cement not be less than 45 minutes and final setting time not be exceed 10 hours.

Figure 3.2: Vicat apparatus for setting time test of normal consistency of cement paste

3.3.2 Aggregates

Coarse aggregate was from crushed basaltic stone which meet ASTM C136 for sieve analysis, ASTM C29 for unit weight test, ASTM C128 for water absorption and moisture content. Fine aggregate was from river sand which is washed and dried before use in mix. Quality was assured by sieve analysis as per ASTM C136, water absorption and specific gravity was verified as per ASTM C127 and ASTM C128. All tests are done minimum three times to increase the accuracy of the test result.

3.3.3 Water

Water is a key ingredient in the manufacture of concrete because it reacts with the cement powder to produce hydration. Additionally, it acts as a lubricant which contributing to the workability of the fresh mixture to secure the necessary space in the paste for the development of hydration products (Mamo, 2020). Water for concrete mix should be clean and free from impurities of oils, acids, alkalis, salts, organic material or other substances that may be deleterious to concrete (Noori Hussein Alhashimi, 2015). Potable water was used for the entire work of concrete sample preparation and curing.

3.3.4 Superplasticizer

Superplasticizer is water soluble organic polymers, which have to be synthesized, using a complex polymerization process, to produce long molecules of high molecular mass, and they are therefore relatively expensive. High range water reducers are admixtures that allow large water reduction or greater flow ability without substantially slowing setting time or increasing air entrainment (Mamo, 2020). As ASTM C494 refers Type 'F' high range water reducer Muraplast SP1 formerly known as Mega flow sp1 types of superplasticizer was used for this research. Mega flow sp1 is liquid form, brown in color, specific gravity of 1.2+/-0.02 and PH value 7-9 as shown on Table 3.1. It is commercially available from lion construction chemicals PLC in Addis Ababa.

Table 3.1 Typical properties of Mega flow superplasticizer

Property	Test Method	Value
Specific Gravity	ASTM C494	1.2 +/-0.02
Component	-	Single
Form	-	Liquid
Color	-	Brown
Air Entrainment	-	Up to 1% over control mix
Chloride content	BSEN 480-10	Nil to BSEN 934-2
PH	ASTM C494	7-9

Source: Lion Construction Chemicals Manufacturer Company

Figure 3.3 Sample of Mega flow superplasticizer

3.3.5 Used Engine Oil

Used engine oil (UEO) is recognized as a hazardous waste produced during engine servicing. It was collected from locally from Adama city car service. Then functional group is identified in laboratory before use as concrete admixture. Currently, more than 28 petroleum distribution companies are licensed under the Ministry of Trade to operate fuel distribution and associated services within the country. Total Ethiopia S.C, National Oil Ethiopia (NOC), Libya oil Ethiopia (oilibya) and Yetebaberut Beherawi Petroleum are the major players in the industry by having an aggregate market share of 85.1% in the petroleum industry in Ethiopia. The sample of used engine oil was taken from vehicles after 5000 km travel. The NOC oil was used for current study because it has high demand rather than others companies as shown on Table 3.2. Sample photos were captured during laboratory work as shown on Figure 3.4.

Table 3.2 Market share of major petroleum distributing campanies in Ehiopia (Tilahun, 2020)

Name of company	Market share in percentage (%)
NOC	31.0
Oil Libya	22.1
Total Ethiopia	17.8
YBP	5.6
TAF	5.1
Gomeju	3.5

Others	14.9

Figure 3.4 Sample of used engine oil

3.3.5.1 Chemical composition

Chemical composition of used engine oil was clearly identified in the research of many authors. It was discussed by Goh & Job, (2021) that UEO has similar superplasticizer properties because of the SO_3 content. Chemical composition of used engine oil was identified as Fe_2O_3(0.43%),CaO (15.9%),SO_3 (37 %),P_2O_5**(** 8.95%),ZnO (17.7%),$C1^-$(15.9%) (Alsadey, 2018; Varghes & sakaria, 2017).The large amount of SO_3 will make it similar with commercially available superplasticizer. Used engine oil contains sulphate amount 4.15 mg/g, lead 0.45 mg/kg and PH value of 7.1 (Abdelaziz, 2015).For this study FTIR analysis was carried out to identify the functional group of used engine oil.

3.4 Methods

3.4.1 Mix Proportions

The Mix design for high strength concrete sample spacemen’s was done as per ACI 211.4R-08 guide for selecting proportions for high-strength concrete using Portland cement.

Mix Design for C-50 Grade of concrete

i. Properties of coarse aggregate

• Maximum size =19mm

• Unit weight air dry = 1,624 kg/m3

• Specific gravity = 2.88

• Absorption =0.5%

• Total moisture content=0.75%

ii. Properties of fine aggregate

• Unit weight air dry = 1,360 kg/m3

• Fineness modulus = 2.77

• Specific gravity = 2.65

• Absorption = 2.5%

• Total moisture content = 1.01%

Target mean strength at 28thday, fcr = 1.1*50+4.83 = 59.8MPA = 8,677.61psi < 12,000psi (maximum limit of ACI high strength table).

Step 1: Slump Selection

Recommended values for concrete slump are given in table 6.1 (ACI 211.4R-08). Although high strength concrete with HRWRA has been produced successfully without a measurable initial slump, an initial starting slump of 1 to 2 inch (25-50 mm) before adding HRWAR is recommended.

To meet the specified compressive strength, f ’c = 50Mpa the concrete was designed to achieve that the average compressive strength results of filed test exceed f ’c by an amount high enough to reduce the number of low test result.

The required concrete strength f ‘cr = 1.1*f ‘c +700psi

f ‘cr = 1.1*7251.9 +700psi = 8676.1psi < 9000 psi where 50Mpa = 7251.91 psi

8676.1psi = 59.82Mpa = 60Mpa

Step 2: Maximum coarse aggregate size selection

Based on the required strength, the recommended nominal maximum size of coarse aggregate is given in table 6.2.

For strength less than 9000 (62Mpa), recommended maximum size of coarse aggregate is ¾ to 1 in. (18.75mm to 25mm) without HRWRA admixture. If HRWRA is used, aggregate size greater than 12.5mm can be used but should not be greater than 25mm anyways. However, to ensure adequate strength 19 mm is selected as maximum size of aggregate.

Step 3: Optimum coarse aggregate amount selection

The optimum content of coarse aggregate depends on its strength, potential characteristics and Maximum size. The recommended coarse aggregate content are expressed as a fraction of the bulk density and given in table 6.3 as a function of nominal maximum size. And those given values are applicable for fine aggregates having a fineness modulus values from 2.5-3.2.

Once the content of coarse aggregate has been chosen from the table 6.3, the required mass of the coarse aggregate per cubic yard of concrete can be calculated by using eq. (6-1).

For this study the fineness modulus of sand is 2.77 and the VCA is become 0.72.

Therefore, mass of coarse aggregate = VCA*bulk density*27. From physical test of coarse

aggregate, the bulk density obtained is 1,624kg/m^3

. Or 1,624kg/m3*2.2lb/1kg*1m^3/35.288ft^3 = 101.25 lb/ft^3

Mass of Coarse aggregate = 0.72*101.25*27 = 1968.3 lb/yd^3 = 892.8kg the required average compressive strength. To do so, the concrete was proportioned in such manner

Step 4: Water and air content

From table 6-4, slump 1-2 inches and 19mm nominal maximum coarse aggregate size using HRWRA the first estimated water is 285 lb/yd ^{3} but Values given must be adjusted for fine aggregates with voids other than 35% using Eq. (6-3).

Mixing water amount=285lb/yd3*0.593(kg/m3)/(lb/yd3) =169.01kg/m3

Void ratio of fine aggregate, V= (1-1360/2410)*100% = 43.5%

Water requirement adjustment is (43.5-35)*4.74 = 40.29 kg/m3

Corrected mixing water amount is 169.01+40.29 = 209.3 kg/m3

Air content =2.0% when using HRWRA

Step 5: W/CM ratio selection

The w/cm is calculated by dividing the mass of the mixing water by the combined mass of the cement & (other cementitious material). In table 6.5, recommended maximum w/cm is given as a function of maximum aggregate size to achieve different compressive strength at either 28 or 56 days. The use of HRWRA generally increases the strength of concrete.

For maximum size aggregate of 19mm, and required target mean strength 59.8 Mpa or 8,677.61psi, 28^{th} day strength and using HRWRA, the w/cm can be interpolated between 9,000psi and 8,000psi with a corresponding 0.35 and 0.40 water-cement ratio. That is,

W/c = 0.3338 = 0.33

Step 6: Cementing material calculation

Cement content = 209.3/0.3338 = 627 kg/m^3

Step 7: Fine aggregate calculations

One trial mixture should be made with Portland cement as the only cementitious material. So the following steps should be followed to complete this basic mixture proportion;

Cement content: the mass of cement equals to the mass of cementitious material calculated in step 6 =627kg/m^3

FA amount = 2410 (1-2 /100-892.8 /2880 -209.3/1000-627/3150) = 626.6 kg/m3

Adjustment for moisture content and absorption of aggregate

	Coarse aggregate. (%)	Fine aggregate. (%)
Moisture content	0.75	1.01
Absorption	0.5	2.5

Weight of sand = 626.6(1+0.0101) = 632.93 kg.

Weight coarse aggregate = 892.8 (1+0.0075) = 899.5kg

Water = 202.2 +626.6(0.025-0.0101) +892.8(0.005-0.0075)

= 209.3 +626.6(0.0149) +892.8(-0.0025)

= 216.4 kg

Adjustment for contribution of superplasticizer in mixing water,

The dosage of HRWR is 0% to 3% from weight of cement from company guide line. Convert the dosage of 1% to ml per kg of cement by using specific gravity of admixture.

0.01*627=6.27kg, change to litres,6.27kg/1.2kg/lit is 5.225 liter is required for 1m^3 of concrete then change this amount to ml per kg of cement.

5225ml/627 kg=8.333ml/kg

The admixture has 80% water and 20% of solid, then adjust the water for admixture contribution.

5.225*0.8=4.18 liter, then deduct this amount from water amount

216.4-4.18=212.22 kg, when dosage is 2%, 10.45liter of admixture required for 1m^3 of concrete. When changed to ml/kg, it became 16.66ml/kg of cement. Again adjust water for contribution of HRWR contain 80% water.0.8*10.45litre=8.36liter.
216.4-8.36=208.04 kg of water required for one cubic meter of concrete.

