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Physical And Mechanical Properties of Concrete Reinforced with Kenaf Fibre

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DECLARATION

I declare that this thesis entitled "Physical and Mechanical Properties of Concrete Reinforced with Kenaf Fibre" is the results of my own research except as cited in the references.

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Sifat Fizikal dan Mekanikal Konkrit Diperkukuh dengan Gentian Kenaf

ABSTRAK

Kini, dunia sangat kekurangan bahan mesra alam dan alternatif selamat kepada alam seperti bahan yang membebaskan karbon dioksida akibat suhu tinggi. Konkrit diperkukuh gentian kenaf (KFRC) boleh mengurangkan pelepasan CO_2 dan meningkatkan penggunaannya dalam bangunan. Walau bagaimanapun, cuaca yang tidak menentu juga menjejaskan masa pematangan konkrit, terutamanya semasa musim tengkujuh. Penyelidikan diperlukan untuk membuktikan tahap keberkesanan KFRC dalam konkrit dan potensinya untuk meningkatkan sifat tegangan dan lenturnya sambil mengurangkan kebolehkerjaan dan kekuatan mampatan. Penyelidikan ini bertujuan untuk menyelesaikan batasan dan menambah baik sifat mekanikal dan fizikal konkrit. Penyelidikan ini adalah untuk mencirikan sifat fizikal dan mekanikal Konkrit Bertetulang Gentian Kenaf serta menganalisis kesan pembebanan gentian yang berbeza terhadap sifat konkrit. Penyediaan KFRC adalah sama dengan Konkrit asas, penyelidikan ini. Pertama sekali, semua bahan perlu diukur sebelum dicampurkan. Nisbah bagi perkadaran bancuhan ialah 1:3 untuk konkrit/agregat dan untuk air/konkrit ialah 1:0.5 diikuti dengan proses penuangan dan pemadatan. Selepas itu, semua sampel akan dibuat kari dalam tiga masa berbeza seperti 7 hari, 14 hari dan 28 hari. Ujian fizikal dan mekanikal akan dijalankan selepas masa pengawetan iaitu penyerapan air, kekuatan mampatan dan kekuatan lentur. Semua ujian mekanikal digunakan Univesal Testing Mechine (UTM). Kadar penyerapan air yang lebih tinggi menjejaskan keliangan permukaan dan jumlah serat kenaf yang betul tidak boleh melebihi 0.03%. dan gentian teras menyediakan konkrit dengan lebih ketegaran. Penambahan serat kenaf boleh meningkatkan kekosongan dan liang, menyumbang kepada peningkatan penyerapan air. Juga meningkatkan beban pasca retak dan kapasiti penyerapan tenaga dan menukar mod kegagalan dari rapuh ke mulur. Mempengaruhi kekuatan mampatan dengan panjang gentian semula jadi dan kepekatan serat dan pecahan Teras yang ideal ialah 0.1%-0.2%. Kajian ini bertujuan untuk menyediakan KFRC pada kuantiti kenaf fiber yang berbeza dengan menggunakan kaedah campuran biasa dan mencirikan sifat permukaan, penyerapan air, kekuatan mampatan dan lenturan KFRC.

Kata kunci: Konkrit, gentian kenaf, sifat mechanical, sifat physical.

Physical and Mechanical Properties of Concrete Reinforced with Kenaf Fibre

ABSTRACT

The world lacks eco-friendly materials and safe alternatives to concrete, which releases carbon dioxide due to high temperatures. Kenaf Fibre Reinforced Concrete (KFRC) could reduce CO_2 emissions and increase its usage in buildings. However, unpredictable weather affects concrete curing time, especially during monsoon seasons. Research is needed to prove the effectiveness of KFRC in concrete and its potential to improve its tensile and flexural properties while decreasing workability and compressive strength. This research aims to solve limitations and improve the mechanical and physical properties of concrete. This research is to characterize the physical and mechanical properties of KFRC and to analysis the impact of different fibre loading on the concrete properties. Preparation of KFRC is like Basic Concrete except the unit for this research the weight unit is small (wt%). Firstly, all the materials should be measured before mixing. The ratio for mix proportions is 1:3 for concrete/aggregate and for water/concrete is 1:0.5 followed with casting and compacting process. After that, all samples were carried in three different time such as 7 days, 14 days, and 28 days. Physical and mechanical testing run after the curing time, which is water absorption, compressive strength and bending strength. All the mechanical testing is used Univesal Testing Mechine (UTM). Higher water absorption rates affect surface porosity and the right amount of kenaf fiber should not exceed 0.03%. and core fibers provide concrete with more rigidity. The addition of kenaf fiber may increase void and pore, contributing to increased water absorption. Also improve post-cracking load and energy absorption capacity andchanging failure mode from brittle to ductile. Influences compressive strength by natural fiber length and fiber concentration and ideal Core fraction is 0.1%-0.2%, based on the studies applications. The study can assess the extent to which the properties of concrete can be improved and used as the main material construction. In addition, the benefits of using natural materials such as kenaf can maintain the sustainability of the environment by reducing chemical reactions.

