CAPITAL UNIVERSITY OF SCIENCE AND TECHNOLOGY, ISLAMABAD

Properties of Concrete Having Used Petrol-Engine Oil and Varying Lengths of Banana Fibers

by

Muhammad Jawad Khan

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I want to dedicate this work to my family, who has helped me throughout my education. This is also a homage to our finest professors who have inspired us to face the challenges of presence with creativity, and courage and who have made us what we are today.

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Acknowledgement

In the Name of **Allah**, The Most Gracious, The Most Merciful. Praise be to God, the Cherisher and Sustainer of the worlds. All thanks to Almighty **Allah**, The Lord of all that exist, who bestowed me with His greatest blessing i.e. knowledge and Wisdom to accomplish my task successfully. Thousands of salutations and benedictions to the **Holy Prophet Hazrat Muhammad (PBUH)** the chosen-through by whom grace the sacred Quran was descended from the Most High.

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Abstract

Concrete is a widely used construction material due to its superior properties, which make it more favorable than any other construction material. However, concrete has some serious drawbacks that are caused by its brittle nature, including vulnerability to cracks, brittle behavior, spalling, and more linear shrinkage. Even though concrete has high compressive strength, it is weak in tension, which leads to cracking and reduces the structure's durability and service life. To address these issues, there are different approaches that can be used to enhance the splitting-tensile and flexural properties of concrete. For example, natural fibers and admixtures can be used to improve the properties of concrete. Additionally, there is a growing interest in using residual waste as a raw material for the manufacturing of sustainable materials. However, some residual wastes can cause severe damage to the environment, such as used petrol-engine oil. On the other hand, agricultural waste, such as banana fibers, which are abundantly available in developing countries, can be used as dispersed reinforcement to improve the properties of concrete. Overall, the use of natural fibers and residual waste as a raw material can help in the development of environmentally friendly materials. Therefore, banana fibers can be used to enhance the properties of concrete, and used petrol-engine oil can be used as a chemical during the manufacturing of concrete.

The purpose of this research project is to examine the use of chemical admixtures and natural fibres in concrete to improve its performance and qualities. Specifically, banana fibers are used as a reinforcement, and used petrol-engine oil is added as a chemical admixture. The study involves preparing four cylinders and two beamlets for plain concrete (PC) and used petrol engine oil banana fiber reinforced concrete (UBFRC). The BF is added to the mixture in fixed proportion of 3.0%, and the length is varied (3+5 cm, 3+7 cm, 5+7 cm, 3+5+7 cm) in combination with the UPEO. The mix design 1:2:4 (cement: sand: aggregates) with a water cement ratio (w/c) of 0.5 is used for preparing PC and used petrol-engine oil plain concrete (UPC). The mix 1:2:4 with a w/c of 0.6 is used for preparing fiber reinforced concrete (FRC). For UBFRC, a fixed amount of UPEO is used, and BF is used with a fixed proportion of 3.0% and varying length. Various tests are performed to determine the influence of BF and UPEO on the properties of concrete, including slump, dynamic, mechanical, water absorption, linear shrinkage, and mass-loss tests. The average of two specimens of each type of concrete and test is taken to evaluate every type of the observed property. In summary, this research work explores the use of banana fibers and used petrol-engine oil as a reinforcement and chemical admixture, respectively, to enhance the properties of concrete. The study involved preparing various types of concrete and performing different tests to evaluate the properties of each type.

From obtained results of tests, findings that were collected. The findings of the slump test demonstrate that UPEO-only concrete has a higher slump value than other types of concrete. With an increase in banana fibre content, FRC's workability is seen to decline. Better performance against dynamic loading has been demonstrated by the UBFRC with fibres that are (3+5cm) in length. According to the findings, UBFRC has greater tensile and flexural strengths than other materials when compared to those that include (5+7cm) and (3+5+7cm) amounts of BF, respectively. Additionally, as the length of BF in the concrete increases, the compression toughness index and splitting tensile toughness index both dramatically improve. When specimens' compression strength increases, a drop is observed.With an increase in fibre content, specimens' compression strength begins to decline. Water absorption and linear shrinkage are both increased by adding more fibre to concrete. This leads to the conclusion that (5+7cm) is the ideal fibre content for concrete tension members since it performs better under tensile, flexural, and dynamic loadings. UBFRCs made with a (3+7cm) fibre composition have performed better than other forms of UBFRCs for compression members.

Keywords: Banana Fibers, Dynamic Properties, Fiber Reinforced Concrete, Mechanical Properties, Used Petrol-Engine Oil.

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Abbreviations and Symbols

BF	Banana Fibers
CE1	Compressive Pre-Crack Energy Absorption
CE2	Compressive Post-Crack Energy Absorption
CS	Compressive Strength
CTI	Compressive Toughness Index
Ed	Dynamic Modulus of Elasticity
FC	Fiber Content
FE1	Flexural Pre-Crack Energy Absorption
FE2	Flexural Post-Crack Energy Absorption
FRC	Fiber Reinforced Concrete
FS	Flexural Strength
FTI	Flexural Toughness Index
MOE	Modulus of Elasticity
PC	Plain Concrete
Rd	Dynamic Modulus of Rigidity
RFL	Response Frequencies Lateral
RFR	Response Frequencies Rotational
RFT	Response Frequencies Transverse
SE1	Splitting-Tensile Pre-Crack Energy Absorption
SE2	Splitting-Tensile Post-Crack Energy Absorption
SP	Superplasticizer
SS	Splitting-Tensile Strength
STI	Splitting-Tensile Toughness Index
STM	Servo-Hydraulic Testing Machine

UBFRC	Used Petrol-Engine Oil Banana Fiber reinforced concrete
UEO	Used Engine Oil
UPC	Use Petrol-Engine Oil Plain Concrete
UPEO	Used Petrol-Engine Oil
UVBFRC	Used Petrol-Engine Oil and varying length Banana Fiber
ζ	Damping Ratio
Δ	Deflection
δ	Deformation

Chapter 1

Introduction

1.1 Background

In the present era, concrete is the most widely used material in construction. However, it has several limitations such as low tensile strength, vulnerability to cracking, and environmental issues. To overcome these limitations, fibers and admixtures are added to concrete to improve its performance and develop sustainable materials. Fiber reinforced concrete (FRC) is a promising material in civil engineering due to its advantages such as toughness, tensile strength, durability, and energy absorption [1-3]. Because of this fact, cannot be relied on concrete. Also, vulnerability to cracking, loading, and environmental issues are the most promising factors which are causing reduction in functionality and serviceability of concrete[4, 5]. It is required to add fibers and admixtures in concrete to meet with high performance, attaining certain properties, and developing a sustainable material [6].

Admixtures are used for different purposes such as enhancing early strength, accelerating or retarding setting times of concrete or to achieve specific property of the concrete such as to reduce the content of cement while having no effect on the physical properties of the concrete. In past few decades, interest had increased in attaining high performance and environmental friendly materials in civil engineering application. One of these materials, fibre reinforced concrete (FRC), has gained popularity in civil engineering because to its features, which include toughness, tensile strength, durability and energy absorption [6]. FRC is concrete having dispersed short discrete fibers, this makes FRC to be studied carefully taking in consideration functionality of fiber within the mix. Many researchers attempted to improve the governing properties of concrete for the production of the high-performance concrete. Used petrol-engine oil (UPEO) has been used as a chemical admixture by many researchers for reducing cement content in concrete or as an admixture. Concrete emits carbon di oxide approximately equal to clinker for production. The reduction of cement content in concrete results in reduction in emission of CO2 during the sintering process and making the composite less adverse to the environment. Addition of UPEO reduces 9.4% cement content in concrete with comparable properties of plain concrete.

The addition of fibers to concrete can greatly enhance its mechanical properties such as flexural, tensile strength, resistance against spalling, cracking, and fatigue. Concrete composed of fibers can improve the performance of the concrete for specific applications, including its resistance to impact loading, flexural strength, and splitting tensile strength. In addition, the tensile strength provided by the fibers also helps to resist the production of cracks in the concrete. By reducing cement content and adding used petrol-engine oil (UPEO) as a chemical admixture, the production of concrete can be made more economical. These approaches can effectively enhance numerous mechanical properties of cementitious composites.

1.2 Research Motivation and Problem Statement

Concrete is the primary construction material in this modern age. Although it has many flaws, it cannot be replaced with any other material. Concrete is a such material which inherent certain issues like appearing of cracks in structural members even from day one. These cracks can be found on different structural members. These cracks affect the service life of structure and structural members. If such cracks can be delayed than service life can also be extended. That's why, what can we do is to have sustainable concrete preferably no or minimum cracks at the start. As, the main concern of this research study is to mitigate or reduce the impact of these shortcomings. The failure of concrete structures can result in the loss of human lives and loss of money. That's why it is required to avoid the failure of the concrete in different scenarios of applications and loadings. The use of natural fibers has been reported to enhance the properties of concrete to avoid its failure. There is need to adopt modern methods in the construction industry. Also, it is needed to aware people regarding high-performance and sustainable material. There are also research studies available on improving concrete properties by the addition of the admixture. But there is a need to use the other hazardous/toxic waste materials (like UPEO) to avoid environmental pollution and to take a step towards the development of sustainable and cleaner production. Moreover, this study will help researchers to provide guidelines and a way of thinking to utilize the wastes and environmental pollution causing materials in construction materials instead of dumping of these materials. The dumping of these materials is a time taking and can be costly. Thus, the problem statement is as follow:

In the building construction, use of concrete is becoming inevitable day by day. The concrete is weak in tension, less resistive against lateral loading, and quasi brittle material. The change in temperature cause volumetric change in concrete. This change is the key to production of drying shrinkage cracks. These flaws of concrete are needed to overcome and to improve the properties of concrete. On one side, natural fibers (i.e. banana fibers) can be used to enhance toughness of concrete. And on the other hand, waste materials (like UPEO) can be utilized. There is a need to explore the behavior of concrete having varying length of BF and fixed amount of UPEO.

1.2.1 Research Questions

- What are the combined effects of banana fibers with varying length and used petrol-engine oil on dynamic properties of concrete?
- What are the combined effects of banana fibers with varying length and used petrol-engine oil on mechanical properties of concrete?

- How much water absorption, mass loss and linear shrinkage of concrete be controlled with used petrol-engine oil and varying length banana fiber?
- How much would be the fiber breakage and fiber pullout with the use of UPEO in BFRC?
- How concrete made of used petrol-engine oil and banana fiber with varying length can be used for the specific real-life applications?

1.3 Overall Objective of the Research Program and Specific Aim of this MS Thesis

The overall objective of the research program is to precisely take a step toward development of the high-performance concrete with the help of waste materials for building construction and civil engineering applications. As concrete has several flaws, and some of these flaws affect the performance of structure and decreases the durability of concrete. There is a need to use the waste materials (instead of dumping them) in construction materials because it is reported to have good potential for bringing better impact in cementitious composite. By incorporating waste materials in the construction industry, we can not only reduce the amount of waste going to landfills but also contribute to the development of more sustainable and eco-friendly construction practices.

The specific aim of this research work is to study the combined effect of varying lengths banana fibers (VLBF) and used petrol-engine oil (UPEO) on properties of concrete.

1.4 Scope of Work and Study Limitations

The workability, mechanical properties, dynamic properties and absorption properties of concrete are investigated by taking two specimens for each property of used petrol-engine oil and varying length banana fiber reinforced concrete (UVBFRC) and used petrol-engine oil plain concrete (UPC). The average of two specimens is taken according to acceptance and recommendation of ACI 311.6-18 standards. Dynamic properties are studied before investigating the mechanical and absorption properties. After appearance of first crack on specimen, it is considered as failure after load application. Other miscellaneous properties like linear shrinkage and mass loss are also examined in this study.

The study is purely limited to mechanical, dynamic and absorption properties of UVBFRC specimens. In this scope of study, durability of UVBFRC is not included. Influence on performance and resistance against the impact loading is not considered in this study. The fibers are used with varying length and fix content for different UVBFRCs with fix amount of the UPEO.

1.4.1 Rationale Behind Variable Selection

Fiber's type selected on the superiority of physical properties comparison to other [7]. Banana fibers has high tensile strength among the natural fibers. And also, these banana fibers are likely to be compatible to use with UPEO [8]. The many other natural fibers can easily get damaged by acidic property of UPEO [9]. Different length and size will help in better mixing to achieve good improved properties.

1.5 Novelty of Work, Research Significance and Practical Implementation

In an experimental work, it was revealed that resistance against impact loading significantly improved by the addition of the natural fibers in concrete [10]. The mechanical properties of concrete were observed to be improved by the addition of natural fibers [11]. Previous conducted studies show that properties of concrete and performance of structure were improved with different types of natural fibers and admixtures. To the best of author's knowledge, no research has been conducted on combined effect of used petrol-engine oil and banana fibers on production and properties of concrete. Thus, the current study is aimed to study the basic mechanical, dynamic and absorption properties of UBFRC using used engine oil and banana fibers. This material is resulted in production of improved properties of concrete for the use in civil engineering and construction industry.

There are several flaws of concrete like cracking, spalling, weak in tension, etc. So, there is a need to mitigate these flaws of concrete. The addition of banana fiber and used petrol-engine (UPEO) in concrete enhances resistance against these flaws of concrete. The addition of fibers in concrete resulted in improved durability and enhanced resistance against production and progression of cracks [12]. Fiber reinforced concrete have shown the improved properties in comparison with respect to the properties of the PC. According to a research, fiber reinforced concrete (FRC) beams along with fiber reinforced polymer bars as reinforcement has shown better performance [13]. In Previous studies, single fiber or combination of two fibers was used in concrete for improving its properties. The very limited studies are available in which artificial fibers were used along with an admixture. Therefore, utilization of natural fibers and used petrol engine oil are way better to be used for improving the properties of concrete, as it cleaning the environment as well by using the UPEO. Banana fibers has the high tensile strength in comparison with the other natural fibers [14]. Hence, there is need to investigate its effect on different properties of the concrete.

The concrete having UPEO can directly be practically implemented at locations where it does not have direct contact with environment. For example, this can be used as lean concrete beneath the foundation. Also, lean concrete is covered within the soil and it has no contact with the air and protected from the chemical attacks of environment. However, it seems to have potential for structural applications. If used with great care.