Table 3.3 Mix proportion for C-50 grade concrete

Materials		Amount for 1m^3 of concrete
Cement		627 kg
Fine aggregate		632.93
Coarse aggregate		899.5kg
Water	1% SP	212.22 kg
	2% SP	208.04kg
Super plasticizer	1%	5.225 liter
	2%	10.45 liter
Used engine oil	1%	5.225 liter
	2%	10.45 liter

Note: 1%, 2% are calculated from weight of cement.

3.4.2 Test Specimens

Totally 48 concrete cubes of 100 × 100 × 100 mm and 24 cylinder samples were made. From the total of cubic samples 36 samples were for compressive strength test, the left 12 samples were for ultrasonic pulse and water absorption test. Cylindrical samples were prepared for split tensile strength. The mix ratio adopted for the mix was 1:1.009:1.43 Cement: fine aggregate: coarse aggregate respectively at a water/cement ratio of 0.33. For SEM analysis the sample was taken from concrete samples cured for 28days. The mix was designed to achieve a nominal 28 days concrete compressive strength of 60MPa. Mixing was carried out at a room temperature of 27 °C and at 70 % relative humidity. To obtain a homogeneous mix, the aggregates were poured in the mixer with half of the mixing water, and mixed for one minute, after which cement was added gradually and mixed for another minute. The UEO and superplasticizer was mixed with the remaining half of the water and then added to the mix and mixed for 3 minutes.

3.4.3 Test Methods for concrete mix

3.4.3.1 Slump and Compaction factor test of the concrete

The workability of the concrete sample was done using slump test. This was done in compliance per ASTM C 143 standard. A cone frustum mould of height 300 mm was used to carry out this test. The bigger opening was placed on a flat surface, and the mould filled with concrete. The filling was done in three layers, with each layer tampered 25 times with a standard 16 mm diameter rod.

The compaction of concrete was estimated by carrying out a compaction factor test. The degree of compaction is defined as the density ratio. That is, the ratio of density actually achieved in the test to the density of the same concrete fully compacted. This test is described in BS1881: Part 103 and is suitable for concrete with a maximum size of aggregate up to 40 mm. The apparatus consists essentially of two hoppers; each in the shape of frustum of a cone, and one cylinder, and they are placed above one another.

Figure 3.5 Slump and compaction factor test

3.4.3.2 Compressive Strength of the concrete

Compressive strength is the measurement of the capacity of a material to carry loads that tends to reduce its size (Alsadey, 2018). Concrete cubes were casted in standard steel moulds of dimensions 100mm x 100mm x 100mm. Concrete was pour in the moulds in 3 layers of nearly the same thickness and after laying each layer then compact. The moulds was remove after 24 hour and cubes immersed in water then compressive strength for concrete mix of grade C-50Mpa was measured at 7,14 and 28 days of curing as per ASTM standards. Three specimens need for each curing days, the results of compressive strength was the average of these three samples. Compressive strength testing machine has 3,000KN capacity and load rate of 0.5.

Figure 3.6 Compressive strength tests after 28 days

3.4.3.3 Split tensile strength of the concrete

Since concrete is brittle, it is weak in tension and can cause cracks. So it is essential to conduct the tensile strength test of concrete. It is an indirect method of testing tensile strength of concrete. Cylindrical samples with 100x200mm (diameter x height) was casted. Three samples were prepared from all mixes for each curing days and tested as per ASTM C496 and an average value is calculated. The main objectives of this test are for determining the tensile strength of concrete; provide the information on the use of sand and aggregate, to determine the uniform stress distribution and for studying the behavior of concrete.

Figure 3.7 Split tensile strength test at 28 curing days

3.4.3.4 Water Absorption of the concrete

The water absorption of concrete samples was assessed, after 28 days of curing. The concrete cubes were dried at 25^{o}C for 3hours in air and weighted. Then dry in an oven at a temperature of 100 to 110 °C for 24hour as per ASTM C642. After removing each specimen from the oven, cool in dry air to, temperature of 20 to 25 °C and mass was determined and designated by A. Then the specimens were immersed, after final drying, cooling, and determination of mass, in water at approximately 21 °C for 48 h and until two successive values of mass of the surface-dried sample at intervals of 24 h show an increase in mass of less than 0.5 % of the larger value. Surface-dry the specimen by removing surface moisture with a towel, and mass of samples were determined. The mass of samples after immersion and final surface-dry were designated by B.

$$\text{Absorption after immersion, \%} = [(B - A/)\ A] * 100$$

3.4.3.5 Ultrasonic pulse Velocity of the concrete

The ultrasonic pulse velocity test is one of the dynamic the non-destructive tests of concrete to determine the presence of cracks, voids and imperfections (Civilworld, 2021). UPV results interpret the time of travel of ultrasonic pulse waves for evaluating the concrete quality. The frequency of the Ultrasonic pulse wave was maintained on 57.7Hz from standard tool. Then apply the grease and put the transmitter at one end and receiver in another end of concrete sample. The pulse generator of the UPV tester produces the pulses and is allowed to pass through the concrete. The pulse velocity is calculated by measuring the traversing distance and divide by time of traversing which displayed in micro second. Higher velocity means the concrete has a higher elastic modulus and density. The concrete samples with UPV values above 4.5km/s are excellent concrete, while 3.5 to 4.5, 3 to 3.5 and below 3.0 in km/sec are good, medium and doubtful respectively. The results were interpreted as per Indian standard(*IS 13311-2 (1992): Method of Non-Destructive Testing of Concret-Methods of Test, Part 2: Rebound Hammer*, 1995).Calculations carried out as the following formula:

$$\mathrm{UPV} = \frac{\text{Length in (m or km)}}{\text{Time in second}}$$

Figure 3.8: Ultrasonic pulse velocity test instrument

3.4.3.6 SEM analysis for concrete

The SEM analyses are used to investigate the morphological structure of hydration products like calcium silicate hydrate, calcium hydroxide, ettringite and also the other products in image. Samples prepared from mix of 1%SP, 1%UEO, 2%SP and 2% UEO have been cured for 28days and the small piece of concrete which represent the sample was taken to Adama Science and Technology University (ASTU, Ethiopia) laboratory of biology department. The SEM scan the sample at different magnification and the results were discussed under the part of result and discussion.

3.5 Validity of samples

Using normal distribution results of compressive strength for all mix types are as shown on Figure 3.9. In order to calculate how far above the failure level the average measurement has to be in order to get a given percentage of defects, it is necessary to know the standard deviation. For the above distribution curve of compressive strength, the minimum value of compressive strength was 58.7 Mpa which is in the boundary of 95% confidence. Sample is valid and it is accepted.

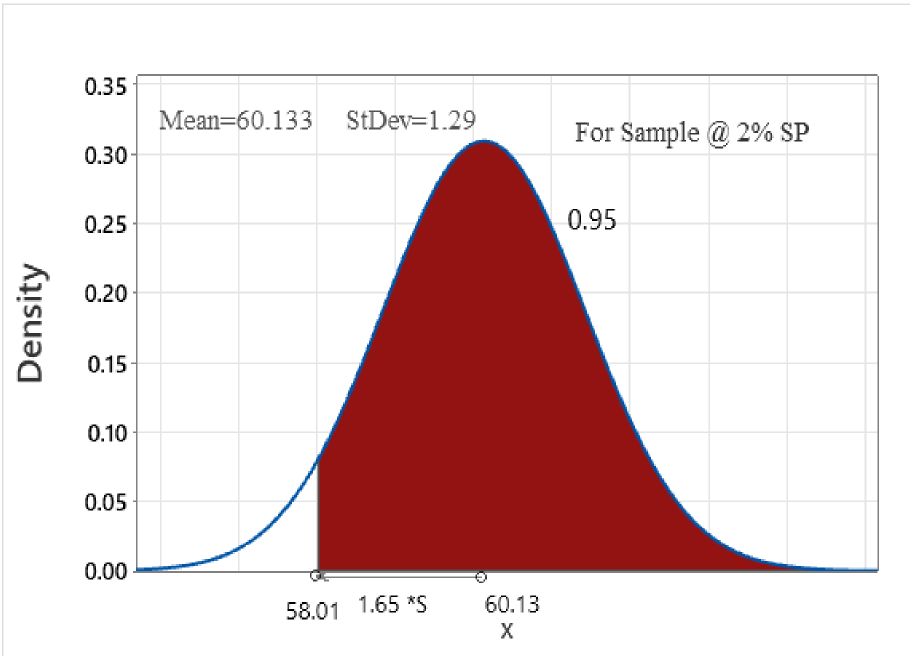


Figure 3.9 Normal Distribution curve for compressive strength of 2%SP at 28days

3.6 Data Analyze techniques

Data from laboratory results were analyzed by descriptive and inferential statistics. For descriptive data analyze mean, mode, median, standard deviation were calculated. Inferential statistics were analyzed Pearson correlation coefficient (r) to calculate the relations between concrete properties. Minitab 20, statistical software tools was used to analyze and present statistical data.

CHAPTER FOUR

4. EXPERIMENTAL RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, results obtained from the experimental activities have been presented, analyzed, and interpreted with details. The properties of materials test result used for current study and the result of workability, strength, durability and microstructure of concrete samples were discussed in this section.

4.2 Test results for cement

For OPC cement fineness test, normal consistency, soundness, setting time and specific gravity tests were conducted and result illustrate as Table 4.1

Table 4.1 Laboratory test results for OPC cement

Tests conducted		Results
Fineness test		91% finer which greater than 90%
Normal consistency		29% water from weight of cement
Soundness test		1.667mm
Setting time	Initial	86.5 min
	Final	5hr. and 15min
Specific Gravity		3.2

4.3 Sieve Analysis results for fine and coarse aggregate

In order to determine the size of fine aggregate, 500 g of fine aggregate was measured, washed and then, kept in oven drier for 24 hrs. After 24 hrs, it was removed from the oven and then, cooled by keeping in fresh air before sieving analysis takes place. As reported in Table 4.2, it was possible to observe various sieve size, weight of fine aggregate retained, and their cumulative % weight determined. The Fineness Modulus of fine aggregate was determined by summing up all the cumulative percentage retained and divided it to 100. Therefore, the fineness modulus of the aggregate used is 2.77. The Fineness Modulus figure is found in acceptable range.