1.6 Brief Methodology

In this experimental study, the basic mechanical, dynamic and absorption properties of Plain Concrete (PC) Used petrol-engine oil Plain Concrete (UPC), and used petrol-engine oil Plain Concrete banana fibers reinforced concrete UBFRC are determined in laboratory. All UBFRCs are prepared with varying length of banana fibers having fixed content 3%. Fixed amount of used petrol-engine oil plain concrete is used in manufacturing of UPC and all types of UBFRCs. Most conventionally used mix design 1:2:4 is used in manufacturing of PC, UPC, and all UBFRCs. For PC and UPC, 0.5 water-cement ratio (w/c) is used whereas 0.6% w/c is used in making of all types of UBFRCs. The w/c is enhanced due to high water absorption of banana fiber as reported by [15]. The value of w/c is restricted to 0.6 because of addition of UPEO which is, also, a liquid. Other wise, 0.7 w/c ratio had been used due the water absorption of natural fibers in cement composites [2]. The slump cone test method is adopted to evaluate the workability of PC, UPC, and UBFRCs. All specimens are cast and tested as per the ASTM standards. After performing the slump test, total 36 number of specimens are cast of PC, UPC, and UBFRCs. Total four cylinders and 2 beamlets are casted of each type of prepared concrete. Two cylinders of each type are used in investigating the compression properties and rest of two are used in determining the splitting-tensile properties of concrete. Flexural properties of each specimen are determined. But here in case of flexural test only beamlets are used. Before the performance of mechanical testing, the dynamic properties are investigated with the help of accelerometer and a hammer. Response-frequency longitudinal (RFL), response-frequency transvers/lateral (RFT), and response-frequency rotational/torsional (RFR) are noted by attaching the accelerometer to the specimen and applying a stroke of hammer for according specific setup of determination of desired frequencies. These frequencies are than used to evaluate the dynamic properties of the all types of manufactured concrete. The fractured surfaces of broken specimens are closely examined as well to check the mixing of fibers within the concrete, bonding of fibers with surrounding cementitious matrix, fiber pull-out, and fiber breakage etc. All specimens are cast and tested as per the ASTM standards. Non-destructive testing are performed before destructive testing. After performing the slump test, total 36 number of specimens are cast of PC, UPC, and UBFRCs. Total four cylinders and 2 beamlets are casted of each type of prepared concrete. Two cylinders of each type are used in investigating the compression properties and rest of two are used in determining the splitting-tensile properties of concrete. Flexural properties of each specimen are determined. But here in case of flexural test only beamlets are used. Before the performance of mechanical testing, the dynamic properties are investigated with the help of accelerometer and a hammer. Response-frequency longitudinal (RFL), response-frequency transvers/lateral (RFT), and response-frequency rota- tional/torsional (RFR) are noted by attaching the accelerometer to the specimen and applying a stroke of hammer for according specific setup of determination of desired frequencies. These frequencies are than used to evaluate the dynamic prop- erties of the all types of manufactured concrete (i.e cylinders and beamlets) The fractured surfaces of broken specimens are closely examined as well to check the mixing of fibers within the concrete, bonding of fibers with surrounding cementitious matrix, fiber pullout, and fiber breakage etc.

1.7 Thesis Outline

The following is a description of the chapters in this thesis:

Chapter 1 introduces the thesis, including the background, research motivation, Problem statement, general and detailed research objectives, work scope, study limitations, methodology, and thesis outline.

Chapter 2 presents a literature review on various topics related to the study, including used petrol-engine oil, banana fibers, recoverable flaws with waste usage, governing values towards improvement in concrete's properties, durability considerations, and design considerations. The chapter concludes with a summary.

Chapter 3 describes the experimental scheme, raw constituents, mix design casting of specimen, testing, and a summary of the chapter.

Chapter 4 presents the detail results obtained from testing and analysis, including the background, dynamic properties and mechanical properties of the mixes (PC, UPC, and UBFRCs), miscellaneous properties, fractured surfaces of tested specimens, and a summary of the chapter.

Chapter 5 outlines the guidelines for practical implementation, including the background, optimization of banana fibers with used petrol-engine oil, empirical relationship, practical implementation, and a summary of the chapter.

Chapter 6 is the conclusion and future recommendation.

At the end, references are provided.

Chapter 2

Literature Review

2.1 Background

Fiber has been used since ancient times to increase mechanical strength parameters and the performance of composites. Natural fibers are favored since they are economical and eco-friendly. The amount of agricultural waste produced annually is measured in the millions of tons. It is need of the time for effective use of these wastes. It is a proven fact that fiber reinforced concrete performs better than conventional concrete. In order to take a step towards sustainable development, it is necessary to investigate the potential of agricultural wastes (natural fiber) as a sustainable construction material.

2.2 Use of Wastes as Construction Materials

With regards to environmental preservation, the construction industry's interest in using waste products as raw materials has been expanding over time. Numerous studies have examined the effects of various waste products on the characteristics of concrete. A number of researchers have used recycled aggregates in concrete to improve the development of sustainable construction materials and cleaner production [16-19]. Various researchers have used glass fiber plastic waste and ceramic waste in concrete [20-23]. Due to their usage as construction materials, agricultural wastes have a significant economic impact all over the world. Natural fibers have helped to build sustainable and ecologically friendly materials by reducing the negative effects of other common hazardous materials. They are used in many different types of composites. Environmentally hazardous materials include the oil used by various sorts of engines and machinery. In order to produce concrete sustainably and to dispose of used engine oil economically, these waste lubricants can be utilized [24]. A research study was conducted by Hamad et al. to investigate the fresh and hardened properties of concrete having used engine oil [25].

Waste engine oil do not have any significant negative impact on the structural components, according to research on the additive effects of used/waste engine oil on the behavior of reinforced structural elements [26]. Waste engine oil cannot be kept and reused in an efficient manner since there is so much of it accessible. It is important to prevent used engine oil from entering the runoff water and combining with it. In the end, it might contaminate the marine and river ecosystems and damage aquatic life. A significant portion of valuable land is covered by the disposal of this trash, which is also harmful to human health [27]. The agricultural waste can also be burned instead of dumped. When a lot of agricultural waste is burned, a lot of heat is released into the atmosphere, affecting the environment and hastening the effects of global warming.

2.2.1 Used Petrol-Engine Oil

Vehicle usage in the transportation sector has been on the rise. The engine is the essential component of the vehicle, and it needs proper lubrication to function efficiently. These lubricants must be replaced after a certain period of engine or motor running. As it contains polluted heavy particles, used petrol-engine oil (used-engine oil) is more hazardous to environment then crude oil. In addition to the heavy particle contamination, the unused oil contains significant amounts of polycyclic aromatic hydrocarbons (PAHs). Used-engine oil, especially used-petrol engine oil, negatively impacts the male reproductive system [27, 28] Waste engine oil can be used in concrete as a chemical additive. According to research, waste-engine oil meets the ASTM C494 standard's criterion for the type A water reduction additive in concrete [29].

Different researchers utilized used engine oil (UEO) in various kinds of composites. In various studies, UEO and used cooking oil were used to contrast and enhance the performance of asphalt pavement [30]. The use of UEO in asphalt pavement did not significantly increase the risk of low temperature cracking, according to research findings [31, 32]. On the other hand, wide number of studies on concrete with the addition of UEO have been reported. For a cost-effective method of dumping and environmental cleanup, the waste from the oil and fat industries was employed as an additive in concrete. UEO helps in the manufacturing of expanded clay aggregates used in research to create lightweight concrete [33-36]. Used petrol-engine oil (UPEO) and banana-fibers (BF) were combined to discover how they affected the concrete's workability. When UPEO was added, the workability increased [36]. Used engine oil can also degrade over time when used as a component in concrete. The degradation of used engine oil in concrete can be influenced by a variety of factors, such as exposure to air, moisture, heat, and chemical reactions with other materials in the concrete[53-55]. In addition to the physical changes that occur with the degradation of used engine oil in concrete, there may also be chemical changes that can result in the release of gases or other harmful substances. For example, the combustion of hydrocarbons in used engine oil can release carbon monoxide, nitrogen oxides, and other pollutants into the air.[56,57]

To effectively mitigate the potential and harmful effects of degradation, it is importance to exercise great care and caution when it comes to utilizing used engine oil as an ingredient in concrete. One must ensure that the mixing and curing process is carried out in a meticulous and thorough manner, taking into account all possible factors that could contribute to the degradation of the material. According to this research, up to 9.4% mass of cement can be reduced and replaced with the UEO. It can be observed clearly that UEO enhanced the slump value of concrete. The initial setting was not affected but a delay observed in final setting time in comparison to normal plain concrete. The 28 days' compressive strength-

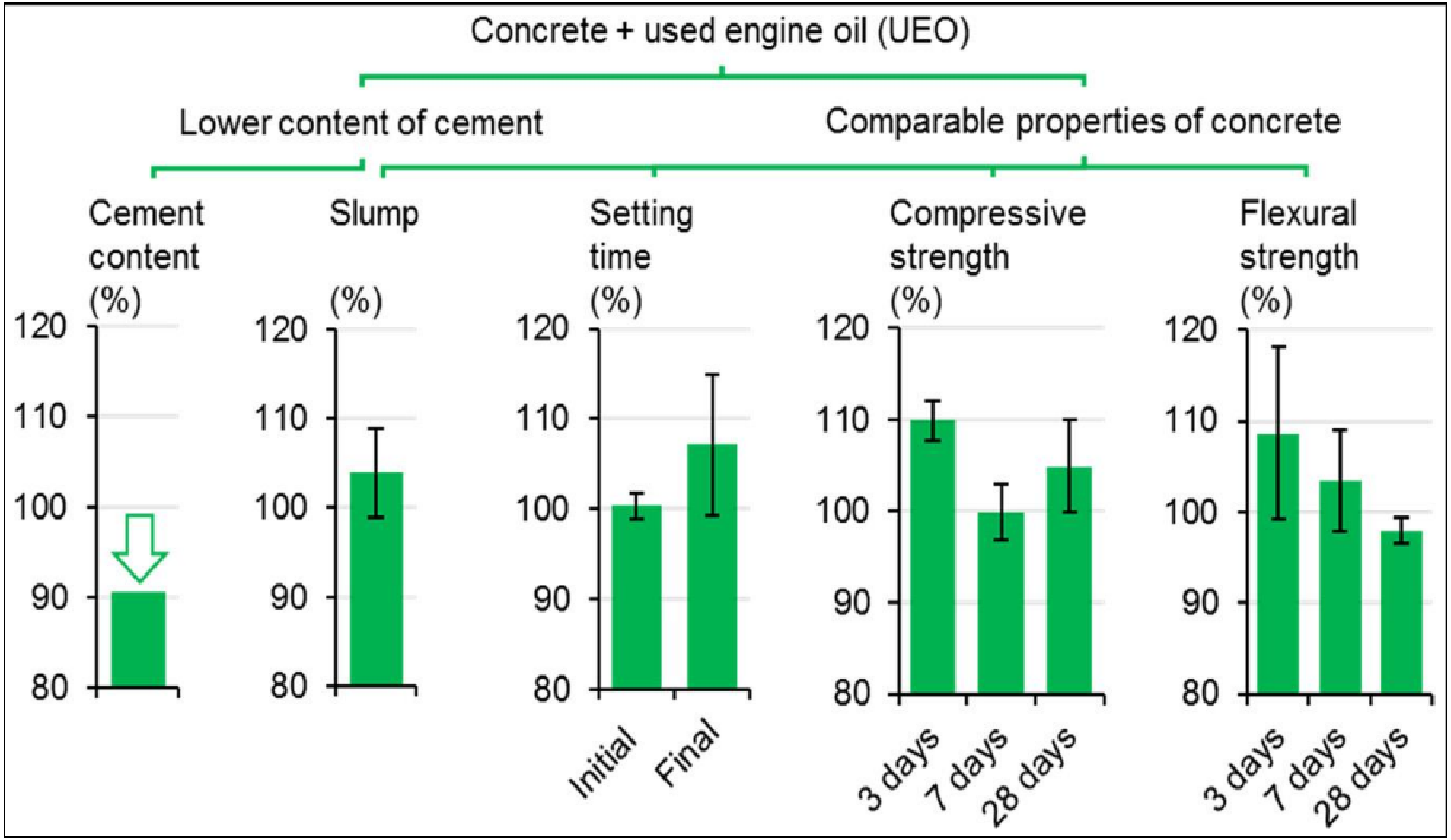

Figure 2.1: Effects of Addition of Waste Engine Oil (UEO) on Concrete's Properties [36]

was improved but a minor decrease was observed in 28 days' flexural strengths. The Figure 2.1 shows the influence of UEO in concrete [56]. UEO fulfills the ASTM C494 and it can be used as water reducing admixture. As per the results, the cement in concrete can be replaced up to 9.4% by mass and comparable properties can be achieved.

2.2.2 Banana Fibers

Various researchers have used natural fibers in composites in different ways and examined the impact that the adding of fibers was expected to produce. For the purpose of plastering the surface of structural components and walls, researchers used coconut fiber [37]. In a research study, an improvement was observed in out-plane lateral loading of the column with natural fibrous plaster on the column [25]. The researchers illustrated in a research that the treated fiber within the cement mortar improved the characteristics and durability properties of the composite [23]. Coconut fibers and coconut-fiber ropes were used in studies to enhance the resistance against the dynamic loading and significant improvement was noticed [38]. Banana fibers (BFs) are a readily available agricultural waste product worldwide, originating from banana farming. They have a variety of eco-friendly qualities, such as low density, light weight, low cost, water and fire resistance, and great tensile strength. Amorphous matrices of hemicelluloses and lignin make up the lignocellulosic materials that make up BFs, which are made of cellulose microfibrils embedded in a matrix. Both the amount of cellulose and the microfibril angle affect the fibres' mechanical characteristics. Banana fibres with a high cellulose concentration and low microfibril angle are capable of obtaining the requisite mechanical characteristics. Additionally, lignins are connected to hemicelluloses and considerably increase the lignocellulosic material's natural resistance to destruction. The water retting method, which includes submerging banana stems acquired from a farm in clean, potable water for six weeks, is used to extract BFs.The stems are then taken out of the water, loosened, and cleaned in a tank of clean water. The fibres are then cut to the proper length after being hand combed and sun-dried to further separate them. In a research work the influence of natural

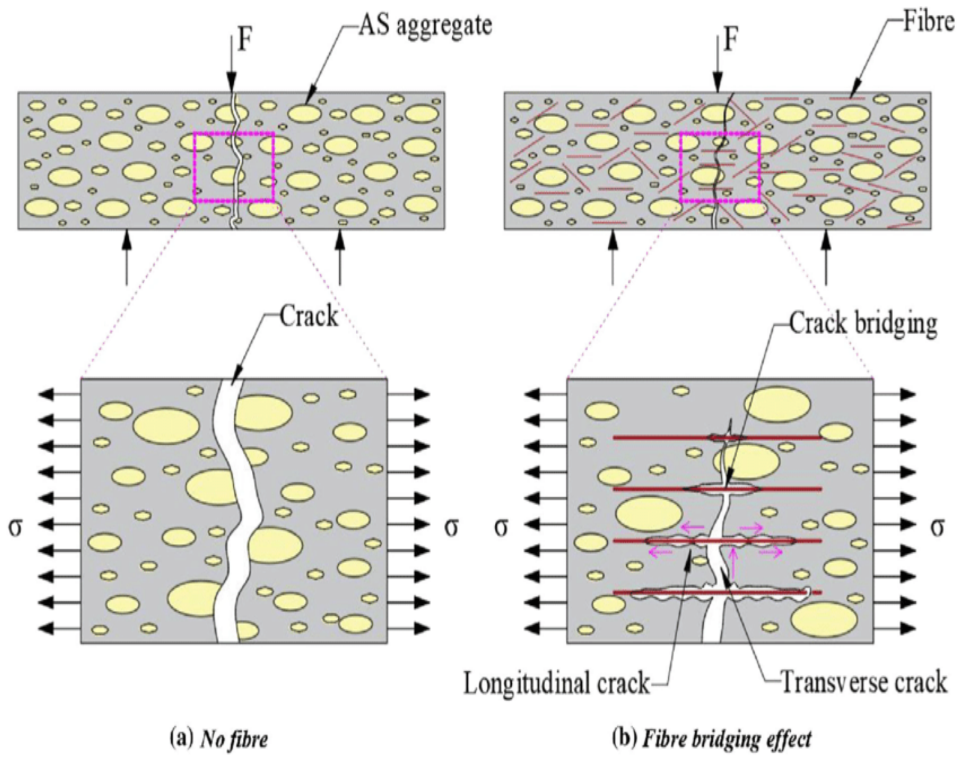

FIGURE 2.2: Schematic Diagram of Fibre Bridging Effect [57]

fibers on self-compacting concrete was investigated [6]. Increment in the length of wheat straw fiber resulted in an increase in pullout peak load and pullout energy [39]. Natural fiber act differently in cement mortar and lime mortars. Natural fibers acted in favor of durability and the strength of the cement mortar [40]. A good mix design, more amount of fibers, and a large value of the water-cement ratio (for natural fibers) lead toward the great toughness and good strength of the composite [41]. The more quantity of banana fibers along with jute fibers in the composite resulted in an increase in the splitting-tensile strength, flexural strength, and impact resistance of the composite [13]. In comparison with other fibers, banana fiber has more average tensile-strength than coconut fiber, bamboo fiber, palm fiber, and sisal fiber [13]. The addition of banana fibers has caused an improvement in tensile strength of composite [42, 43] due to bridging effect as shown in **Figure 2.2**.

Chemical treatments can increase the strength of banana fibers (BFs) by eliminating impurities and improving wettability. There are several chemical treatments available to purify and strengthen natural fibers, with alkali treatment producing the best results. Water tends to be absorbed by BFs, especially in the first few hours after immersion. The surface roughness of the fibres is increased by alkali treatment, which enhances mechanical bonding and reduces water absorption. However, alkali treatment modifies the fibres' botanical constituents. Elbehiry and Mostafa (2018) evaluated the effects of sodium hydroxide at a concentration of 6 % for two hours at room temperature. Following a thorough rinsing in a water tank to get rid of any inactive reactions and make sure they were alkali-free, the fibres were dried for 24 hours at 80 °C. By soaking the fibres in NaOH solutions with concentrations ranging from 5 to 15 percent for three hours, Nor Azwin bt Ahad et al. (2019) evaluated the impact of the BF treatment. Since contaminants were observed on the surface of untreated fibers, the study concluded that the application of NaOH to the fibres from banana and coconut husks eliminated the contaminants. Alkaline treatment also increased the quantity of exposed cellulose on the surface and roughened the surface of the fibers, which can aid in interlocking the fibres and matrix.

A research study was conducted using the banana fiber bars as reinforcement. According to this study, the ability of concrete to resist cracking and spalling was increased [3]. Based on the findings of a comprehensive research study, it can be asserted that the incorporation of banana fiber bars as a reinforcing agent in concrete has been demonstrated to significantly enhance the material's ability to withstand cracking and spalling. Therefore, this study underscores the potential benefits of utilizing such natural fibers as an effective and sustainable solution for reinforcing concrete structures. The use of banana fibers significantly enhanced the resistance against cracking in the concrete beams [34]. This shows that addition of natural fiber contributed to reduction of depth of the concrete section by improving the flexural strength of concrete. The addition of banana and water hyacinth fibre to concrete was made using bio fillers, according to experimental research. The mechanical features of concrete—the maximum bearing load capacity, splitting-tensile strength, flexural strength, and compressive strength—as well as its physical characteristics—true density, bulk density, and water absorption—were improved by the introduction of water hyacinth and banana fibres. Banana fibre reinforced concrete was subjected to mechanical testing, and cement was substituted with banana leaf ash. Flexural strength and tensile strength were shown to have increased based on test findings [10].

2.3 Recoverable Concrete's Flaws with Waste Usage

There is no good building or construction material that can replace concrete in construction projects. In the construction industry, concrete is considered as a foundational element. Despite concrete's superiority, there are still a number of defects that need to be reduced or managed. The effects of flaws as weak in tension, cracking vulnerability, low impact resistance, and spalling, etc. The use of agricultural waste as dispersed reinforcement in concrete could, in some ways, reduce the impact of these flaws. The resistance to impact loading increased as a result of using agricultural waste and glass fiber reinforced polymer bars together [44, 45]. Utilizing both glass and steel fibers improved the energy absorption's ability to resist cracking again [46, 47]. The addition of jute fibers to concrete improved its resistance to impact loading and seismic performance [36, 48]. Concrete performed better when fine aggregates were swapped with the proper amounts of waste marble powder, that also provides an approach to sustainable development [36]. The behavior of mortar-free blocks to dynamic loads was studied using coconut fiber ropes generated from agricultural waste. The addition of glass fiber reinforced plastic waste increased the flexural strength of the concrete . Plastic waste and palm oil fuel ash combined to increase the ductility and energy absorption capabilities of concrete. In last 100 years, concrete production had imposed adverse ecological effects on environment. So, it is exerting contrary effects than benefits. Billions of tons of concrete are produced every year which emit carbon dioxide during mixing process and require large quantity of raw materials. The cement industry generated the total carbon dioxide of the world [11]. The agricultural and industrial wastes produced in urban and rural areas need proper disposal. The recycling of wastes to useful products is the solution of the crises of dumping wastes. The byproducts like silica fume, fly ash, granulated blast slag and palm oil fuel ask had been used as sustainable construction materials [12]–[37]. These materials can be utilized in concrete for further use in different structural elements. Jute fiber was used by [46] as sustainable material for pavement application for freeze-thaw conditions. It was observed that the jute fiber reinforced concrete reduced the freeze-thaw effect. By the incorporation of jute fibers, the pavement with reduced thickness showed same results as compared with the pavement laid by the conventional concrete. The wheat straw has good properties to be used in cement composites as per studies conducted on the wheat straw fiber reinforced concrete. Wheat straw had been used by different researchers for application in concrete [13], [50]. A biobased composite i.e., wheat straw concrete was developed for the purpose of thermal insulation. The outcomes indicated that the biobased composite developed by using wheat straw showed excellent hygric properties. These properties can ensure the building's hygrothermal comfort [51]. Wheat straw was used in cement-based mortar for attaining sustainable cement mortar. Fiber length are used with fixed oil content. Natural fibers like banana fibers are locally available and used engine oil are also available. There is no proper method used to prepare thes material. Which are locally available in market with out treatment. Under the impact compression loading the specimen did not separate apart but only showed discrete cracking. The overall mechanical properties were enhanced with no change in thermal properties.

2.4 Governing towards Improvement in Concrete's Properties

Macro cracks are formed by the amalgamation of micro cracks. The properties and performance of concrete are affected by cracking and independent size of crack. The propagation of crack affects the concrete strength [49]. The phenomenon of cracking in concrete depends upon the properties of concrete [34]. The properties those influence the performance of the structure includes compressive strength, splitting-tensile strength, and flexural strengths. Splitting-tensile strength resists and control the cracking in concrete [39].

The durability and design of structure are affected up to some limits by above mentioned properties of the concrete. By making certain changes in production of concrete can alter the properties of concrete. This can be done, up to certain limits, by changing and/or introducing the ingredients to design consideration and durability considerations.

2.4.1 Material Behavior with Wastes

The ability of concrete to withstand abrasion, chemical attacks, and weathering over an extended period of time is commonly referred to as its durability. It is apparent that the mechanical properties of concrete play a significant role in durability in order to produce a construction material that is durable and extends the life of a structure. As concrete is a brittle material with weak flexural and tensile strength relative to compressive strength, durability of concrete depends on these properties as discovered in a research study [18]. Within 24 hours of concrete placement, the very first cracks were discovered on the concrete surface. At that time, composite does not have the ability to resist these microscopic cracks caused by ageing. durability of concrete means that ability of concrete to resist and with stand longer against weathering actions, checmical attacks and abrasion during the service. To obtain a durable construction material and service life of structure, it is obvious that mechanical properties of the concrete play important role to durability. In a research study, it was explored that the durability depend upon tensile and flexural properties of concrete are important as concrete is a brittle material, weak in flexural and tensile strength compared to compressive strength. The very first cracks found on the surface of the crack within 24 hours after placing of concrete [47]. At that time, composite does not have sufficient strength so it can resist these early age micro cracks. To avoid and resist these types of cracking there is need to add some additional constituents in concrete. The durability of concrete has inverse relation to linear shrinkage. On the other hand, high water absorption property of concrete has direct relation to durability of concrete and under severe environmental conditions, can cause corrosion of steel reinforcement inside concrete having cracks. The durability of structure also depends upon the width of produced cracks and structural properties of concrete.

2.4.2 Strength Properties

There is need to add some additional ingredients to concrete in order to prevent and resist these types of cracks. Linear shrinkage has an inverse relationship with concrete durability. On the other hand, a high water absorption property of concrete has a direct correlation to concrete durability and can lead to corrosion of the steel reinforcement inside of cracked concrete under severe environmental conditions. Additionally, The durability of structure also depends upon the structural properties of concrete and width of produced cracks [50]

2.4.3 Water Absorption Properties

Compressive strength, splitting-tensile strength, and flexural strength are the key factors that determine the strength and design of structural members. Compared to tensile strength, concrete is much stronger under compression. Due to this, concrete's splitting-tensile and flexural strengths are given more importance in design structural members of concrete. In the different applications and according to strength aspects, splitting-tensile strength and flexural strength are given more importance than the compressive strength like in rigid pavement and beams, respectively. This splitting-tensile strength resist cracks caused by the shrinkage stresses. To obtain sustainable and high-strength material, banana fiber can enhance the mechanical properties of concrete.Water are absorb more in concrete of banana fiber mixed then PC concrete as pore available in banana fiber reinforced concrete.Water are absorb in concrete of banana fiber then PC concrete as pore available in banana fiber reinforced concrete. As water gets absorbed into the concrete matrix of banana fiber reinforced concrete, it fills up the pores present in the banana fibers, allowing for the effective transfer of stress between the fibers and the surrounding matrix of Portland cement concrete. Water absorbed more in concrete of banana fiber mixed then PC concrete as pore available in banana fiber reinforced concrete specimens.

2.4.4 Dynamic Properties

The researchers have investigated that concrete can be produced by replacing some amount of UPEO with cement comparable with PC. UPEO can be used as admixtures to reduce the cement content within the concrete result in minimize the cost production [13]. by improving concrete's mechanical and durability properties higher, the deterioration of concrete can be avoided. Natural fibers are locally available and used engine oil is very dangerous to environment as it is not dumped. We used both natural fiber and locally available these engine oil with out treatment.Natural fibers are locally available and used engine oil is very dangerous to environment as it is not dumpted. We used both natural fiber and locally available these engine oil with out treatment. used engine oil plain concrete specimens dynamic properties are good as compare to PC. Dynamic modulus of elasticity shown better values then dynamic modulus of rigidity. This highlights the importance of carefully assessing the intended use of concrete and selecting the appropriate strength criteria accordingly to ensure optimal performance and longevity of the structure. In the different applications and according to strength aspects, splitting-tensile strength and flexural strength are given more importance than the compressive strength like in rigid pavement and beams, respectively. This splitting-tensile strength resist cracks caused by the shrinkage stresses. To obtain sustainable and high-strength material, banana fiber can enhance the mechanical properties of concrete. The researchers have investigated that concrete can be produced by replacing some amount of UPEO with cement comparable with PC. UPEO can be used as admixtures to reduce the cement content within the concrete result in minimize the cost production [6]. by increasing concrete's mechanical and durability characteristics improved, the deterioration of concrete can be avoided

2.5 Summary

The discussion above comes to the conclusion that adding natural fibers and the admixture to concrete can enhance its durability-related properties. To prevent cracking and the growth of micro - cracks into macro cracks, it is necessary to improve mechanical and dynamic properties. It is clear from this chapter that banana fiber enhances the concrete's splitting-tensile strength and crack resistance. On the other hand, used petrol-engine oil can be used as a chemical admixture to concrete. Used petrol-engine oil improves the concrete's compressive strength to some level. The literature comes to the conclusion that used petrol engine oil has potential and can be used in combination with natural fires that have the same chemical (acid) nature as used petrol engine oil.

Chapter 3

Experimental Scheme

3.1 Background

Natural fibers are increasingly being used in concrete due to their low cost, simple handling, strong mechanical properties, easy availability, and environmentally friendly nature. In this research, used petrol engine oil is used as a chemical admixture in the production of concrete and banana fiber is used as reinforcement. The utilization of banana fibers and used petrol engine oil in various studies is discussed in detail in the previous chapter. However, the combined effects of used petrol engine oil and banana fibers have not yet been studied. Therefore, Slump cone test, dynamic test, mechanical test, tests for mass loss, linear shrinkage, and water absorption are taken into consideration. Broken specimens' fractured surfaces are also investigated at. These fiber length are used with fixed used engine oil content. Natural fibers like banana fibers are locally available and be cut into required length and used engine oil are locally available. The banana fiber having required cut lengths were commercially obtained from the market. Superplasticizer (Sika® ViscoCrete®-20 HE) was used in the UPC specimen to enhance strength of concrete. Superplasticizer was used 1% in UPC specimen by mass of cement. All these material cannot be treated. This chapter examines in great detail about the raw ingredients, fibre treatment, PC, UP, and UBFRCs mixing processes, casting process, and testing methodologies.