Table 4.2 Seive analysis test result for fine aggregate

ASTM sieve size in (mm)	Weight retained (g)	% retained	Cumulative % retained	% cumulative passing
9.5	0	0	-	
4.75	10	2	2	98
2.36	31.6	6.32	8.32	91.68
1.18	71.6	14.32	22.64	77.36
600	165	33	55.64	44.36
300	173.3	34.66	90.3	9.7
150	40	8	98.3	1.7
Pan	8.5	1.7	100	0
		FM	2.77	

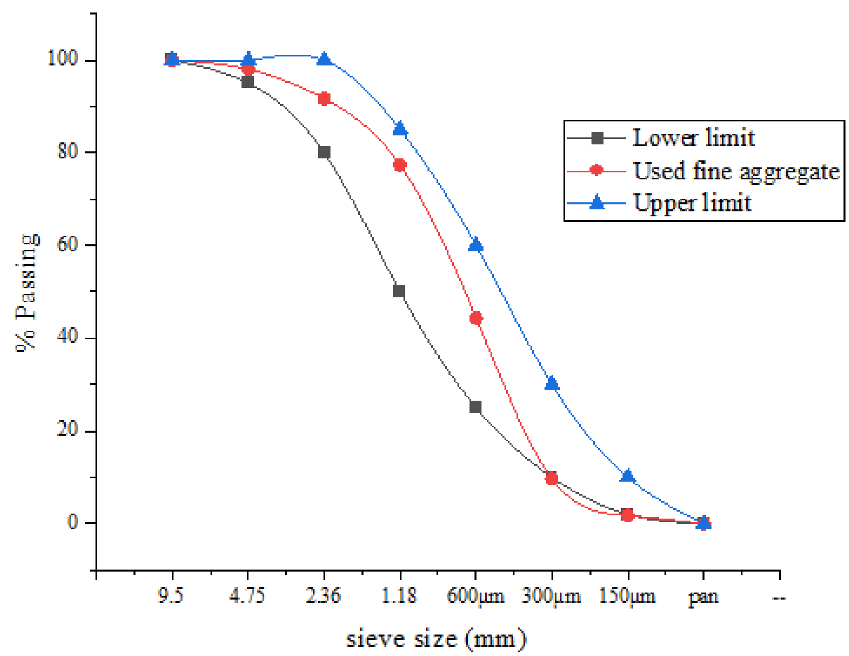


Figure 4.1 Fine aggregate gradation as ASTM C33

In order to determine the size of coarse aggregate, 2000gm of sample has been weighed, and then washed with water, and put in oven drier for 24 hrs. After 24 hrs, it has been removed and then cooled before sieving process take place with sieve sizes from 37.5 mm to 4.75 mm. The retained weight and their cumulative percentage of coarse aggregates in each sieve size found in the Table 4.3. The Fineness Modulus of coarse aggregates determined was 3.04

Table 4.3 Seive analysis test result for coarse aggregate

ASTM sieve size in (mm)	Weight retained (g)	% retained	Cumulative % retained	Cumulative % passing	ESC.D3.201
37.5	0	0	-	100	100
25	0	0	-	100	100
19	100	5	5	95	95-100
12.5	640	32	37	63	-
9.5	1060	35	72	28	25-55
4.75	360	18	90	10	0-10
Pan	200	10	100	-	-
			FM 3.04		

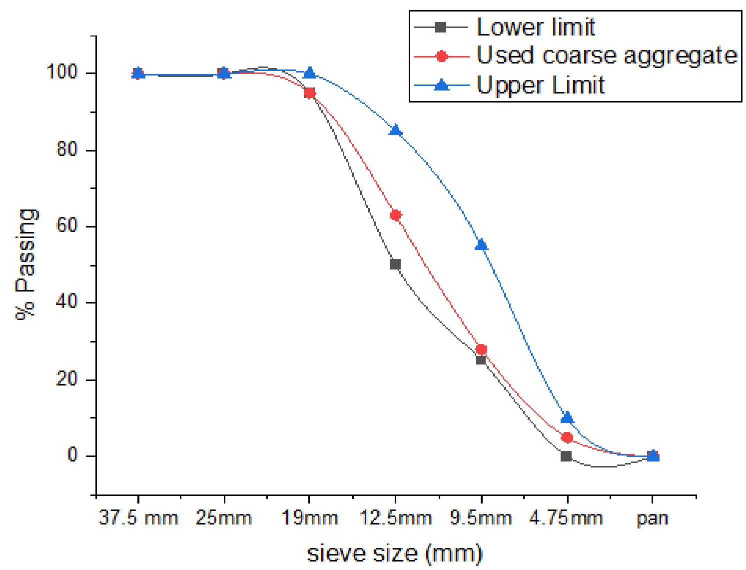


Figure 4.2 Coarse aggregate gradation as ASTM C33

Table 4.4 Summary of test conducted for fine and coarse aggregate

S/N	Tests descriptions		Test result: Fine aggregate	Test result: Coarse aggregate
1	Silt content			
2	Moisture Content		1.01	0.75
3	Unit weight	Compacted(kg/m^3)	1360	1624

		Loose (kg/m^3)	1160	1471
4	Specific Gravity	Bulk	2.65	2.88
		Bulk (SSD)	2.7	2.9
		Apparent	2.82	2.94
5	Absorption Capacity (%)		2.5	0.75
6	Fineness Modulus		2.77	3.04

For the detail calculations of table 3.4 refer Appendix A1.1-A1.3

4.4 FTIR analysis for superplasticizer

Figure 4.3 describes the FTIR spectrum of SP1 super plasticizer. The asymmetric peak of hydroxyl (–OH) stretching vibration lies in the range of 3115–3655 cm^{-1}, indicating that the absorption peak at 3358.18 cm^{-1} may be related to carboxyl (–COOH) and hydroxyl (–OH) groups. The peaks at 1117.27 and 1179.36 shows the sulfur oxy compounds group in the range of 1100-1200.Which realize superplasticizer contains the sulphate compound. 2111.79, 1179.36, and 1033.47 cm^{-1} represent the characteristic absorption of methyl and methylene groups, and the peak at 1636.04 cm^{-1} denotes the stretching vibration of –C=O– in the ester group. The characteristic absorption peak at 1117.27 cm^{-1} is also ascribed to the polyether –C–O–C– stretching vibration in mega flow superplasticizer (Xun et al., 2020)

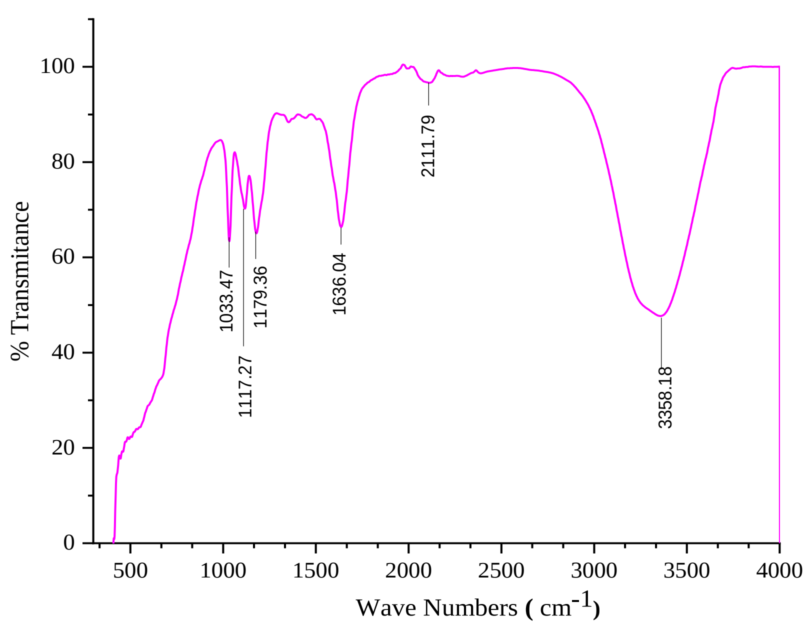


Figure 4.3 FTIR spectra for mega flow superplasticizer

4.5 Flow rate for superplasticizer

The flow rate is how much fluid passes through an area in particular time. For this research volumetric flow volume of fluid; which passes per unit time is measured. The SI unit is cubic meters per second (m^3/s).One and half liter of superplasticizer added to v funnel cone.

Flow rate=volume/time

Volume of sp1 added to funnel cone =1.5 liter

Time recorded while flow out from funnel cone which have 10mm diameter=15 second

Flow rate=1.5 l/ 15 sec=0.0015 m^3 / 15 sec

Flow rate=$1x10^{-4}$ m^3/ sec

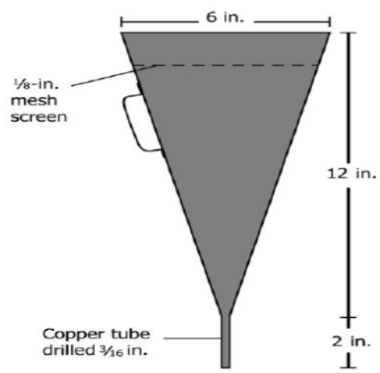


Figure 4.4 Vfuunel cone for flow rate test of superplasticizer

4.6 FTIR Analysis for used engine oil

Fourier Transform Infrared (FTIR) has been developed as a tool for the simultaneous determination of organic components, including chemical bond, as well as organic content (e.g., protein, carbohydrate, and lipid). Stretch methylene group range from wave numbers 3000-2850 cm^{-1}. Figure 4.5 show that the peak of 2918.42 and 2851.59 categorized under alkene group of stretching C-H. The finger print region (600-1500 cm^{-1}) is contain vinyl related compound and aromatic compounds. Wave numbers of 968.4cm^{-1} identify the vinyl terminals ($-CH=CH_2$). Between 965 and 960 cm^{-1} for unsaturated vinyl (CH=CH), and about 890 cm^{-1} for double olefin bonds in single vinyl ($C=CH_2$) (Nandiyanto et al., 2019).Additionally the peak 1373.66cm^{-1} show the availability of nitrate ion and organic sulphate in used engine oil. Wave number 968.14 cm^{-1} show the existence of Silicon ion in the range from 1100-900 cm^{-1}