3.2 Raw Constituents

Ordinary Portland cement, Margalla crush, and readily available local sand are used to create normal plain concrete (PC). For the production of both fibers reinforced concrete and plain concrete, the aggregate size limit is 20 mm (FRC). While creating UPC and UBFRCs, UPEO is used as an admixture.the maximum permissible aggregate size is 20 mm. As for used petrol engine oil plain concrete (UPC) and used petrol engine oil banana fiber-reinforced concrete (UBFRC), used petroleum engine oil (UPEO) is incorporated as an admixture. It should be noted that all of the materials utilized in this study were sourced from local markets and were not subjected to any form of treatment or modification prior to use.

It should be noted that this research used commercially available UPEO. Since UPEO is considered as waste material industry, there is no information on its characterization. Banana fiber is used for the preparation of FRC. 3% BF content (by cement mass) was used. Varying lengths (3+5 cm, 3+7 cm, 5+7 cm, 3+5+7 cm) of fiber is used in the preparation of the FRC. Equal percentage of cut length are considered (for 3+5cm, 3+7cm, 5+7cm, 1.5% fiber for each length are considered; and for 3+5+7cm, 1% fiber for each length are considered). The banana fibers having required cut lengths were commercially obtained from the market. UPEO is used within plain concrete to prepare used petrol-engine oil added plain concrete (UPC) and FRC. Superplasticizer (Sika® ViscoCrete®-20 HE) was used in the UPC specimen at 1% by mass of cement. The PC, UPC, and UBFRCs are prepared using normal-temperature tap water. Different type of specimens is manufactured using two different water-cement ratios. For the creation of PC and UPC, a water-cement ratio of 0.5 is used, and a ratio of 0.6 is used for all UBFRCs. increase english " According to a literature review, the BF (natural fibers) have a higher water absorption property, which has resulted in an increase in the water ratio for UBFRCs. Other raw material used for this research like used engine oil and admixture are arrange from local market. It should be noted that all of the materials used in this research were sourced from local markets and were not subjected to any form of treatment or modification prior to use. Loclly available materials like natural fiber and used engine oil are used.

3.3 Mix Design, Concrete Preparation, Fresh Properties, Casting of Specimens and Density Determination of Hard Concrete

The ratio of cement, sand, and aggregate in the mix design is 1:2:4 for the preparation of PC. Fixed amount 9.4% of UPEO by mass of cement is used for the preparation of UPC. For the preparation of used petrol engine oil banana fiber reinforced concrete (UBFRC), fixed proportion 3.0% and varying length (3+5 cm, 3+7 cm, 5+7 cm, 3+5+7 cm) BF are added to the mixture together with the UPEO. All the material is placed in the drum mixture for preparing the PC mix. Then water is added, in mixture machine, 30-45 seconds after start of rotating the mixture machine. The mixture machine is rotated for the five minutes. The slump cone test is performed after preparation of PC. For the preparation of the UPC, same procedure repeated with a change that used petrol engine oil is added one minute later after addition of the water. The rotating time for mixture is kept same five minutes as for the PC mix.

For the manufacturing of BFRC with varying length of (3+5 cm) and fixed content of 3.0% banana fiber by the mass of cement, the materials are placed in the form of layers to achieve the good mixing of fiber within the concrete. Three set of layers is used to‘ make a good mix of the UBFRC. One third set of layers of aggregates, sand, banana fibers and cements placed in the mixer machine. Then the second and third set of layers of aggregate, sand, banana fibers and cement are placed with the same approach. Then the mixture machine turned on to start rotating. And the two third water is added with the start of machine. Three minutes after of continuous rotation of mixer machine, remaining one third quantities of water and UPEO are added and mixture machine is kept rotating for further two minutes and slump cone test is performed to check the workability of the fresh UBFRC. Same approach was for the remaining the types of UBFRCs with varying length (3+7 cm, 5+7 cm, 3+5+7 cm) and fixed content (3.0%) of banana fibers. For the manufacturing of BFRC with varying length of (3+5 cm) and fixed content of 3.0% banana fiber by the mass of cement, the materials are placed in the form of layers to achieve the good mixing of fiber within the concrete. Three set of layers is used to‘ make a good mix of the UBFRC. One third set of layers of aggregates, sand, banana fibers and cements placed in the mixer machine. Then the second and third set of layers of aggregate, sand, banana fibers and cement are placed with the same approach. Then the mixture machine turned on to start rotating. And the two third water is added with the start of machine. Three minutes after of continuous rotation of mixer machine, remaining one third quantities of water and UPEO are added and mixture machine is kept rotating for further two minutes and slump cone test is performed to check the workability of the fresh UBFRC. Same approach was for the remaining the types of UBFRCs with varying length (3+7 cm, 5+7 cm, 3+5+7 cm) and fixed content (3.0%) of banana fibers

For the preparation of used petrol engine oil banana fiber reinforced concrete (UBFRC), fixed proportion 3.0% and varying length (3+5 cm, 3+7 cm, 5+7 cm, 3+5+7 cm) BF are added to the mixture together with the UPEO. To assess the workability or consistency of the manufactured precast concrete (PC), a slump cone test is conducted prior to pouring the concrete into molds. The ASTM standard C143/C143M-15a is followed, which specifies that the test be carried out with a slump cone having a bottom diameter of 200 mm (8 in), top diameter of 100 mm (4 in), and height of 300 mm (12 in), and a non-absorbent mold. The cone is filled with three equal volumetric layers of concrete, each of which is compacted 25 times with a tamping rod having a hemispherical end and a diameter of 16 mm (5/8 in) and length not exceeding 600 mm (25 in). The excess concrete is removed by striking off the tamping rod, and the surface is smoothed with screeding and rolling. The slump cone is lifted vertically upward, and the length of the reach over the concrete is measured using a ruler to determine the value of slump.

No standard test is available for evaluating the workability of fresh ultra-high-performance concrete (UPC) and ultra-high-performance fiber-reinforced concrete (UBFRC). Therefore, the same procedure and test standard used for PC is adopted for determining the workability of UPC and UBFRCs, to the best of the authors' knowledge. The relation between the observed slump values and determined hard densities are given in figure 3.1. Once the mixing is complete, the specimens are cast, and mechanical tests are carried out at 28 days after curing. Prior to dynamic testing, tests such as water absorption, mass loss, and linear shrinkage are conducted. Once all the tests are completed, the results are compiled, and figures and tables are created to represent the findings. Subsequently, a conclusion is drawn based on the results. For measuring the densities, an average of two specimens is taken for each mix design. The volume of the beamlets is determined in terms of m3 by taking the internal volume of the moulds that are used for the casting of the beamlets. After the final setting time of the concrete, moulds are then removed and the mass in kilograms of each specimen is noted by using the weighing balance. The least count of weighing balance used for the determination of the masses is 5 grams. The densities are found by taking ratio of weight (kg) and volume (m^3). Before casting of specimes will check fresh properties of concrete.Water to cement ratio and other values like slump value are also checked before casting of specimens same is case check density determination before casting. After mixing, casting of specimens other tests like mechanical tests are performed after 28 days and after curing. Water Absorption, Mass loss and Linear Shrinkage are performed before dynamic testing. After all these tests result are to be compile and figures and table are made of these result. After this all work conclusion are made and for futher work recommendations are made. The fiber length are used with fixed oil content. Natural fibers like banana fibers are locally available and be cut into required length and used engine oil are locally available.

The workability of fresh concrete and density of hard used petrol engine oil plain concrete (UPC) and used petrol engine oil banana fiber-reinforced concrete (UBFRC) cannot be evaluated using standard tests, as far as the authors are aware. Therefore, the same procedure and test standard are used to determine the workability and densities of UPC and UBFRC.Following the mixing process, the specimens are cast, and various mechanical tests are conducted after 28 days of curing. Water absorption, mass loss, and linear shrinkage tests are then performed before the dynamic testing phase. Subsequently, all of the collected results are compiled and presented in figures and tables. Based on these findings, conclusions are drawn, and recommendations are provided for further work in this field.

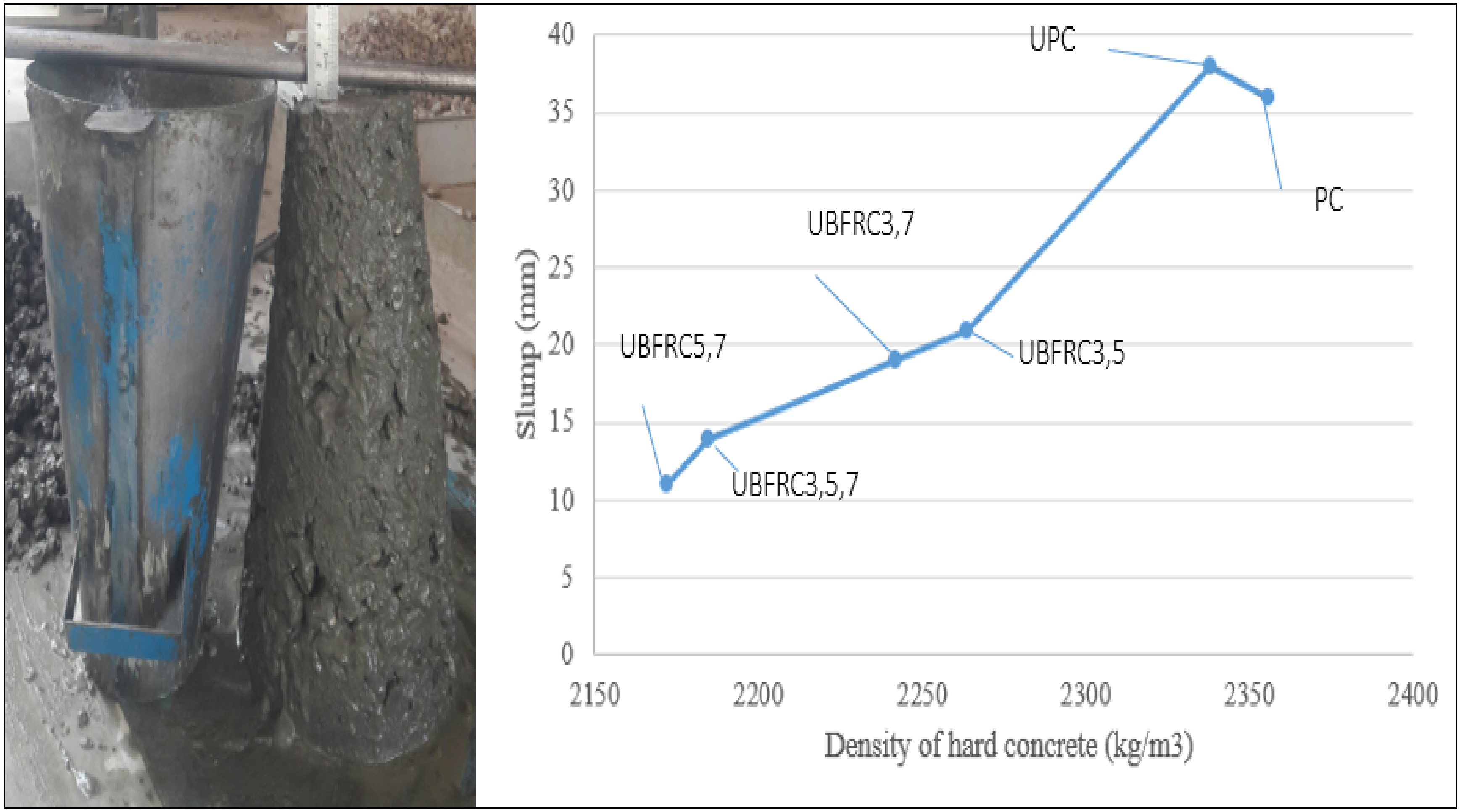

FIGURE 3.1: a) Measuring the Value of Slump of UBFRC, b) Combined effect of UPEO and BF on the relation between slump of fresh concrete and density of hard concrete

Table 3.1: Mix Design, Specimen Labeling, Slump of Fresh Concrete, and Density of Hard Concrete

Labeling	C:S:A	Addition of percentage by cement mass				W/C	Slump of fresh concrete	Density of hard concrete
		UPEO	SP	BF	BF Length (cm)	(-)	(mm)	(kg/m^3)
PC	1:2:4	0	0	0	0	0.5	36	2356
UPC	1:2:4	9.4	1	0	0	0.5	40	2338
UBFRC3,5	1:2:4	9.4	0	3*	3+5	0.6	23	2264
UBFRC3,7	1:2:4	9.4	0	3*	3+7	0.6	19	2242
UBFRC5,7	1:2:4	9.4	0	3*	5+7	0.6	17	2185
UBFRC3,5,7	1:2:4	9.4	0	3**	3+5+7	0.6	13	2172

* 1.5% for each length text   ** 1.0% for each length

3.4 Testing Methodology

All tests conducted in this study are summarized in Table 3.2 and explained in following sections. The mechanical tests (i.e. destructive testing) are conducted after the dynamic and miscellaneous tests. In miscellaneous tests, selected specimens of all combinations were exposed to different exposure conditions as per their standards in order to check the maximum degradation in specimens strengths. **Figure 3.2** shows different test setups.

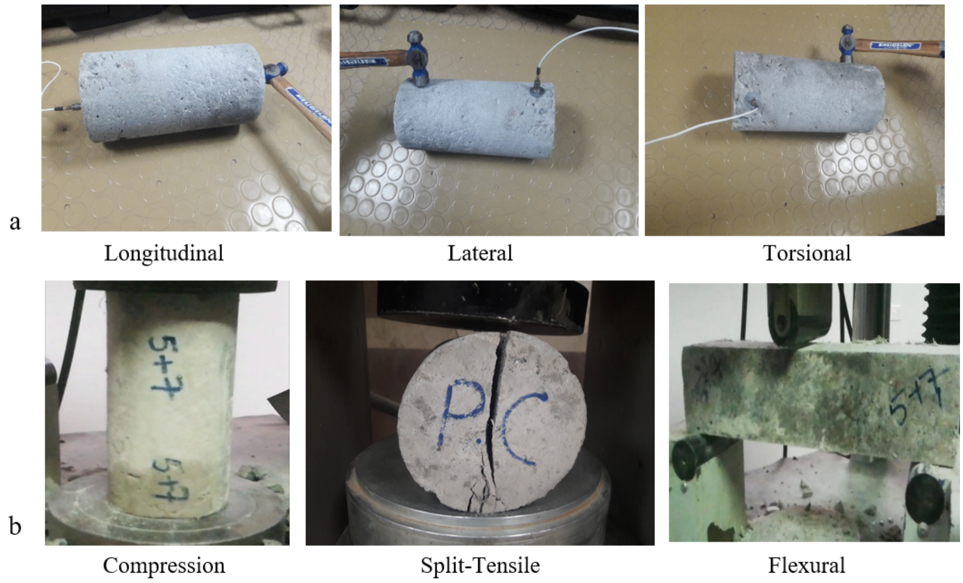

FIGURE 3.2: Tests Setup; a) Dynamic Test, and b) Mechanical Properties

3.4.1 Dynamic Tests

Dynamic test is performed before the destructive (mechanical) testing of the specimens as per ASTM 215-14. Response frequencies lateral (RFL), response frequencies transverse (RFT) and response frequencies rotational (RFR) are determined with the help of hammer and accelerometer. The test is conducted on both cylinder and beamlets. For determining the RFL, the accelerometer is attached to once side of cross section of cylinders and beamlets while a strike of hammer is given to the opposite side of the cross section of specimens. The accelerometer observes the frequencies and transfer the record of these frequencies to the computer attached with it. The procedure of RFT and RFR attaching the accelerometer and strike location of hammer is different for cylinders and the beamlets. In case of cylinders, for RFT, the accelerometer is attached at side showing face of length of cylinder at least 25 cm away before the edge. Then a strike of hammer is given at same side showing face on the center of cylinder's length.