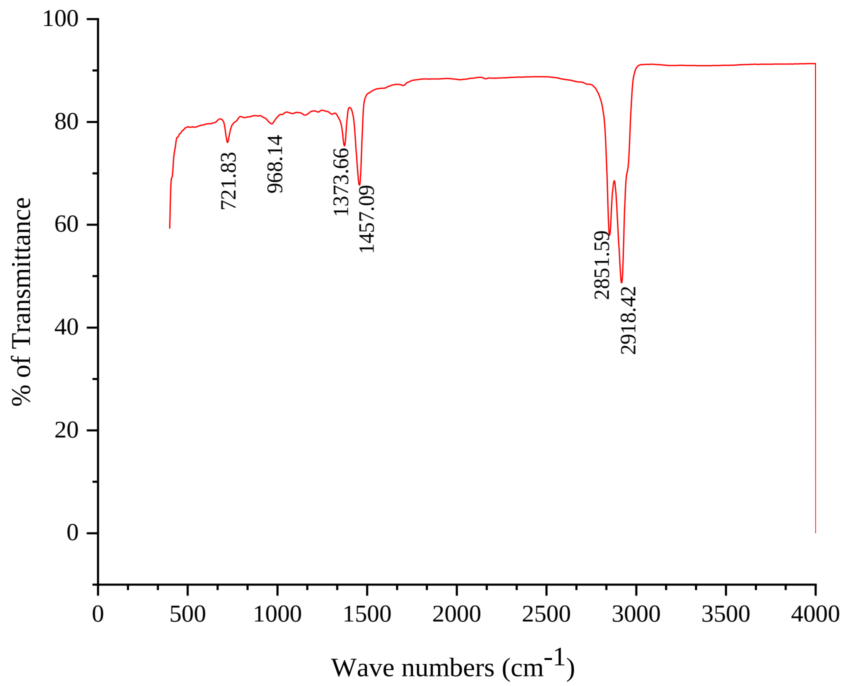


Figure 4.5 FTIR spectra for used engine oil

4.7 Flow rate test for used engine oil

For used engine oil flow rate is calculated similar as mega flow superplasticizer.

Volume of UEO added to funnel cone =1.5 liter

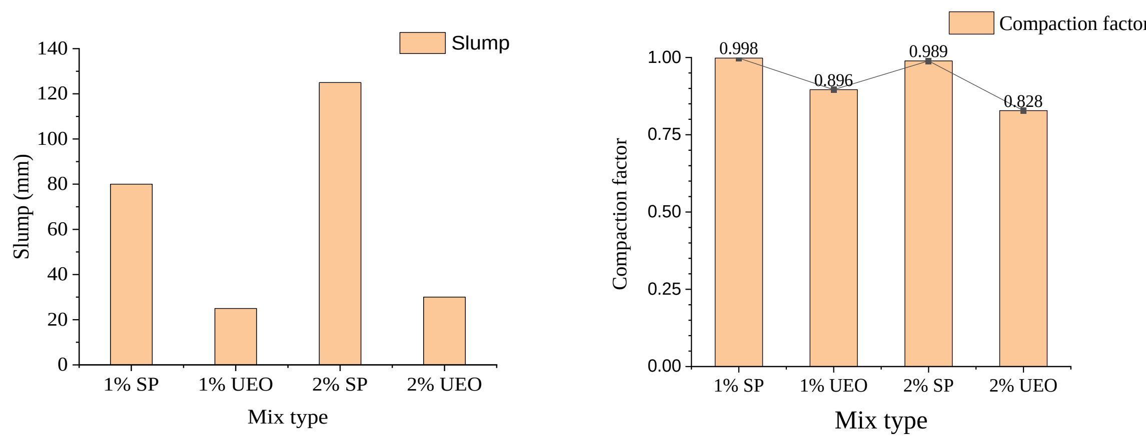
Time recorded while flow out from funnel cone which have 10mm diameter=70 second

Flow rate=1.5 lit/ 70 sec=0.0015 m^3 / 70 sec

Flow rate=2.1428x10^{-5} m^3/ sec

4.8 Workability Tests results of fresh concrete

Workability is a concrete property determining the effort required to manipulate a fresh mixed quantity of concrete with minimum loss of homogeneity. Concrete workability measured by slump test and compaction factor test as shown on Figure 4.6. The test results show that the mix with 1% of superplasticizer from weight of cement has 80mm and 0.998 slump value and compaction factor respectively. Using 1% of used engine was decreased both slump value and compaction factor to 25mm and compaction factor also decrease from 0.998 to 0.896.This is due to less flow rate of used motor oil about 2.1428×10^{-5} m^3/ sec could affect the workability of concrete when compared to control mix which is mix with superplasticizer. Admixture which is less viscous means can increase workability of concrete. Mix3 which contains 2% SP show the large slump value of 125mm.But compaction factor was not such much changed. For used engine oil the slump value was in the range of standard used in mix design for 19mm aggregate size the slump value to be 25mm-50mm as per American concrete institute. Dosage of superplasticizer up to two percent increases the slump of fresh concrete rapidly. Or consumption may cause segregation and bleeding of concrete which would be the initial cause of failures in strength and durability of concrete.



(a) (b)

Figure 4.6 Slump (a) and Compaction factor test result(b)

4.9 Compressive Strength of concrete

The compressive strength results for all mix type at 7, 14 and 28 curing days were presented as Table 4.5.

Table 4.5 Compressive strength test reult

Mix Type	Average compressive strength in Mpa		
	7days	14days	28days

M1,1%SP	32.876	45.04	62.09
M2,1%UEO	29.04	46.46	63.83
M3,2%SP	27.5	46.03	60.13
M4,2%UEO	28.95	43.456	57.63

The result shows that at early age, the concrete sample from 1% mega flow superplasticizer has 32.876Mpa at 7days.1% of used engine oil show less compressive strength when compared with the control sample which is 1% dosage of superplasticizer at early age. This result was also improved by(Yaphary et al., 2020).But at 2% dosage, the concrete sample contains used motor oil resulted in greater compressive strength than the sample from 2% of superplasticizer at 7curing days. This is because the FTIR peaks show the availability of nitrate ion in UEO which increased speed of cement hydration than the concrete from 2% of SP. The early strength of 2% SP mixes type show lower strength. This is due to the fact that carboxyl group in superplasticizer which was identified by FTIR results at the range 315-3655cm^{-1}can create complexion with ca^{+2} ions on the cement surface and resulted in hindered of early hydration. The wave numbers of 3358.18 $cm^{-}1$ indicate the carboxylic group in superplasticizer chemical admixture (Özen et al., 2020).

The result after 28 curing days reveal that 1% of used motor oil was optimum dosage in respect to the compressive strength of 63.83Mpa when compared to control which is 62.09Mpa.This result shows the enhancement of compressive strength by utilizing the UEO as high range water reducer admixture for high strength concrete is possible. At two percent dosage of used engine oil the concrete samples was start to decline. This is due to the heavy metals present in the used engine oil become active when the addition of used engine oil to concrete is increased. These heavy metals lead the problem of reducing the rate of hardening of concrete by affecting the C-S-H gel, hence decreasing the strength development of concrete. Presence of ZnO in UEO can affect hydration of cement in concrete due to the formation of amorphous layer Zn $(OH)_2$ which cover the clinker particles(Ghahari et al., 2018). This argument was supported by the research of(Varghese & Sakaria, 2017). As this research result shows increasing the dosage of superplasticizer from 1% to 2% decrease the compressive strength. This show the same insight with research result concluded by (Salem et al., 2016).

When the dosages go beyond the limit reduction of compressive strength occur. This phenomenon resulted by disruption of the cohesiveness and uniformity of the concrete. The research result of (Varghese & Sakaria, 2017) agreed with the improvement of strength when used engine oil used as superplasticizer, conclude that Ultimate load capacity and ductility ratio was increased by using used engine oil. Detail value for all sample are on Appendix C1 Table 6 for all curing days.

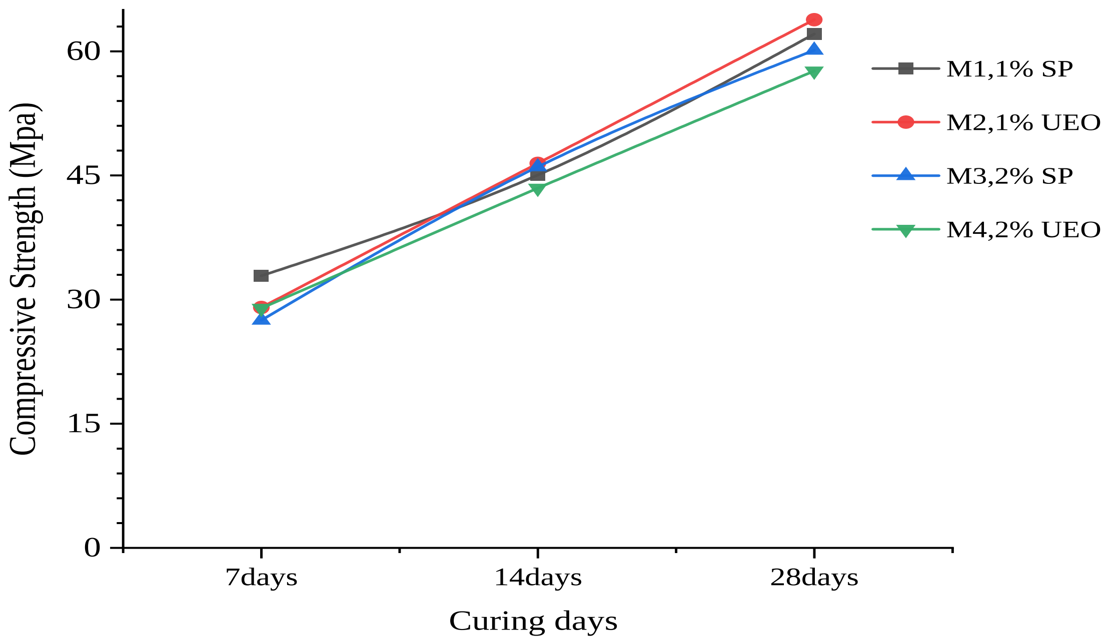


Figure 4.7 Compressive strength test results

4.10 Split Tensile Strength of concrete

The result of Split tensile strength test which was conducted on cylindrical sample was shown graphically as Figure 4.8. The results show that sample with 2% of superplasticizer show the largest split tensile strength than all mixes. At 28 curing days increasing amount of SP could improve the split tensile strength from 2.96 to 3.515 Mpa. For the concrete from used engine, as amount of oil increase the split tensile strength start to decrease and show 3.023Mpa at 1% dosage and 2.97 Mpa for 2% dosage. It is due the presence of oxides of heavy metals like ZnO and P_2O_5 in used motor oil which show similar effect with research by (Varghese & Sakaria, 2017). As split tensile strength test result 1% of used engine oil from weight of cement can be optimized as superplasticizer for high strength concrete. The result of mix with 2% UEO did not meet with the control sample of mix with 2% SP at 28 curing days. That means as the amount of used engine oil increase in the mix from one percent to two percent the split tensile strength start to decrease slightly.

Table 4.6 Split tensile strength test result

Mix Type	Average split tensile strength in Mpa	
	7days	28days
M1,1%SP	2.7525	2.96
M2,1%UEO	2.819	3.023
M3,2%SP	3.203	3.515
M4,2%UEO	1.998	2.97

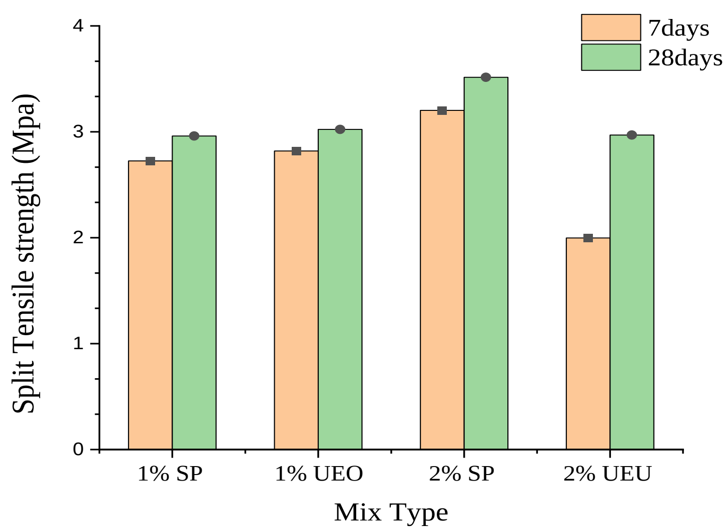


Figure 4.8 Split tensile strength test result at 7 and 28 days

4.11 Water Absorption of concrete

Water absorption test was conducted for the concrete samples produced from mega flow superplasticizer and used motor oil at 1% and 2% dosage from weight of cement as per ASTM C624. The test result revealed that the concrete produced from used engine oil absorb less percent of water when compared with the control sample which contain high range water reducer at both 1 and 2% consumption. This point out that as concrete durability can be improved by using used motor oil as superplasticizer in high strength concrete, which is similar with study of (Beddu et al., 2016b; Shafiq et al., 2018b).

Calculation:

A - Weight of oven dried sample for 24hrs

B - Weight of sample after immersion in water for 48hrs

$$\text{Absorption (\%)} = \frac{\text{B} - \text{A}}{\text{A}} * 100$$

The water absorbed in percentage by concrete sample prepared from using used engine oil at 1% and 2% are 3.696 and 4.15 respectively. Whereas for control mix at both 1 and 2% the water absorbed were 3.95 and 4.22 % respectively as shown on the Table 4.7. Less percent of water absorbed by the samples of concrete at 1% dosage for used engine oil and superplasticizer. Adding SP or UEO could increase free water in the mix which caused very high workability, increase capillary porosity, lower strength and potential decrease in durability of concrete (Özen et al., 2020). Water absorption of all samples of high strength was less than 5% .Hence all mixture of this concrete would be classified as normal concrete as Euro-International Committee for Concrete. The classifications were less than 3% is good concrete; 3-5% is normal and greater than 5% would be bad concrete.

Table 4.7 Water absorption test result

Mix type	Water Absorption (%)
M1,1%SP	3.95
M2,1%UEO	3.696
M3,2%SP	4.22
M4,2%UEO	4.15

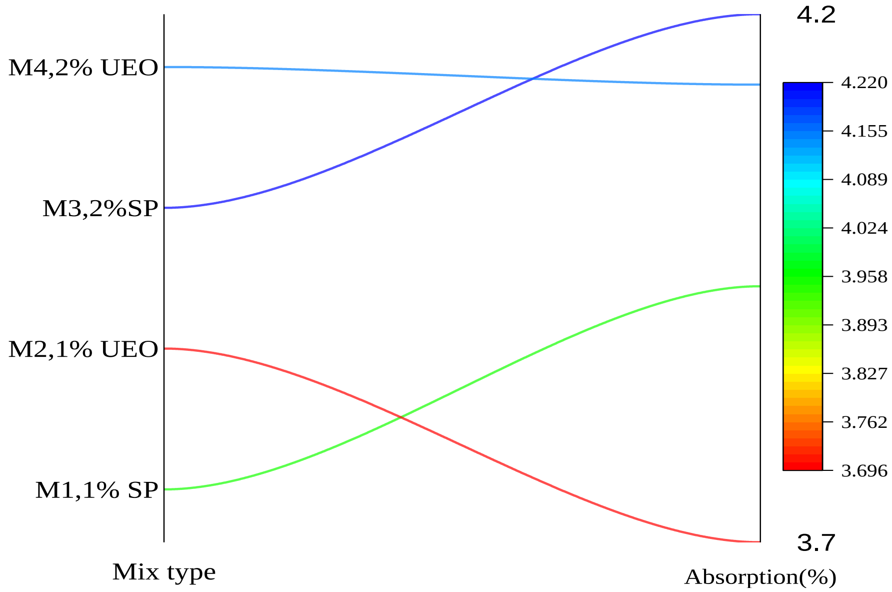


Figure 4.9: Water Absorption test results

4.12 Ultrasonic pulse velocity

Ultrasonic pulse velocity test was conducted as the procedure pointed out under research methodology and the results were presented as the graph shown on figure 4.5.The mix with 1% used engine oil show as the sample has more quality than the control sample. At 2% dosage used engine oil make the concrete quality less when compared with superplasticizer at 2% dosage. The increment of used engine oil may affect the concrete quality. Generally the test result shows that as the percentage of superplasticizer increased from 1 to 2%, the ultrasonic pulse velocity was decreased from 4 to 3.89 km/sec or 4000 to 3890 m/sec. For used engine oil, increase from 1 to 2% the value of UPV may decrease from 4.37 to 3.77km/sec. This result indicates that adding UEO more than one percent would affect the quality of concrete which directly participate in short and long time performance of concrete. Good quality concrete would improve the problems related to strength and durability. UPV value for all samples for this research was between the ranges of 3.5 to 4.5, which shows the concrete have good quality as Indian standard of IS 13311-2 (1992).

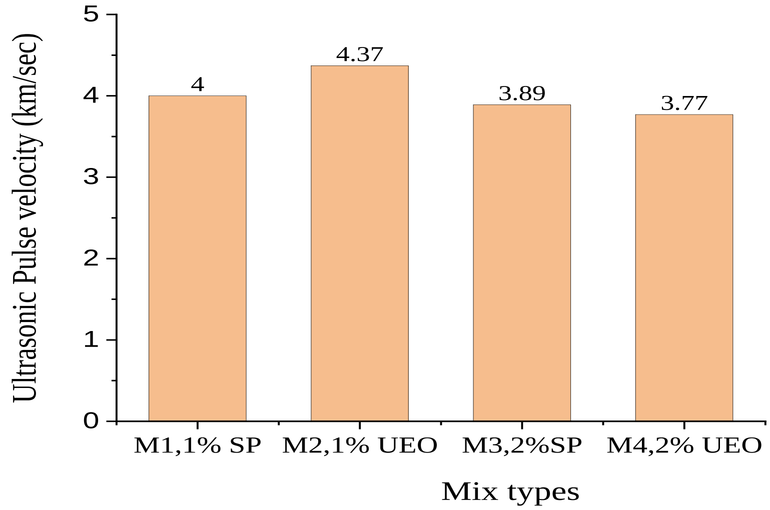


Figure 4.10 Ultrasonic pulse velocity test result at 28days

The structures of the capillary pores that develop in concrete mixtures are closely related to UPV. Many elements in the mixtures can affect the transition of sound waves, including aggregate type and ratio, void ratio, void distribution, and dimension. As a result, a cementitious system with high porosity is likely to have low UPV values and compressive strengths. Generally UPV results of all mixture show the positive relationship with water absorption and compressive strength of the concrete. This impression also concluded by (Özen et al., 2020).

4.13 Chemical analysis of concrete

Scanning electron microscopy (SEM) analysis was conducted for all of concrete samples for analyses of hydration product of cement and morphological image of concrete samples for all concrete mixes.

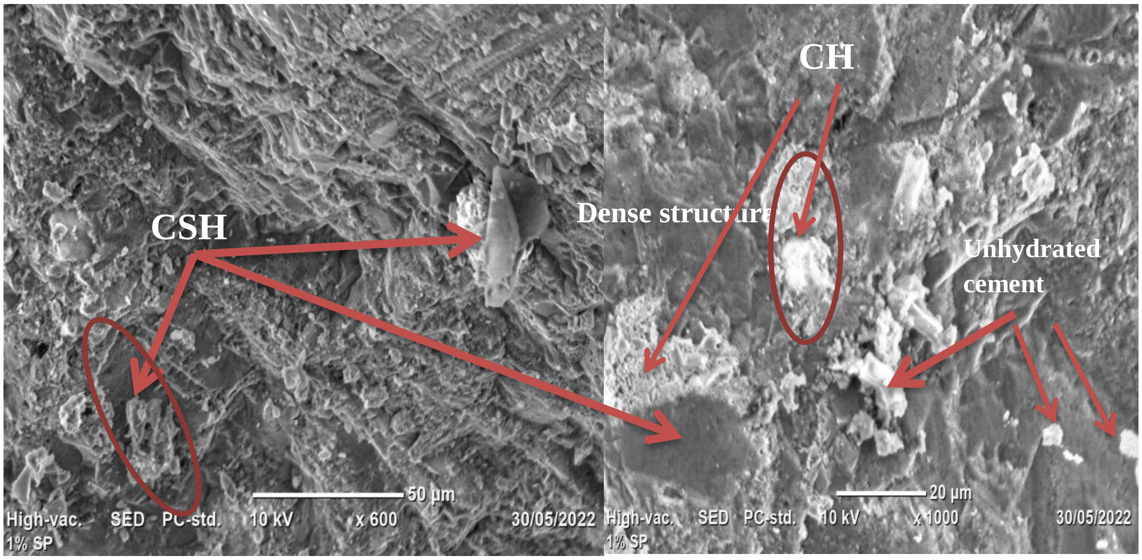


Figure 4.11 SEM result of Morphological structure for sample of 1% SP at resolution of 600x and 1000x

Figure 4.11 shows the internal structure of hydrated concrete after 28 curing days. The mix was produced from 1% of superplasticizer from weight of cement and mix was design as ASTM standards for C-50 grade concrete which was the control sample for 1% UEO. As the result of SEM image at 600x and 100x magnification revealed microstructure of this concrete is dense and porosity is diminished. The calcium hydroxide quantity also less compared to calcium silicate hydrate formed in the hydration product of this concrete sample. This sample has good workability at fresh state which improves the concrete density.