For RFR, the accelerometer is attached at top showing face of length of cylinder with same space from the edge like RFT. The strike is given at perpendicular accelerometer on opposite edge of the cylinder length. In case of the beamlets, for RFT determination, accelerometer attached at one side of length at same margin, used for cylinders, on length of beamlets from edge. Strike of hammer is given at center of length of same side at which accelerometer is attached. For RFR, the accelerometer is attached at top corner of rectangle (side face of the beamlet). A strike is given at other side bottom corner of same side of rectangle in such a way that line joining the point of hammer's strike and accelerometer make the diagonal of the rectangle. From these observed frequencies, damping ratio, dynamic modulus of elasticity, the dynamic modulus of modulus of rigidity and poison's ratios are calculated. These calculated properties support to understand the behavior and resistance of PC, UPC, and all types of UBFRC against the dynamic loading. These properties are key to the design of structure undergoing the dynamic loadings and earthquake

3.4.2 Miscellaneous Tests (Water Absorption, Linear Shrinkage, and Mass Loss)

To calculate the water absorption properties of PC, UPC, an d UBFRCs, the ASTM C642 standard is followed. First of all, specimens are dried in the oven and then these dried specimens are placed, at room temperature, in water. This method is used to determine the water absorption property of all types of specimens. For the evaluation of linear shrinkage, ASTM C157 / C157M-08 is followed by observing and measuring the variations in the length of specimens (OPSS standard LS-435). For this purpose, a line of 6 inches is marked as a reference on the length of specimens before conducting the test. The variation of the length is

TABLE 3.2: Standards Testing and Studied Parameters

Test	**Standards / References**	**Parameters Considered for the Study**
1. Dynamic Properties	ASTM 215-14	Resonant frequency longitudinal (RFL), Resonance frequency transverse (RFT), Resonance frequency torsional (RFR), damping ratio (), Poisson ratio, dynamic modulus of elasticity and dynamic modulus of rigidity (Ed)(Rd).
2. Miscellaneous		
a. Water Absorption	ASTM C642-13	Water absorption (%)
b. Linear Shrinkage	ASTM C157	Linear shrinkage (percentage decrease),
c. Mass Loss	ASTM C157M-08	Mass loss by gradually increasing temperature
3. Mechanical Properties		
a) Compressive Properties	ASTM C39	Stress-strain curves, compressive strength (CS), modulus of elasticity (MOE) compressive pre-crack energy absorption (CE1).

Test	Standards / References	Parameters Considered for the Study
		Compressive toughness indexes, compressive post-crack energy absorption (CE2), and compressive total energy absorption (CTE) (CTI).
b) Splitting Tensile Properties	ASTM C496M-02	Load-deformation curves, splitting-tensile toughness indexes, splitting-tensile strength (SS), splitting-tensile pre-crack energy absorption (SE1), splitting-tensile post-crack energy absorption (SE2), and splitting-tensile total energy absorption (STE) (STI).
c) Flexural Properties	ASTM C78	Load-deflection curves, flexural toughness indexes, flexural strength (FS), flexural pre-crack energy absorption (FE1), flexural post-crack energy absorption (FE2), and flexural total energy absorption (FTE) (FTI).
4. Role of Fibers in Concrete	Affan, M (2019)	Broken surfaces of specimen, failure mechanism of fibers, and bonding of fiber with the surrounding matrix

measured after following the procedure of standard. measured after following the procedure of standard.

The linear shrinkage is then measured by taking percentage difference of marked length before and after the test procedure. ASTM C157M-08 is used for the determination of mass loss in PC, UPC and UBFRCs.

After following the test procedure, various result are obtained related to shrinkage water ratio and mass loss. As pore are increases due to fibers. When fibers increasing in contents are with length. Shrinkage are less as compare to other miscelenious values like mass loss. Variations and shrinkage in the reference line are marked before being evaluated. Each type of concrete mix specimen is placed in a high-temperature heating oven. After following the test procedure, various result are obtained related to shrinkage water ratio and mass loss. As pore are increases due to fibers. When fibers increasing in contents are with length. Shrinkage are less as compare to other miscelenious values like mass loss. Variations and shrinkage in the reference line are marked before being evaluated. Each type of concrete mix specimen is placed in a high-temperature heating oven.The temperature is raised from 20°C to 100°C at the rate of increase of 3°C per minute and maintained at 100°C for one hour. This is done to obtain more realistic data. Then specimens are cooled down with the same rate of decrease in temperature at 3°C to avoid thermal cracking.The temperature is raised from 20°C to 100°C at the rate of increase of 3°C per minute and maintained at 100°C for one hour. This is done to obtain more realistic data. Then specimens are cooled down with the same rate of decrease in temperature at 3°C to avoid thermal cracking.

3.4.3 Mechanical Tests

a) Compression test

A servo-hydraulic testing machine (STM) is used for the determination of the compressive strengths of PC, UPC, and UBFRCs. The test is performed according to ASTM C39 on cylinders of PC, UPC, and UBFRCs.

In this test properties are determined to include compressive strength (CS), compressive behavior, compressive pre-crack (CE1) and post-crack energy (CE2), compressive total absorbed energy (CTE), and the compressive toughness index (CTI) of PC, UPC, and UBFRC. To distribute the load uniformly throughout the cylinder the capping of the cylinder is done with the plaster of paris.

b) Splitting Tensile Test

ASTM C496M-02 standard is used for the splitting-tensile test.

The same machine STM is used for performing the test. The test is performed on the cylinders of PC, UPC, and UBFRCs. The capping of cylinders is not required in the case of the splitting-tensile test. From this test, load-deformation curves, splitting-tensile strength (SS), splitting-tensile pre-crack energy absorption (SE1), splitting-tensile post-crack energy absorption (SE2), splitting-tensile total energy absorption (STE), and splitting tensile toughness indexes (STI) are calculated.

c) Flexural Test

The flexural test is performed on the basis of standards ASTM C78. Flexural test in performed in Servo-Hydraulic Testing Machine. The three-point loading mechanism is adopted. The test is performed on the beamlets of PC, UPC, UBFRCs. Two specimens are prepared for each length, and the average result is taken after testing. The studied parameters in this test are load-deflection curves, flexural strength (FS), flexural pre-crack energy absorption (FE1), flexural post crack energy absorption (FE2), flexural total energy absorption (FTE), and flexural toughness indexes (FTI).

3.4.4 Visual Inspection of Crack Surface

After performing the mechanical testing, the fractured surfaces of broken specimens are examined carefully. In this examination, fiber breakage, pullouts, and bridging effect due to fibers are investigated. For this purpose, microanalysis is done carefully over the broken surfaces of the tested samples. From the fracture surfaces, mixing of all the ingredients can be observed, either it is a good mix or not. It is through achieving a proper mixing of ingredients that the desired properties can be obtained. Good mixing of ingredients results in achieving the desired property, otherwise, it can lead to digression of the property instead of increasing it. The basic purpose of this investigation is to elaborate the failure mechanism of fibers and the bonding of the fibers with the surrounding matrix. Following mechanical testing, the shattered surfaces of the damaged specimens are closely inspected. This investigation looks at fibre breakage, pullouts, and abridging effects caused by fibres. Microanalysis is carefully performed across the damaged surfaces of the analysed materials for this reason. The blending of all the materials, whether it is a good combination or not, can be seen on the fracture surfaces. It is through achieving a proper mixing of ingredients that the desired properties can be obtained. Good mixing of ingredients results in achieving the desired property, otherwise, it can lead to digression of the property instead of in

-creasing it. It is a good mix or not.

If ingredients are mixed properly, the intended characteristic is produced; if not, the property may actually decrease instead of increase. Fibers after cracking of concrete material have the ability to control brittle failure of concrete. Thus by using fiber brittle nature of fiber to ductile nature. And these type of fiber are locally available. but strength of concrete is reduced specially compressive strength. The main goal of this inquiry is to clarify the connection between the fibres and the surrounding matrix and the failure mechanism of the fibres.

3.5 Summary

PC, UPC, and UBFRCs are prepare using the 1:2:4 mix design, which is the most widely used. The UBFRCs used 0.6 w/c whereas the PC and UPC used 0.5 w/c. For the preparation of UPC and UBFRCs, a fixed amount of 9.4% of UPEO by mass of cement is used. For the preparation of used petrol engine oil banana fiber reinforced concrete (UBFRC), fixed proportion 3.0% and varying length (3+5 cm, 3+7 cm, 5+7 cm, 3+5+7 cm) BF are added to the mixture together with the UPEO. Total number of 36 specimens are prepared in which 24 are cylinders and 12 are the beamlets. ASTM standards are followed in slump, dynamic, mechanical, and miscellaneous tests of PC, UPC, and UBFRCs. The evaluated results of each corresponding tests are discussed in detail in next chapter (i.e., chapter 4).

Chapter 4

Results and Analysis

4.1 Background

PC, UPC, and UBFRCs are prepare using the 1:2:4 mix design, which is the most widely used. The UBFRCs used 0.6 w/c whereas the PC and UPC used 0.5 w/c. For the preparation of UPC and UBFRCs, a fixed amount of 9.4% of UPEO by mass of cement is used. For the preparation of used petrol engine oil banana fiber reinforced concrete (UBFRC), fixed proportion 2.0% and varying length (3+5 cm, 3+7 cm, 5+7 cm, 3+5+7 cm) BF are added to the mixture together with the UPEO. This chapter is based on comprehensive findings that were attained following testing of each PC, UPC, and UBFRC specimen.

4.2 Dynamic Properties

To evaluate the combined effect of UPEO and BF on the properties of concrete specimens, dynamic properties are investigated. ASTM C215-14 is used to determine these dynamic properties of concrete (PC) specimens. The same methods are used to determine the dynamic properties of UPC and UBFRCs as there is no specific standard available for this purpose. Due to the absence of a specific standard similar methods are often utilized. Table: 4.1 shows the investigated values is taken to achieve dynamic properties of the PC, UPC, and UBFRCs. For this, an average of two appropriate results of corresponding dynamic properties. The damping ratio (ζ) of UPC is reduced by 6.42% and 21.88% in cases of cylinders and beamlets, respectively, as compared with PC. As comparing the values with PC, the damping ratios of UBFRC3+5, UBFRC3+7, UBFRC5+7, and UBFRC 3+5+7 are increased by 18.02%, 20.27%, 25.4%, 29.48% in the case of cylinders respectively. In the case of beamlets, the damping ratio of UBFRC3+5, UBFRC3+7, UBFRC5+7, and UBFRC 3+5+7 are increased by 1.52%, 6.25%, 9.3% and 17.02% in comparison with the damping ratio of PC respectively. Increment/decrement in demping ratio is directly releted to resistence against dynamic loading. The resistance against the dynamic loading has been reduced by the additive influence of the UPEO. On the other hand, the addition of the BF has improved the resistance against the dynamic loading impact in comparison to the simple plain concrete. In the case of cylinders, the impact of dynamic modulus of elasticity (Ed) is enhanced by 6.15% the 9.4% addition of UPEO in concrete. Contrarily the reduction is observed in values of Ed of UBFRC3+5, UBFRC3+7, UBFRC5+7, and UBFRC 3+5+7 by 7.02%. 10.24%, 13.66% and 15.82% respectively.

The dynamic modulus of rigidity has shown better values in the case of the cylinder than the beamlets. From this experiment, it is observed that the addition of the BF in concrete has improved the dynamic properties of the fiber reinforced concrete than that of plain concrete. The increments are observed in both types, cylindrical test specimens and beamlets test specimens. This is an indication that the members made of UPEO and BF can resist and withstand more against the lateral loading in either it is a cylindrical or a beamlet. These improved properties are the indications that the occupancy of some portion of BF in UBFRC can sustain more against impact loading and may be enhance the durability against earthquake loading as compared to that of plain concrete. In the case of the cylinder instead of the beamlets, the dynamic modulus of rigidity has shown better values. According to the results of this experiment, addition of BF to concrete improved the dynamic properties of fiber reinforced concrete more than plain concrete. Both types of test specimens beamlets and cylindrical show the increments.

This is an indication that UPEO and BF members can withstand and resist lateral loads more effectively, whether they are cylindrical or beamlet. These improved properties are the indications that the occupancy of some portion of BF in UBFRC can sustain more against impact loading and may be enhance the durability against earthquake loading as compared to that of plain concrete. This is an indication that UPEO and BF members can withstand and resist lateral loads more effectively, whether they are cylindrical or beamlet. These improved properties are the indications that the occupancy of some portion of BF in UBFRC can sustain more against impact loading and may be enhance the durability against earthquake loading as compared to that of plain concrete.