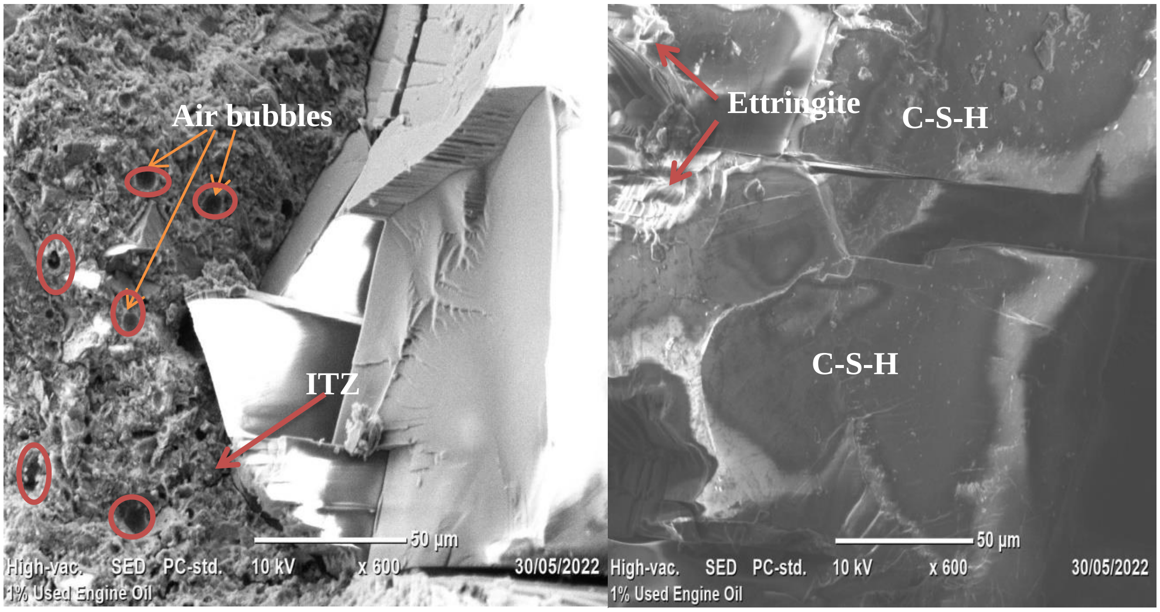


Figure 4.12 SEM result for 1% of UEO at resolution of 600x

Figure 4.12 shows that, the SEM result at 1% consumption of UEO as superplasticizer for high strength concrete. The scanning electron microscopy result identified the availability of air bubbles, micro crack and hydration product compounds like CH and CSH gel which comes from hydration of C_2S and C_3S in cement. The hydrated part of this sample is dense which is agreeing with other test result as they are related to the micro structure of concrete. Porous micro structures lead to less strength and durability. The air bubbles formed in this sample have positive effect on the durability of concrete. It use for resisting action of crack during freezing of concrete. At the time of freezing and thawing of concrete, the water surround the bubbles are move to inside of bubbles. If there are no any bubbles the water goes inside concrete and form crack. Additional CaO from used engine oil would improve the ratio of calcium to silicate which the surface charge of C-S-H depends on. When the Ca/Si ratio is high, the surface charge of C-S-H is positive, and anions (but not cations like Na+ and K+, which remain in the pore solution) are adsorbed on the C-S-H fibers; when the Ca/Si ratio is low, the surface charge of C-S-H is negative, and alkali cations are incorporated on the C-S-H fibers. The Si/Ca ratio varies depending on the quantities, although it is normally around 0.45–0.50 in hydrated Portland cement and up to roughly 0.6 if slag, fly ash, or micro silica are present(Mohamed Sutan et al., 2015). The results of water absorption and UPV in this research indicate as mix from 1% UEO has less percentage of water absorption and high in the ultrasonic pulse velocity which is agree with the result of SEM image. Porosity decrease when UEO used in concrete(Goh & Job, 2021).

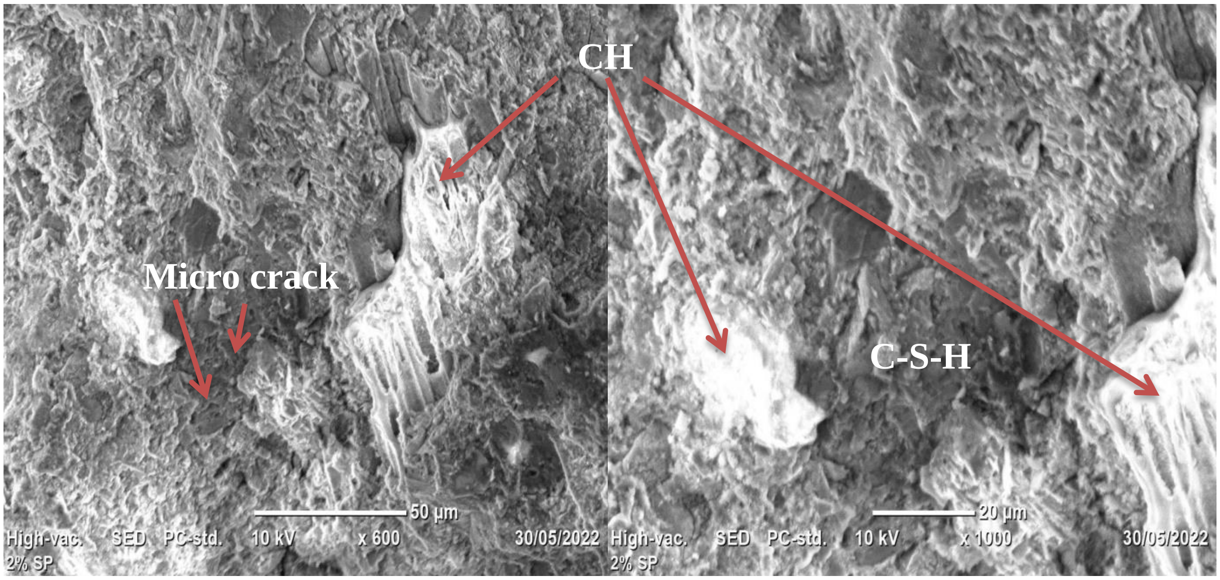


Figure 4.13 SEM Image of morphological for 2% SP at resolution of 600x and 1000x

As Figure 4.13 results, the concrete sample prepared from the addition of 2%SP from weight of cement have less homogeneity of internal structure. The occurrence of micro crack was shown on the phase between calcium silicate hydrate and calcium hydroxide. The morphological structure of this sample show as internal structure is starts to disintegrate. This would resulted for the lower compressive strength of concrete at 28days when compared to the sample from 1% of SP in mix 1.This show the direct relationship of microstructure and strength of concrete. This is because sample has the slump value of 125mm which is so far from the designed slump 25-50mm in the time of mix design. Wave number of 1636.04cm^{-1} from FTIR analysis indicates short side chain of ester functional group in mega flow superplasticizer. Ester functional group can be slowdown the cement hydration rate(Xun et al., 2020).It would be make the micro structure of concrete less dense. Holanda et al.,(2017) discuss as ester functional group have the same effect on hydration of concrete .