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Table 4.1: Dynamic Properties of PC, UPC, and UBFRCs

Concrete	Parameters						
Specimen Type	RFL (Hz)	RFT (Hz)	RFR (Hz)	ζ (%)	Ed (GPa)	Rd (GPa)	Poisson Ratio (-)
Cylinders*							
PC	3417±44	3417±45	3298±22	3.88±0.104	4.30±0.040	4.40±0.165	0.52±0.005
UPC	3452±23	3387±48	3392±23	1.68±0.058	4.30±0.019	4.01±0.045	0.47±0.008
UBFRC3+5	3506±23	3232±23	3245±44	3.83±0.056	3.70±0.015	4.91±0.006	0.53±0.005
UBFRC3+7	3535±89	3255±42	3263±65	3.73±0.203	3.70±0.014	4.80±0.022	0.51±0.015
UBFRC5+7	3478±22	3384±82	3392±28	3.71±0.211	4.10±0.035	4.00±0.033	0.49±0.003
UBFRC3+5+7	3412±52	3333±66	3205±62	3.29±0.017	4.00±0.023	3.70±0.748	0.46±0.012
Beamlets**							
PC	3395±88	3231±67	3385±26	1.76±0.022	21.3±1.785	26.6±0.645	0.60±0.004
UPC	3488±65	3334±66	3292±35	1.77±0.051	22.3±1.151	26.3±0.412	0.58±0.003
UBFRC3+5	3245±25	3340±38	3332±57	3.35±0.052	21.6±0.486	27.5±0.002	0.61±0.010
UBFRC3+7	3288±38	3418±28	3298±86	2.83±0.057	22.3±0.745	25.9±0.112	0.57±0.018
UBFRC5+7	3312±78	3408±98	3357±24	2.78±0.033	22.5±0.552	24.6±0.052	0.54±0.014
UBFRC3+5+7	3535±89	3360±55	3205±36	2.72±0.014	21.9±0.912	24.3±0.122	0.55±0.012

4.3 Miscellaneous Properties

Water absorption, mass loss, and linear shrinkage are all important properties used to determine the suitability of materials for various applications. Water absorption is a measure of a material's ability to absorb water, and it can affect the durability and strength of the material. Materials with high water absorption may be more susceptible to damage from environmental factors such as freezing and thawing cycles or exposure to moisture. Mass loss is another property that is often used to evaluate materials. This property measures the amount of weight loss that occurs when a material is exposed to a specific temperature or environment. It can be an indicator of the material's thermal stability or its ability to resist degradation from exposure to chemicals or other environmental factors. Mass loss is an important property. Linear shrinkage is a measure of how much a material will shrink or expand when it is exposed to heat or moisture. This property can be important in applications where tight tolerances are necessary, such as in the manufacturing of electronic components or in the construction of buildings. Miscellaneous properties are shown in **Table 4.2**.

4.3.1 Water Absorption,

Water absorption is an important property of concrete as it affects its durability and strength. Water absorption process occurs through capillary action, and usually calculated as the absorbed water total mass divided by the actual mass of specimen's after oven drying. In this study, the water absorption percentage of PC, UPC, and UBFRCs were measured, and the results are presented in Table 4.3 shows the values of water absorption percentage of plain concrete (PC), used petrol engine oil plain cocncrete (UPC), and UBFRCs; these are 2.53, 2.76, 3.05, 3.95, 3.98, and 3.84 respectively. The water absorption for the UBFRC3+7 and UBFRC5+7 are relatively higher. And the water absorption values are increased with the increase in the length of fiber. So, this shows that the water absorption property of concrete increased with the increase in the length of BF.

4.3.2 Mass Loss

The high temperature oven is used for performing the mass loss test. The method described by ASTM standard C157M-08 is adopted to measure linear shrinkage and mass loss in PC, UPC, and UBFRCs. The values of linear shrinkage PC, UPC and UBFRCs are 0.188, 0.166, 0.122, 0.098, 0.092, and 0.095 respectively.

Table 4.2: Water Absorption, Linear Shrinkage, and Mass Loss of PC, UPC,and UBFRCs

Concrete	Water Absorption	Linear Shrinkage	Mass Loss		
Type	(%)	(%)	@ 50°C	@ 75°C	@ 100°C
PC	1.55±0.5	0.188	-0.034	-0.037	-0.104
UPC	1.10±0.2	0.166	-0.044	-0.048	-0.125
UBFRC3+5	3.10±0.5	0.122	-0.053	-0.067	-0.147
UBFRC3+7	2.7±0.5	0.098	-0.059	-0.071	-0.156
UBFRC5+7	2.65±0.6	0.092	-0.069	-0.078	-0.185
UBFRC3+5+7	3.95±0.2	0.095	-0.070	-0.081	-0.195

4.3.3 Linear Shrinkage

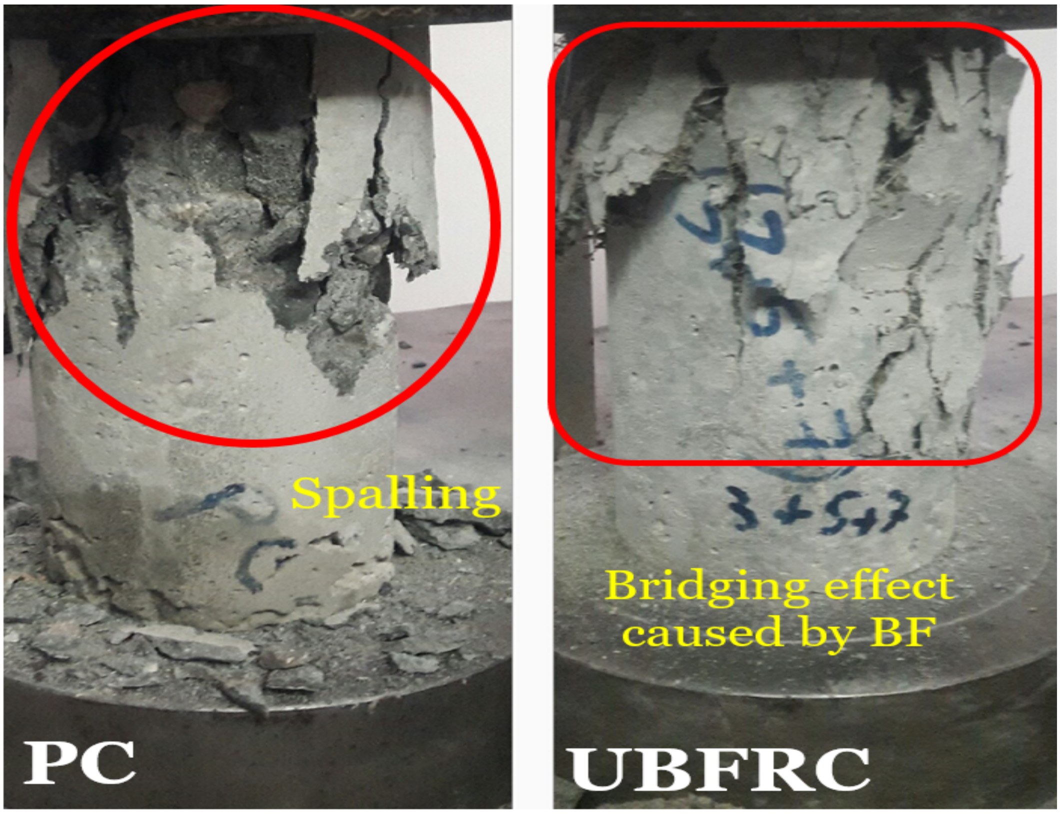
The measurement of linear shrinkage in PC, UPC, and UBFRCs was conducted using the ASTM standard C157M-08. The values of linear shrinkage PC, UPC and UBFRCs are 0.188, 0.166, 0.122, 0.098, 0.092, and 0.095 respectively. The data revealed that an increase in fiber length led to a decrease in the value of linear shrinkage, indicating that BF can resist linear shrinkage. Specifically, the results showed that increasing the length of the fibers led to a decrease in the value of linear shrinkage, While UBFRCs still exhibited some linear shrinkage, it was less with a higher content of BF, suggesting that the addition of BF could potentially reduce the risk of cracks in concrete. The addition of UPEO in UPC resulted in a decrease in the value of linear shrinkage in comparison to PC, implying that the presence of UPEO reduced voids in concrete.

4.4 Mechanical Properties

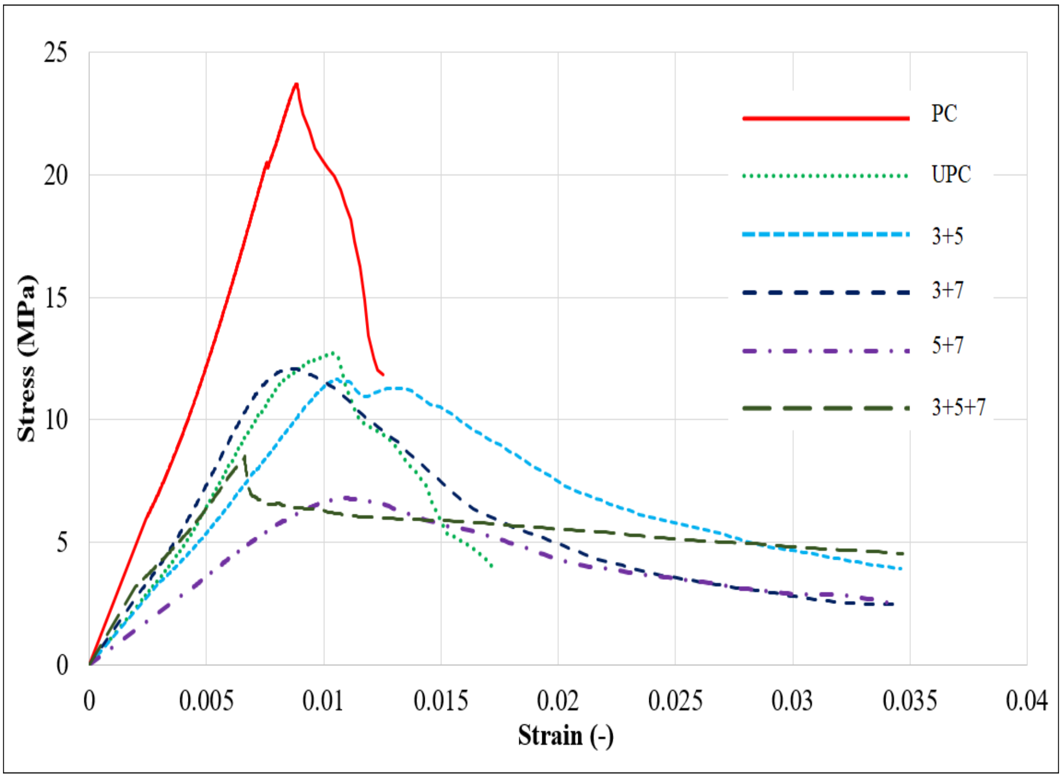
4.4.1 Compressive Properties

Figure 4.1 displays stress-strain graphs for plain concrete (PC), UPEO-modified plain concrete (UPC), and various ultra-high-performance fiber reinforced concretes (UBFRCs) containing different amounts of basalt fiber (BF). UPC exhibits the highest compressive strength (CS) among all specimens, with an increase of 2.17% compared to PC. However, the CS of UBFRCs with higher amounts of BF decreases, with reductions of 6.23%, 23%, 40% and 31% for UBFRC3+5, UBFRC3+7, UBFRC5+7 and UBFRC3+5+7, respectively. This suggests that UPEO enhances the CS of concrete while BF reduces it. **Table 4.3** shows the modulus of elasticity (MOE) and various absorbed energies and toughness indices under compression for all specimens. The CS of concrete has increased when UPEO is added in normal concrete. On the other way around, the addition of BF has caused in negative effect. Hence, CS is decreased with an increase in length of BF. The MOE of UPC is 1.08% higher than that of PC, but the MOE of UBFRCs decreases as the length of BF increases.

Table 4.3 shows the values of compressive pre-crack absorbed energy (CE1), compressive post crack absorbed energy (CE2), compressive total absorbed energy (CTE), and compression toughness index (CTI). All these types of compressive absorbed energies are calculated as per criteria and method described by in the research studies. There is reduction of 33% 40% and 60% in the values of CE1 for UPC, UBFRC3+7 and UBFRC5+7 respectively, when compared with PC. On the other hand, the respective CE2 is increased by 20%, 11.11%, 33.88%, 36.5%, and 40.3% as compared to PC. There is reduction of 33%, 40% and 60%, in the values of CE1 for UPC, respectively, when compared with PC CE2, and CTI generally increase as the length of BF increases, with the largest CE2 observed in UBFRC3+5+7. These improvements in absorbed energies and toughness indices are due to the addition of BF, and further improvements are achieved through the incorporation of UPEO. **Figure 4.1b** shows the relationship between stress and strain for all specimens under compressive loading.



a)



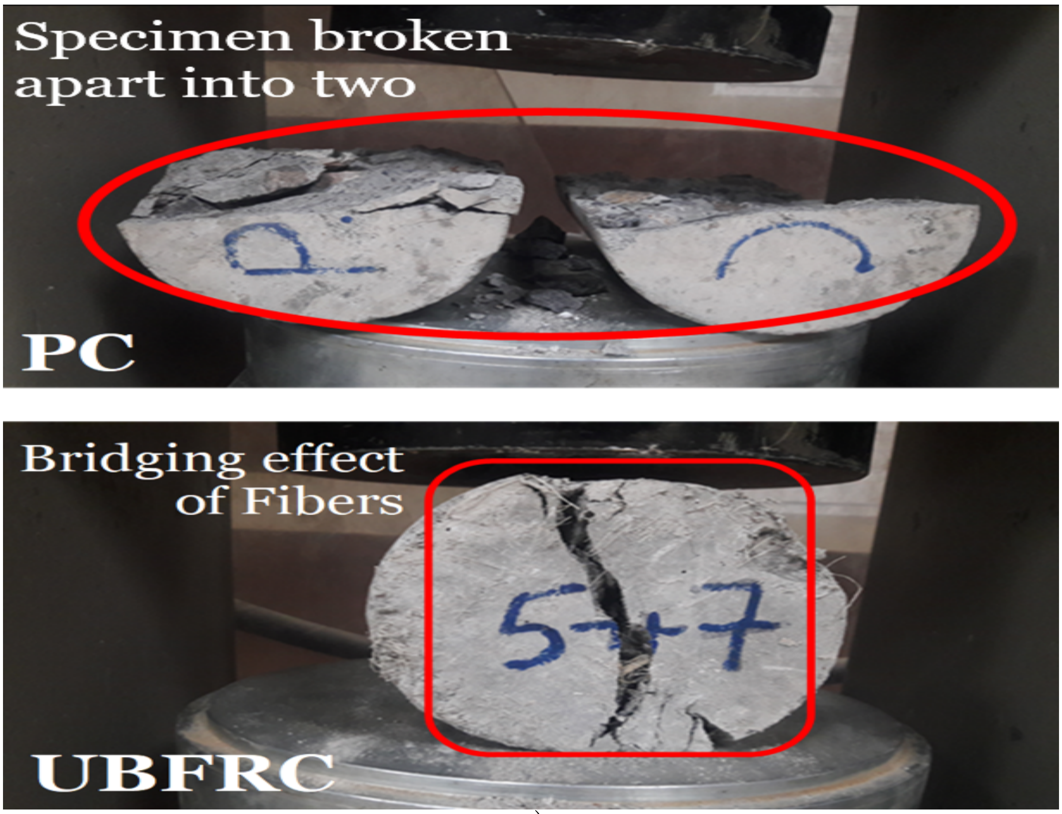
b)