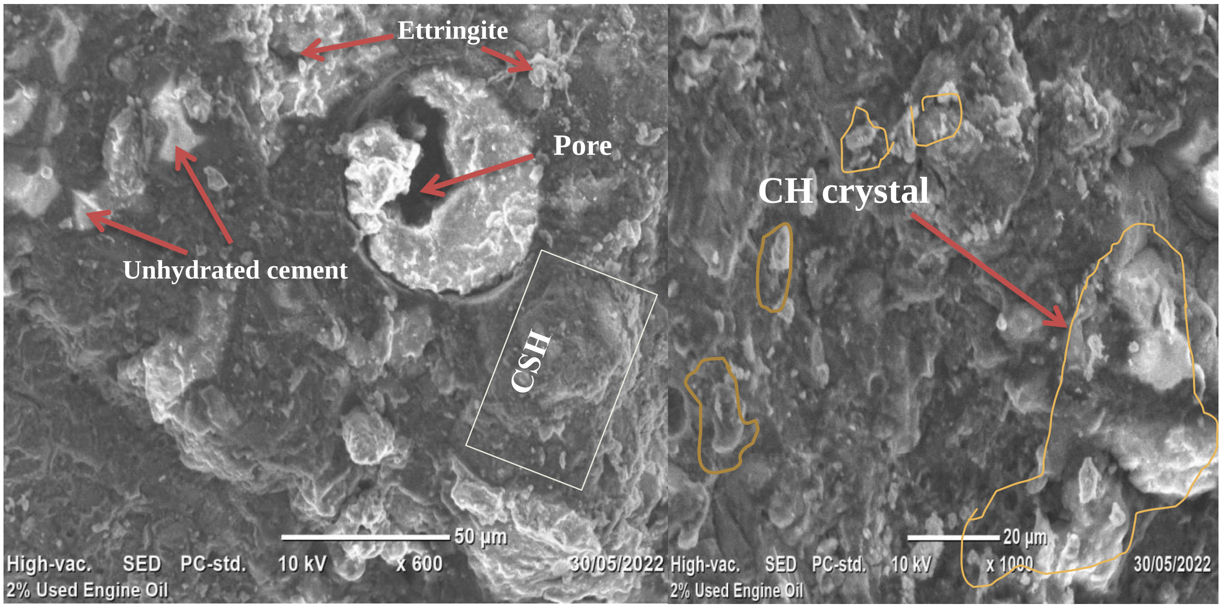


Figure 4.14 SE M Image result for 2% UEO at resolution 600x and 1000x

SEM analysis was conducted to concrete sample after 28 curing days. Micro structure for mix4, which is adding 2% UEO as concrete admixture was analyzed as illustrated on the above Figure 4.14. Color of hydration product was identified in the research of (Gallucci et al., 2007).Dark grey is color show the inner calcium silicate hydrate (CSH),light grey was for calcium hydroxide (CH),white was for unhydrated cement particles and black color show the pore in the micro structure of concrete. As the result from FTIR spectrum for used engine the sharp peaks at 1373.66cm^{-1} show the availability of sulphate in the waste product. Additionally researchers like(Alsadey, 2018; Beddu et al., 2016b; Shafiq et al., 2018b; Varghes & sakaria, 2017) discovered that as used engine oil contain more percentage of sulphate (SO_3) in addition to other oxides like CaO,Fe_2O_3,P_2O_5 and ZnO. Li et al.,(2014),summarize the effects of CH on micro structure of concrete. Ca $(OH)_2$ crystal particles formed at an early age fill the holes in hardened paste, which aids in the development of strength. As the reaction progresses continued, larger crystal particles form, increasing the porosity of the paste and impeding the development of strength. Unhydrated cement particles formed due to the mineral composition of used engine oil like phosphorus oxide and zinc oxide. This phenomenon would decrease the strength of concrete through its life time. Ettringite is the compounds which formed by reaction between C_3A and gypsum or other admixtures which are source of calcium sulphate. When cement gets into touch with the mix water, this reaction happens very quickly. The gypsum is usually consumed first, after which the leftover tri calcium aluminate (C_3A) reacts with the previously created ettringite to make calcium monosulfoaluminate ($3CaO•Al_2O_3•CaSO_4•12H_2O$). Ettringite takes up more space than monosulfoaluminate. It's a stable molecule until more sulfates become available, at which point it can combine with them to generate ettringite in an expansive reaction. Using this used motor oil beyond the optimum may enrich the sulphate contents of concrete which is the main cause for sulphate attack. So researchers should ensure about optimum percentage dosage of used engine oil in concrete.

4.14 Statistical Correlation among concrete properties

Compressive strength, slump value, water absorption, and ultrasonic pulse velocity were analyzed Pearson correlation among variables by Minitab 20 software. All the data except slump were after 28 days curing time.

.As shown on Table 4.9, Correlation was analyzed by Pearson correlation. Compressive strength correlated positively with ultrasonic pulse velocity (0.191) of high strength concrete but negatively related with slump (-0.052) and water absorption (-0.358).The relationship show that, as UPV higher the compressive strength also resulted higher and reverse relation with water absorption.

Table 4.8 Correlation between variables

Pearson correlation	Correlation between variables			
	Compressive strength	Slump	Water absorption	UPV
Compressive strength	1.00	-0.052	-0.358	0.191
Slump	-0.052	1	0.531	0.602
Water absorption	-0.358	0.531	1	-0.128
UPV	0.191	0.602	-0.128	1

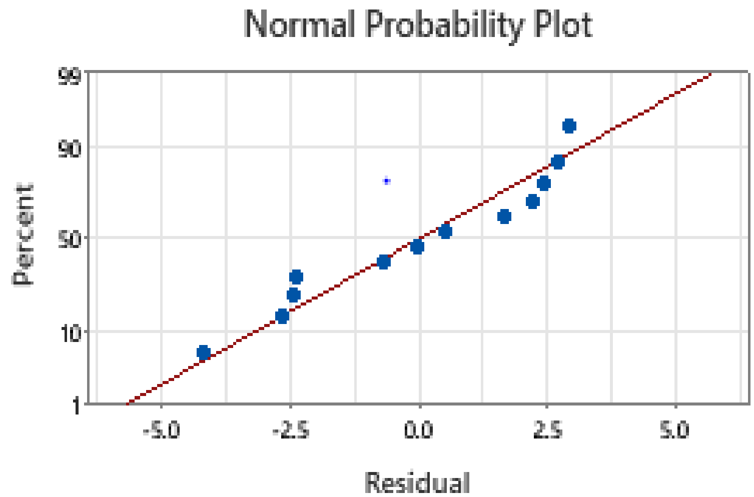


Figure 4.15 Normal probability plot for compressive strength at 28days in Mpa

In the normal probability plot, the actual scores are ranked and sorted. Basically, the actual values line up along the diagonal from the lower left to the upper right. This plot indicates that compressive strength is normally distributed. The predicted and standardized values are concentrated around the center, which indicates that compressive strength is normally scattered.

Table 4.9 Minitab Results for mean,median,st.dev and variance

Variables	N	Mean	St.dev.	Variance	Minimum	Maximum	Median
Compressive strength in Mpa	12	60.922	2.684	7.202	56.230	65.200	60.880
slump in mm	12	65.0	42.8	1831.8	20.0	130.0	55.0
water absorption in %	12	3.782	0.470	0.221	2.950	4.820	3.725
UPV	12	3.9750	0.2914	0.0849	3.7200	4.5100	3.7900

Descriptive Statistics

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The Experimental study was conducted on the effects of consuming used engine oil as high range water reducer on the fresh and hardened properties of high strength concrete. Based on the results, conclusion drawn as follow:

1. The workability and compaction factor was conducted for all mixes with superplasticizer and used engine oil. At both percentages 1% and 2% the slump value of mix by adding superplasticizer was highly workable then the mix with used engine oil. Particularly on 2% adding SP, the fluidity of concrete increase rapidly from 80mm to 125mm.The mix from used engine has less workable but it is in the range of designed slump which is 25-50mm.
2. Compressive strength results for Mix1, Mix2, Mix3 and Mix 4 were conducted at 7, 14 and 28 curing days.at 7days the control mix show compressive strength of 32.876Mpa, while Mix2 which was mix added 1% of UEO from weight of cement is 29.04Mpa.The second control mix is mix3 which is 2% of SP, compressive strength is 27.5Mpa.Mix4, 2%UEO result in 28.95Mpa of compressive strength. For Mix3 compressive strength was less because high slump might affect concrete strength due to formation of segregation and bleeding. At 14 curing days not such much difference was occurred. The 28days compressive strength result shows that, used engine oil can be used as superplasticizer at 1% from weight of cement. But at 2% strength start to decline due to the heavy metals oxides affect the hydration of cement. Zn (OH) formed in concrete cover the cement particles and makes the cement unhydrated. Because it form amorphous layer which protect water from cement.
3. Water absorption and ultrasonic pulse velocity test result were the indication of concrete durability and quality. Both tests result show that, the positive relationship with the strength of concrete.
4. The Scanning electron microscopy (SEM) analyses the formation of hydration products, pores, and micro crack of concrete samples. The mix prepared from 1% UEO show the dense the same with the control sample of 1%SP.This mix was taken as

optimum amount of used engine oil added to concrete as superplasticizer without affecting the strength, durability and micro structure of concrete. At 2% added used engine oil from weight of cement in kg to concrete, expansive ettringite formed due to the availability of sulphate and calcium sulphate compounds in concrete. Statistical relationship among concrete properties show that as water absorption inversely related to compressive strength and ultrasonic pulse velocity.

5. Depending on the data for the quantity of waste engine oil yearly in Ethiopia, it can be totally use the available waste in construction industry. As current information $8.9x10^{10}$ Kg (8.9 million ton) of cement consumed. Simple calculation be 8.9x1010*0.01kg of waste would be use which is 890,000,000 liter. This improve the environmental effect and cost of waste disposal also eliminated.

5.2 Recommendations

1. Before using chemical admixtures directly in concrete mixtures, prior tests should be performed to ensure cement and superplasticizer compatibility.
2. In mix design of high strength concrete, the quality of ingredients have great role rather than normal strength concrete .So need to keep all as standards
3. Further study shall be performed on the effects of used engine oil in chemical properties of concrete more detail than addressed now.

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APPENDIX

Appendix A

A1. Material Characterization

A1.1 Cement

Table 1: Fineness Modulus

S/N	Sieve size (mm)	Cement sample (g)	Weight of retain	% retain	Average Retain	Remark
1	150	50	4	8	9%	Recommended
2	150	50	5	10		

Figure 1: soundness test of cement

Table: 2 Normal consistencies

Trial No.	Water (g)	Cement Sample (g)	Penetrated depth from the top surface of sample (mm)	Time taken (min)
1	135	500	8	0.5
2	140	500	8.5	0.5
3	145	500	9.5	0.5

Figure 2: Normal Consistency test

Table 3: Soundness Test

Trial No.	Initial distance b/n the indicator needles (mm)	Final distance b/n the indicator needles (mm)	Soundness values	Average soundness(mm)
1	13	14	1	1.667
2	12	14	2	
3	13	15	2	

Figure 3: Setting time of cement paste

Table 4: Setting time

Trial 1		Trial 2		Setting time
Penetration	Time	Penetration	Time	
0	0:00	0	0:00	
40	0:15	39	0:15	
40	0:30	39	0:30	
39	0:45	38	0:45	
39	1:00	39	1:00	
39	1:15	38	1:15	
38	1:30	37	1:30	
36	1:45	35	1:45	
35	2:00	34	2:00	
32	2:15	32	2:15	
28	2:30	27	2:30	Initial ST interpolated=86.5 min
26	2:45	23	2:45	
23	3:00	22	3:00	
18	3:15	16	3:15	
14	3:30	12	3:30	
10	3:45	10	3:45	
6	4:00	7	4:00	
3	4:15	3	4:15	
2	4:30	1	4:30	
1.5	4:45	1	4:45	
1	5:00	0	5:00	
1	5:15	0	5:15	Final ST,average=5hr and 15min
0	5:30	0	5:30	

A1.2 Fine aggregate

A1.2.1 Silt Content

V_1= silt content, V_2 =sand content

Silt content (%) determination, before washing the fine aggregate

Total volume occupied by fine aggregate and silt in measuring cylinder= 310ml

Content of silt over sand in measuring cylinder= 6ml

Content of fine aggregate in measuring cylinder = 70ml

Silt content % = [76ml – 70ml]/70ml *100 = 8.57%

The silt content % in fine aggregate is greater than the permissible percentage, since it is greater than 6%. Therefore, washing of fine aggregate is mandatory and after washed, the silt content % is determined and it becomes 4.5%, which is in range of permissible.