FIGURE 4.1: Compression Behavior ; a) Typical Tested Compression Specimens and b) Stress Strain Curves

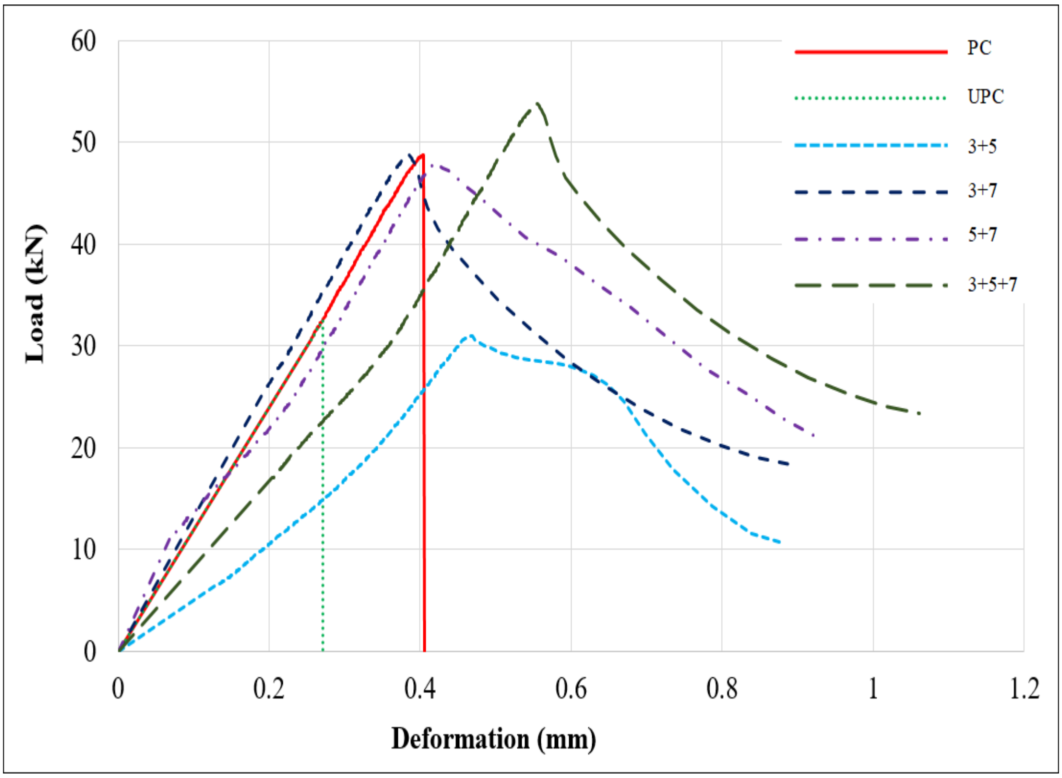
4.4.2 Splitting Tensile Properties

Based on the information provided, it seems that the addition of banana fibers (BF) has a positive effect on the splitting-tensile strength of concrete. The load-deformation curves presented in **Figure 4.2** show that specimens of plain concrete (PC) and concrete with used petrol engine oil(UPC) failed suddenly after reaching their maximum load, while the addition of 3% banana fibers to UPC with varying length improved its splitting-tensile strength and post-crack energy absorption. Moreover, increasing the length of BF led to an improvement in the splitting-tensile strength and energy absorption of the UBFRC (used banana fiber-reinforced concrete) specimens. Also, it has absorbed some energy after appearance of first crack and did not failed suddenly as compared to PC and UPC. The addition of high length BF has absorbed more post-crack energy along with more splitting-tensile strength. **Figure 4.2** shows comparison between typical failure of PC and UBFRC under maximum splitting-tensile loading.

By admixing (3+5 cm) of banana fibers along with same content of UPEO used in UPC, the splitting-tensile strength is improved up to some extent and, also, resisted the some loading after appearance of first crack. This has proved that the addition of banana fibers has improved the splitting tensile strength. Also, it has absorbed some energy after appearance of first crack and did not failed suddenly as compared to PC and UPC. The addition of high length BF has absorbed more post-crack energy along with more splitting-tensile strength. **Figure 4.2a** shows comparison between typical failure of PC and UBFRC under maximum splitting-tensile loading. **Table 4.3** summarizes the splitting-tensile properties of the different concrete specimens, including splitting-tensile strength (SS), pre-crack absorbed energy (SE1), post-crack absorbed energy (SE2), total absorbed energy (STE), and toughness index (STI). The presence of BF is reported to enhance the splitting-tensile strength of concrete. It can be noted that UBFRC5+7 has the maximum load as shown in **Figure 4.2b**. Also, after the maximum load, the UBFRCs have shown load-carrying capability due to the bridging effect of BF. Under the section of splitting-tensile properties, splitting-tensile strength (SS), splitting-tensile pre-crack absorbed energy (SE1),



a)



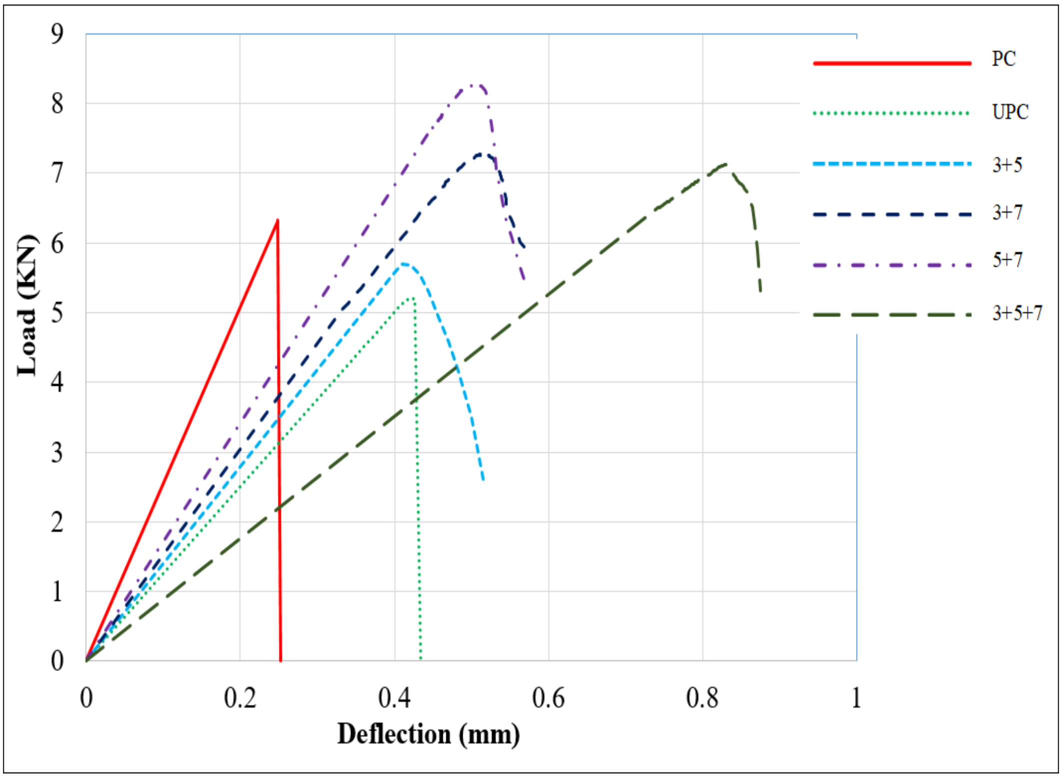
b)

FIGURE 4.2: Tension Behavior ; a) Typical Tested Tension Specimens and b) Load Deformation Curves

4.4.3 Flexural Properties

Figure 4.3 shows the relationship between load-deflection curves of PC, UPC, UBFRC3+5, UBFRC3+7, UBFRC5+7, and UBFRC 3+5+7 samples under flexural loading. UBFRC5+7 has resisted the maximum flexural load as shown in **Figure 4.3b**. It may be observed that maximum flexural strength in the case of the UBFRC5+7 as shown in **Table 4.3**. The more deflection is experienced in UBFRCs than the PC and UPC. In the section on flexural properties, Table 4.2 presents data on flexural strength (FS), flexural pre-crack absorbed energy (FE1), flexural post-crack absorbed energy (FE2), flexural total absorbed energy (FTE), and flexural toughness index (FTI). This behavior is primarily due to the bridging effect caused by the fiber reinforcement. The FS is increased and has shown maximum value in the case of UBFRC5+7 as compared with the other FS values of other specimens. This increase in FS is caused by the addition of the optimum value of BF in concrete. Beyond this, the value of FS is reduced. **Table 4.3** presents data on flexural pre-crack absorbed energy (FE1), flexural post-crack absorbed energy (FE2), flexural total energy absorption (FTE), and flexural toughness indexes (FTI) for different concrete types, including UBFRC with a high content of BF. Compared to PC, the flexural pre-crack absorbed energy of UBFRC2.0 decreased by 15.33% due to the presence of UPEO. The reduction in FE1 for UPC, compared to PC, is also attributed to the presence of UPEO. PC samples did not exhibit any flexural post-crack absorbed energy as they broke into two pieces at the peak load.However, the addition of UPEO led to an increase in the concrete slump value, while the addition of BF decreased the concrete slump value.The efficiency and performance of concrete are affected by these loadings, including FS properties. While All types of UBFRCs have shown some of the FE2 This means the UBFRC may sustain better than PC and UPC after the cracks appear in the concrete. BF has resisted the sudden failure of under Flexural loading concrete comparing to those of PC and UPC. While All types of UBFRCs have shown some of the FE2 This means the UBFRC may sustain better than PC and UPC after the cracks appear in the concrete. BF has resisted the sudden failure of under Flexural loading concrete comparing to those of PC and UPC.

a)



b)

FIGURE 4.3: Flexural Behavior ; a) Typical Tested Flexural Specimens and b) Load Deflection Curves

TABLE 4.3: Compressive, Splitting-Tensile, and Flexural Properties of PC, UPC, and all UBFRCs

Concrete Type	Parameters																
	Compression Properties						Splitting-Tensile Properties					Flexural Properties					
	CS (MPa)	MOE (GPa)	CE1 (MJ/m^3)	CE2 (MJ/m^3)	CTE (MJ/m^3)	CTI (-)	SS (MPa)	SE1 (Nm)	SE2 (Nm)	STE (Nm)	STI (-)	FS (MPa)	Δ (mm)	FE1 (Nm)	FE2 (Nm)	FTE (Nm)	FTI (-)
PC	**23.72** ± 0.5	**27.77** ± 1.4	**0.1** ± 0.02	**0.068** ± 0.01	**0.167** ± 0.01	**1.68** ± 0.02	**1.5** ± 0.1	**9.92** ±0.2	0	**9.92** ± 0.2	1	**3.22** ± 0.2	**0.32** ±0.1	**0.78** ± 0.1	0	**0.78** ± 0.1	1
UPC	**12.73** ± 0.2	**20.33** ± 0.7	**0.071** ± 0.03	**0.052** ± 0.01	**0.124** ± 0.01	**1.73** ± 0.03	**1** ± 0.2	**4.39** ± 0.1	0	**4.39** ± 0.1	1	**2.9** ± 0.1	**0.51** ±0.1	**1.17** ± 0.2	0	**1.17** ± 0.2	1
UBFRC3+5	**11.65** ± 0.4	**19.45** ± 1.2	**0.062** ± 0.02	**0.173** ± 0.01	**0.235** ± 0.02	**3.79** ± 0.04	**0.96** ± 0.1	**6.35** ± 1.2	**9.07** ± 1.2	**15.4** ± 1.2	**2.43** ± 0.2	**2.64** ± 0.1	**0.5** ±0.1	**1.14** ± 0.1	**0.32** ± 0.1	**1.46** ± 0.1	**1.28** ± 0.1
UBFRC3+7	**12.09** ± 0.2	**19.81** ± 1.2	**0.055** ± 0.02	**0.142** ± 0.01	**0.197** ± 0.01	**3.57** ± 0.02	**1.5** ± 0.2	**9.66** ± 1.2	**14.3** ± 1.3	**24.1** ± 1.5	**2.48** ± 0.1	**3.71** ± 0.2	**0.57** ±0.1	**2.18** ± 0.2	**0.44** ± 0.1	**2.63** ± 0.2	**1.2** ± 0.1
UBFRC5+7	**6.8** ± .9	**14.9** ± 1.2	**0.041** ± 0.02	**0.1** ± 0.01	**0.141** ± 0.01	**3.43** ± 0.02	**1.48** ± 0.2	**10.4** ± 1.3	**17.1** ± 1.5	**27.4** ± 2.4	**2.65** ± 0.2	**4.21** ± 0.2	**0.87** ±0.1	**3.01** ± 0.2	**0.3** ± 0.1	**3.31** ±0.2	**1.1** ± 0.1
UBFRC3+5+7	**8.52** ± 1.0	**16.7** ± 0.3	**0.029** ± 0.01	**0.155** ± 0.01	**0.184** ± 0.01	**6.25** ± 0.01	**1.66** ± 0.2	**13.7** ± 0.2	**16.8** ± 1.3	**30.5** ± 3.2	**2.23** ± 0.2	**3.63** ± 0.2	**0.56** ±0.1	**1.98** ± 0.1	**0.36** ± 0.1	**2.4** ± 0.2	**1.18** ± 0.1

4.5 Fiber Breakage and Pullout

Figure 4.4 shows broken surfaces of fibrous concrete after mechanical loading. The failure pattern and surfaces of Ultra-High-Performance Fiber-Reinforced Concretes (UBFRCs) are found to be different from that of plain concrete (PC). Fractured surface images are used to study the bonding between banana fibers and the surrounding concrete. The images reveal clear fiber pullout, indicating a strong bonding between the fibers and the matrix. The broken surfaces of the tested specimens also exhibit very few and extremely small voids, which is an indication of proper mixing of concrete ingredients.