Silt content % determination, after washing the fine aggregates.

Total volume occupied by sand and silt = 76ml

Content of silt over sand = 3ml

Content of sand = 73

Silt content % = [76ml – 73ml]/73ml *100 = 4.1 %

A1.2.2 Moisture content

Weight of original sample (W1) =500gm

Weight of Oven Dry sample (W2) = 495gm.

Moisture Content = (W1-W2)/W2 = (500 – 495)/ 495= 1.01%

For coarse aggregate,

Weight of original sample (W1) =2000 gm.

Weight of Oven Dry sample (W2) = 1985gm.

Moisture Content = (W1-W2)/W2 = (2000 – 1985)/ 1985= 0.75%

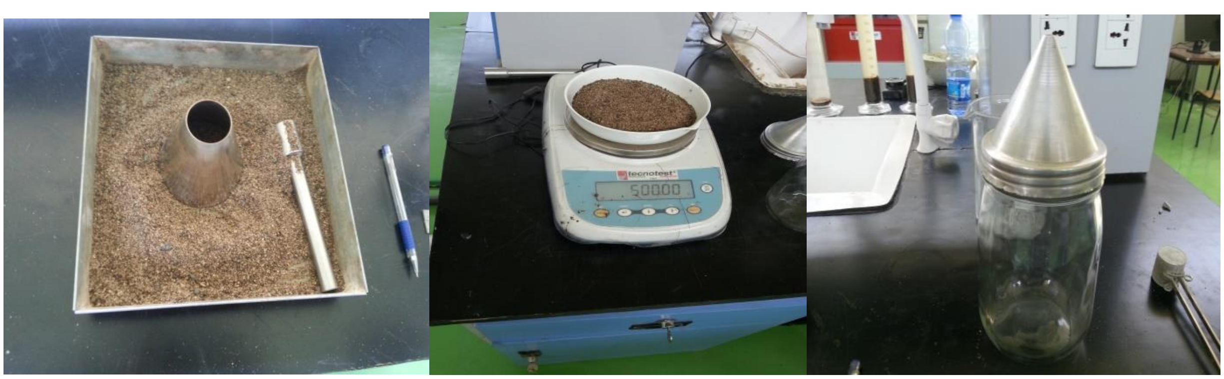

Figure 4: Photo for moisture content and Absorption capacity of sand

A1.2.3 Unit weight

A1.2.4 Specific Gravity and absorption capacity

Weight of original sand Sample = 500gm

Weight of pycnometer + weight of sand sample = 512.1gm

Weight of pycnometer + sand + water (C) = 1872.6gm

Weight of oven dried sand sample (A) = 488gm

Wt. of pycnometer filled with water (B) =1557.4gm

Bulk specific gravity = A/B+500-C = 488/1557.4+500-1872.6 = **2.65**

A = Oven dried sand sample

B = Wt. of pycnometer filled with water

C= Weight of pycnometer + sand + water

Bulk spec gravity (Saturated surface dry base) = 500/B+500-C = 500/71557.4+500-1872.6= **2.7**

Apparent specific gravity = A/B+A-C= 488/1557.4+488-1872.6 = **2.82**

Absorption capacity=500-A/A*100= 500-488/488 *100

Absorption capacity=2.5%

A1.3 Coarse Aggregate

A1.3.1 Unit weight

A1.3.2 Specific Gravity and absorption capacity

Weight of oven dry sample (A) =4975gm

Weight of saturated surface dry sample (B) =5010gm

Weight of saturated sample in water (C) =3283.4gm

Calculation:

$Bulk\ Specific\ Grav. = \frac{A}{B-C}$ = **2.88**

$SSD = \frac{B}{B-C}$= 2.9

$\text{ApparentSpecific Grav.} = \frac{A}{A-C}$= **2.94**

$\text{Absorption capacity} = \frac{B-A}{A}$ *100 =**0.75%**

Appendix B

B1.Properties of Fresh concrete

Table5: slump and Compaction factor test result

Mix Type	Slump value (mm)	Compaction Factor
M1,1% SP	80	0.998
M2,1% UEO	25	0.896
M3,2% SP	125	0.989
M4,2%UEO	30	0.828

Figure 5: Photo for Workability tests

Appendix C

C1.Properties of Hardened Concrete

C1.1 Compressive Strength

Table 6: Compressive Strength test results

Compressive Strength result for 1% SP							
S/N	Test age	Dimension(cm)			Volume (cm^3)	Failure Load	Compressive Strength(Mpa)
		L	W	H			
1	7days	10	10	10	1000	313.33	31.33
2		10	10	10	1000	325	32.5
3		10	10	10	1000	346.8	34.8
						Mean	**32.876**
1	14 days	10	10	10	1000	455.3	45.53
2		10	10	10	1000	446	44.6
3		10	10	10	1000	450	45
						Mean	45.04
1	28 days	10	10	10	1000	631	63.1
2		10	10	10	1000	626	62.6
3		10	10	10	1000	605.6	60.56
						Mean	**62.09**

Compressive Strength result for 1% UEO							
S/N	Test age	Dimension(cm)			Volume(cm3)	Failure Load	Compressive Strength (Mpa)
		L	W	H			
1	7days	10	10	10	1000	290.2	29.02
2		10	10	10	1000	300.7	30.07
3		10	10	10	1000	280.3	28.03
						Mean	**29.04**
1	14 days	10	10	10	1000	468.7	46.87
2		10	10	10	1000	467	46.7
3		10	10	10	1000	458	45.8
						Mean	**46.46**
1	28 days	10	10	10	1000	652	65.2
2		10	10	10	1000	643	64.3
3		10	10	10	1000	620	62
						Mean	**63.83**

Compressive Strength result for 2% SP							
S/N	Test age	Dimension(cm)			Volume(cm^3)	Failure Load	Compressive Strength(Mpa)
		L	W	H			
1	7days	10	10	10	1000	267.5	26.75
2		10	10	10	1000	270	27
3		10	10	10	1000	287.4	28.74
						Mean	**27.5**
1	14 days	10	10	10	1000	461.4	46.14
2		10	10	10	1000	459	45.9
3		10	10	10	1000	460.5	46.05
						Mean	**46.03**
1	28 days	10	10	10	1000	605	60.5
2		10	10	10	1000	612	61.2
3		10	10	10	1000	587	58.7
						Mean	60.13

Compressive Strength result for 2% UEO							
S/N	Test age	Dimension(cm)			Volume cm^3	Failure Load	Compressive Strength
		L	W	H			
1	7days	10	10	10	1000	292.7	29.27
2		10	10	10	1000	286.3	28.63
3		10	10	10	1000	289.5	28.95
						Mean	**28.95**
1	14 days	10	10	10	1000	427.77	42.77
2		10	10	10	1000	440	44
3		10	10	10	1000	436	43.6
						Mean	**43.456**
	28 days	10	10	10	1000	585.17	58.52
		10	10	10	1000	562.32	56.23
		10	10	10	1000	581.54	58.15
						Mean	**57.63**

Figure 6: Compressive strength test

C1.2 Split tensile strength

Table 7: results of split tensile strength

Split tensile strength test result for 1% SP						
S/N	Test age	Dimension(cm)		Volume (cm^3)	Failure Load(KN)	Split tensile strength (Mpa)
		Dia.	H			
1	7days	10	20	6283.2	86.4	2.752
2		10	20	6283.2	85.46	2.722
3		10	20	6283.2	84.78	2.7
					Mean	2.725
1	28 days	10	20	6283.2	85.3	2.72
2		10	20	6283.2	98.4	3.13
3		10	20	6283.2	95.5	3.05
					Mean	2.96
Split tensile strength test result for 1% UEO						
S/N	Test age	Dimension(cm)		Volume (cm^3)	Failure Load	Split tensile strength (Mpa)
		Dia.	H			
1	7days	10	20	6283.2	88.4	2.815
2		10	20	6283.2	89.7	2.856
3		10	20	6283.2	87.5	2.786
					Mean	2.819
1	28 days	10	20	6283.2	90.3	2.876
2		10	20	6283.2	98.4	3.134
3		10	20	6283.2	95.7	3.05
					Mean	3.023

Split tensile strength test result for 2% SP						
S/N	Test age	Dimension(cm)		Volume (cm^3)	Failure Load(KN)	Split tensile strength (Mpa)
		Dia.	H			
1	7days	10	20	6283.2	101.9	3.244
2		10	20	6283.2	100.7	3.186
3		10	20	6283.2	99.88	3.179
					Mean	3.203
1	28 days	10	20	6283.2	122.6	3.904
2		10	20	6283.2	95.5	3.041
3		10	20	6283.2	113	3.6
					Mean	3.515

Split tensile strength test result for 2% UEO						
S/N	Test age	Dimension(cm)		Volume (cm^3)	Failure Load(KN)	Split tensile strength (Mpa)
		Dia.	H			
1	7days	10	20	6283.2	62.3	1.984
2		10	20	6283.2	63.05	2.007
3		10	20	6283.2	62.96	2.005
					Mean	1.998
1	28 days	10	20	6283.2	81.8	2.605
2		10	20	6283.2	96.2	3.06
3		10	20	6283.2	101.3	3.23
					Mean	2.97

C1.3 Water Absorption

Table :8 Water absorption test

Mix type	Weight of oven dry (A) in kg	Weight of immersed (B) in kg	Formula	Water Absorption (%)
M1,1%SP	2.49	2.595	$\frac{B-A}{A}*100$	3.95
M2,1%UEO	2.57	2.665		3.696
M3,2%SP	2.53	2.63		4.22
M4,2%UEO	2.41	2.51		4.15

Figure 7: Weight of samples after immersion

C1.3 Ultrasonic Pulse Velocity

Table 9: ultrasonic pulse velocity

Mix type	Traversing distance in meter	Traversing time in micro second	UPV in (km/sec)
M1,1% SP	0.1	25	4
M2,1%UEO	0.1	22.9	4.37
M3,2% SP	0.1	25.5	3.89
M4,2%UEO	0.1	26.5	3.77

Photo of time of traversing recorded in microsecond for mixes

Appendix-D

Sample Photo

Obtaining Coarse and Fine aggregate

Fine and coarse aggregate prepared for sieve analysis

Sample prepared for compressive and split tensile test