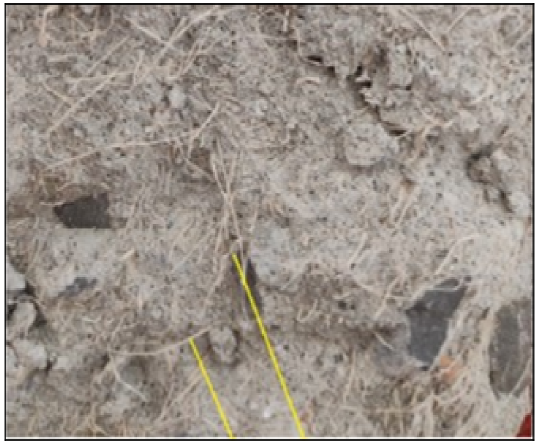
After mechanical testing, UBFRC specimens are broken into small pieces that are attached to other broken particles. The observed attachment is believed to be the outcome of the robust bridging impact of the banana fibers present within the composite material, whereby the fibers act as reinforcement agents, spanning across any gaps or fissures in the material and enhancing its overall mechanical stability and strength. which is not observed in normal plain concrete. The presence of fibers also causes fiber pullout at the location of the fracture surface instead of fiber breakage, indicating that the UBFRC specimen can withstand loading longer than PC. After the failure of the UBFRC specimen, it continues to resist loading due to the bridging effect of banana fibers between the cracks. Therefore, the presence of banana fibers helps in resisting the production and progression of micro cracks in the concrete. The addition and mixing of fibers were performed following the procedure outlined in section 3.3. Therefore, the presence of banana fibers helps in resisting the production and progression of micro cracks in the concrete. The addition and mixing of fibers were performed following the procedure outlined in section 3.3. Broken surface of specimes are shown in figure 4.4.The broken surfaces of the tested specimens in Figure 4.4 reveal a uniform distribution of fibers. Some small fragments, shown in the bottom right image of Figure 4.4, are attached to the broken surface through the fibers, which indicates that structural elements containing BF can withstand spalling. This attachment is due to the bridging effect caused by the BF, resulting in enhanced durability and performance of the concrete.

Bond of fibers with surrounding matrix

Sticked small particles due to fibers

Bridging effect of fibers

Hanging of small broken particles



Pullout of banana fibers

Breakage of banana fibers

Figure 4.4: Fractured Surfaces of Different Tested Specimens

4.6 Summary

The current chapter presents a comprehensive analysis of the properties of concrete mixed with different ratios of banana fibers and used petrol-engine oil (UBFRCs), compared with plain concrete (PC) and concrete mixed with only used petrol-engine oil (UPC). The workability properties, densities of hard concrete, dynamic properties, mechanical properties, water absorption, mass loss, and linear shrinkage properties are discussed in detail. It is observed that the addition of BF has a positive effect on the dynamic modulus of rigidity, splitting-tensile strength, splitting-tensile toughness index, splitting-tensile pre-crack energy absorption property, splitting-tensile post-crack energy absorption property, and compressive toughness index. However, the addition of UPEO resulted in an increase in the slump value of concrete, while the addition of BF caused a reduction in the slump value of concrete. The flexural strength was reduced by the addition of UPEO, while the flexural strength was improved by the addition of BF.The water absorption property increased with increasing BF content in the concrete, while the linear shrinkage showed the opposite relationship with increasing BF content. Furthermore, the mass loss was observed to increase with increasing BF content in the concrete. The bonding between the banana fibers and surrounding matrix was found to be good when the broken surfaces of fractured specimens were examined. Overall, the results indicate that the addition of banana fibers has a positive effect on several properties of the concrete, although there are some limitations associated with the use of this material.

Chapter 5

Guidelines for Practical Implementation

5.1 Background

The paragraph discusses the results obtained from testing the impact of fiber ratio on the properties of used petrol-engine oil and banana fiber reinforced concrete (UBFRC).The study generated quantitative results graphs of stress-strain, load-deflection, and load-deformation, which demonstrated how fibres affected the mechanical properties and dynamic properties of UBFRC. The study revealed that increasing the fiber content in UBFRC resulted in improved mechanical properties, including an increase in compressive strength and modulus of elasticity. The addition of fibers also resulted in enhanced dynamic properties, such as impact resistance and energy absorption. The study demonstrated that a higher fiber content is not always better and that there is an optimal fiber ratio that can provide the best balance between mechanical and dynamic properties. The chapter also includes discussions on the practical implementation and recommendation of UBFRC in real-life applications.Overall, the study provides valuable insights into the properties of UBFRC and the impact of fiber content on its mechanical and dynamic properties. The empirical relation developed in the study can be used to optimize the use of UBFRC in different construction applications.

5.2 Optimization of Banana Fibers with Waste Petrol-Engine Oil

Table 5.1 provides details of the maximum and minimum values obtained from mechanical and dynamic tests. This information can help to select a particular combination for a specific application.

UPEO showed better properties. The addition of BF in concrete significantly influenced its properties. The effects of different proportions of BF on UBFRC properties can be seen in Figure 5.1. Some properties are significantly improved, such as the compression toughness index (CTI), while others have an adverse effect on the banana fibers, such as a decrease in compressive strength (CS). The splitting-tensile properties of UBFRCs are highly improved compared to compression and flexural properties, and the flexural properties are affected in a progressive manner with the addition of fibers.Banana fibers UBFRC3+5, UBFRC3+7, UBFRC5+7, and UBFRC 3+5+7 are used and used engine oil locally available material are used. Overall, the study provides insights into the use of UBFRC in construction and the effects of adding BF and UPEO on its properties. Some properties are significantly improved, such as the com- pression toughness index (CTI), while others have an adverse effect on the banana fibers, such as a decrease in compressive strength (CS).However, the addition of UPEO resulted in an increase in the slump value of concrete, while the addition of BF caused a reduction in the slump value of concrete.

This study focuses on the optimization of banana fibers as a reinforcement material in the context of ultra-high performance fiber-reinforced concrete (UBFRC), utilizing waste petroleum engine oil (UPEO) as an additive to improve its overall performance and sustainability. By investigating the effects of various ratios and combinations of BF and UPEO on the material's mechanical properties, as well as its environmental impact, this research contributes to the ongoing efforts to develop more efficient and eco-friendly construction materials.The present study examines the effects of incorporating banana fiber (BF) and used engine oil (UEO) on the properties and performance of used petrol engine oil banana fiber-reinforced concrete (UBFRC). By conducting a series of tests to evaluate the mechanical strength, durability, and sustainability of the composite, as well as its workability and environmental impact, this research aims to shed light on the potential of BF and UEO as additives in UBFRC. The results of this study could have significant implications for the development of more sustainable and cost-effective construction materials. The utilization of waste products such as used engine oil (UEO) in the production of building materials has gained increasing attention in recent years due to its potential to reduce environmental pollution and waste. overall performance and properties. By investigating the various parameters and characteristics of the resulting composite, including its water absorption, mass loss, linear shrinkage, slump value, and mechanical strength, this research contributes to a deeper understanding of the potential benefits and limitations of UBFRC, Some properties are significantly improved, such as the com- pression toughness index (CTI), while others have an adverse effect on the banana fibers, such as a decrease in compressive strength (CS).It was observed that the inclusion of used petrol engine oil (UPEO) in the concrete mixture led to a marked increase in its slump value, indicating a greater workability and ease of handling during the casting process. On the other hand, the addition of banana fibers (BF) to the composite had the opposite effect, resulting in a decrease in the slump value of the concrete, which may be attributed to the higher surface area and roughness of the fibers, leading to increased friction and resistance within the mixture.

This research project seeks to optimize the use of banana fibers (BF) as a reinforcement material in used petrol engine oil reinforced concrete (UBFRC), with the added benefit of incorporating waste petroleum engine oil (UPEO) as an eco-friendly additive to enhance the material's properties. By exploring the effects of different ratios and combinations of BF and UPEO on the mechanical and physical properties of UBFRC, including its compressive strength, flexural strength, and water absorption capacity, By analyzing the impact of UEO on the physical through a series of tests and measurements, this study aims to provide insights into the feasibility of using waste products in the development of sustainable and high-performance construction materials and to provide valuable insights into the potential of UBFRC as a more efficient and eco-conscious construction material.

Table 5.1: Optimization of Banana Fiber Content in UBFRC

Concrete	Compression				Splitting-Tensile			Flexural			Dynamic**		
Type	**CS** (MPa)	**MOE** (GPa)	**CTE** (MJ/m^3)	**CTI** (-)	**SS** (MPa)	**STE** (Nm)	**STI** (-)	**FS** (MPa)	**FTE** (Nm)	**FTI** (-)	ζ (%)	**Ed** (GPa)	**Rd** (GPa)
PC	**23.72** ± 0.5	**27.77** ± 1.4	**0.167** ± 0.002	**1.68** ± 0.02	**1.5** ± 0.1	**9.92** ± 0.2	1	**3.22** ± 0.02	**0.78** ± 0.1	1	**1.76** ± 0.012	**21.3** ± 1.785	**26.6** ± 0.645
UPC	**12.73** ± 0.2	**20.33** ± 0.7	**0.124** ± 0.006	**1.73** ± 0.05	**1** ± 0.2	**4.39** ± 0.1	1	**2.9** ± 0.03	**1.17** ± 0.02	1	**1.77** ± 0.051	**22.3** ± 1.151	**26.3** ± 0.412
UBFRC* with minimum values	**6.8** ± 0.9 5+7	**14.9** ± 1.2 5+7	**0.141** ± 0.01 5+7	**3.43** ± 0.02 5+7	**0.96** ± 0.1 3+5	**15.4** ± 1.2 3+5	**2.23** ± 0.2 3+5+7	**2.64** ± 0.1 3+5	**1.46** ± 0.1 3+5	**1.1** ± 0.1 5+7	**2.83** ± 0.077 3+7	**21.6** ± 0.486 3+5	**24.3** ± 0.052 3+5+7
UBFRC* maximum values	**12.09** ± 0.2 3+7	**19.81** ±1.2 3+7	**0.235** ± 0.02 3+5	**6.25** ± 0.01 3+5+7	**1.66** ± 0.2 3+5+7	**30.5** ± 3.2 3+5+7	**2.65** ± 0.2 5+7	**4.21** ± 0.2 5+7	**3.31** ±0.2 5+7	**1.28** ± 0.1 3+5	**3.35** ± 0.082 3+5	**22.5** ±0.912 5+7	**27.5** ± 0.002 3+5

5.3 Application of this Research in Real Life

Concrete is used in various civil engineering applications and is subjected to different types of loadings, including mechanical and dynamic loading. The efficiency and performance of concrete are affected by these loadings, including properties like compressive strength, tensile strength, and flexural strength. Concrete durability also depends on these loadings, as cracks can be produced due to high water absorption, more linear shrinkage, and less strength of concrete in tension. Flexural strength property of concrete control rigid pavements cracking. Spalling of concrete is another issue that reduces its durability, and it can be caused by exposure to high temperatures. However, tensile strength improve spalling of concrete with the addition of fibers in the composite. Impact loading, such as blasting or vehicle collisions with concrete bridge piers, can also lead to the failure of structures. Therefore, concrete resistance against it impact loading can be improved by enhancing its dynamic modulus of rigidity and energy absorption property. Therefore, UBFRC(5+7) is more suitable as it has shown better mod- ulus of rupture and modulus of elasticity, which are key factors in the stability and durability of the rigid pavements. For compression members that go purely under uniaxial loading, UBFRC(3+7) is suitable as it has shown higher compres- sion strength than any other type of UBFRCs.

This study explores the behavior of different types of concrete, including plain concrete (PC), Used petrol engine oil plain Concrete (UPC), and UBFRCs, by using used petrol-engine oil (UPEO) and different contents of banana fibers (BF). The specimens of UBFRC(3+7) have shown better performance against compressive loading, while the properties of UBFRC(3+5+7) are improved against tension loading and can be used for members like beams and slabs. Rigid pavements are designed by keeping in mind the flexural strength and modulus of elasticity of the concrete. Therefore, UBFRC(5+7) is more suitable for rigid pavements (light vehicles) as it has shown better modulus of rupture and modulus of elasticity, which are key factors in the stability and durability of the rigid pavements. For compression members that go purely under uniaxial loading, UBFRC(3+7) is suitable as it has shown higher compression strength than any other type of UBFRCs. UBFRC(3+7) has shown good compres

-sion strength along with some resistance against moment forces, There has been a compromise on CS with gains in CTI, SS, STI, FS and FTI. Accordingly, where compromise on CS can be made (i.e. for non-important structure like shed / storage structure), these materials (i.e. UPC BFRC) can be utilized. Therefore, UBFRC(5+7) is more suitable as it has shown better mod- ulus of rupture and modulus of elasticity, which are key factors in the stability and durability of the rigid pavements. For compression members that go purely under uniaxial loading, UBFRC(3+7) is suitable as it has shown higher compres- sion strength than any other type of UBFRCs In summary, this study provides insights into the behavior of different types of concrete and the effects of adding waste petrol-engine oil and banana fibers. It also offers recommendations for the practical implementation of UBFRC in various civil engineering applications based on its properties under different types of loadings.

5.4 Summary

In this study, optimization of banana fibers and used petrol-engine oil in UBFRCs is carried out, and recommendations are made based on strength and toughness index. The optimization is done by varying the content of banana fibers in UBFRCs and testing them under different types of loading such as mechanical and dynamic loading. Based on the results obtained, specific recommendations are made for using UBFRCs in different civil engineering applications. The developed empirical relations are used to calculate the strength properties of UBFRCs, which are then compared with the experimental properties. Overall, the study provides valuable insights into the performance of UBFRCs under different types of loading and their suitability for specific applications

Chapter 6

Conclusions and Recommendations

6.1 Conclusions

The value of waste materials is increasing with the passage of time. Some of these wastes are severe damaging to the environment. One of these hazardous wastes is used petrol-engine oil. There is a need to dump these waste in an effectice way so that the impact of environmetnal pollution causing phenomenons can be reduced. In this study, the waste materials are utilized to explores the behavior of the waste/used petrol-engine oil and banana fiber reinforced concrete (UBFRC). Various values of banana fibers (BF) have been used along with waste petrol engine oil (UPEO) to investigate the dynamic properties, mechanical properties, water absorption property, linear shrinkage property, and mass loss. Concrete is admixed with BF and UPEO in various ratios by adding cement mass. From this research, following conclusions have been made:

- UBFRC having smaller fiber lengths has highest damping ratio compared to UBFRC having longer fiber lengths in both cylinders and beamlets.
- WA, LS, ML are effected by the addition of BF and UPEO.

  - UBFRC 5+7 has least water absorption.
  - UBFRC 5+7 has shown least linear shrinkage.
  - UBFRC 3+5 has least mass loss.

- The mechanical properties of concrete are influenced by the incorporation of the BF and UPEO.
  - There has been a significant compromise on compression strength with considerable gain in compressive toughness.
  - UBFRC 3+5+7 has highest SS and UBFRC 5+7 has highest STI.
  - UBFRC 5+7 has highest FS and UBFRC 3+5 has highest FTI.
- Both fibers breakage and fiber pullout are observed on the fractured surfaces.

Based on this research work, customized UBFRC could be utilized for different applications as there is no single combination which has shown reasonably favorable improvement in all studied properties.

6.2 Future Works

- Concrete having fibers, admixture and used petrol engine oil should be carefully studied in depth for robust outcomes.
- Durability of such concretes may also be explored.

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