Keywords: Concrete, kenaf fibre, mechanical properties, physical properties.

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LIST OF ABBREVIATIONS

NaOH	Sodium Hydroxide
CO_2	Carbon Dioxide
KFRC	Kenaf Fibre Reinforced Concrete
TGA	Thermogravimetric Analysis
CA	Chemical Analysis
C-S-H	Calcium Silicate Hydrate
C_3S	Tricalcium Aluminate
CH	Calcium Hydroxide
pH	Potential of Hydrogen
$CaCO_3$	Limestone
SiO_2	Silicon Dioxide
Si, Al, Fe	Silicon, Aluminium, Iron
Fe_2O_3	Iron Oxide
FRC	Fibre Reinforced Concrete
SEM	Scanning Electron Micrographs
SCMs	Supplementary Cementitious Materials
PP	Polypropylene
GMT	Glass Mat Thermoplastics
PC	Portland Cement
Al_2O_3	Aluminum Oxide
SiO_2	Silica Sand
$Ca(NO_3)_2$	Calcium Nitrate
PPC	Portland pozzolana cement
OPC	Ordinary Portland Cement

XRF	X-Ray Fluorescence Spectrometer
SO_3	Sulfur Trioxide
MgO	Magnesium Oxide
CSA	Calsium Sulfoaluminium Cement
TMT	Thermo Mechanical Treatment
KF	Kenaf Fiber

LIST OF SYMBOLS

%	Percentage
mm	Millimetre
m	Meter
µm	Micrometre
gm/cm^3	Gram Per Cubic Centimetre
m^3	Cubic Meter
˚C	Degree Celsius
$t^{1/2}$	Time (Square Root)
S_m	Sorptivity
$min^{-1/2}$	Minute (Inverse square root)
MPa	Megapascals
PSI	Pounds Per Square Inch
N	Newton
g/ml	Gram Per Millilitre
wt%	Weight Percentage
g	Gram
cm	Centimeter
N/mm	Newtons Per Square Millimeter
κN	Kilonewton

CHAPTER 1

INTRODUCTION

1.1 Research Background

` In recent years, permanent formwork, facades, tanks, pipes, long span roofing components, and strengthening of existing structures are just a few examples of the many applications for these cement composites (Silva et al., 2010). Concrete is widely used in construction due to properties that can be change and always use in infrastructure development. The durability, high-performance and easy to handle of concrete is the main reasons why concrete we use in building.

There are various types of studies that have been conducted related concrete especially in advanced material, fibre reinforce concrete (Wang et al., 2014). Recently, the foam concrete is one of the new applications and has enough strength to be use as a building material for the industry building system to fill holes and voids over a substantial distance without any vibration or compaction.

The numerous materials use to prepare foam concrete, which mostly consists of aggregate and cement. Therefore, the advanced materials science creates new materials form composite also have green materials concepts. The tensile qualities of kenaf fibre, which can increase the reinforced material's flexural and shear strength and ductility, are the scientific basis for its use as reinforcement.

Because kenaf fibre recycles natural resources into reinforced materials, it is also viewed as a promising green material. Treatment for kenaf fibre is to lessen its high-water absorption characteristic. Sodium hydroxide (NaOH) is one of the solutions for chemical treatment. The main functional to lessen the fibre's hydrophobic characteristic, improving the adhesion between the fibre surface and the matrix.

The process can also make the fibre's surface rougher, which enhances the fibre's tensile qualities (Syed Mohsin et al., 2018). Furthermore, kenaf fibre has a higher impact strength than other natural fibres, which makes it a useful reinforcement material (Lee et al., 2021). Kenaf fibre is an appropriate reinforcement material for a variety of applications due to its tensile qualities and possibility for using green materials.

The composition in concrete mixture will give impact to the environment. Either high or low impact. Concrete also releases some chemical substance after reaction happen on the materials (Bandara et al., 2023). These reactions can cause pollution to environment and dangerous for human respirations such carbon dioxide (CO_2). The idea Kenaf Fibres Reinforced concrete is relevant to replace the ordinary concrete and low cost in production.

Then Kenaf Fibres Reinforced Concrete can help to reduce some problem related to the environment. One of the benefits, kenaf plant can absorb 1.5 times its weight in carbon dioxide (Lam & Yatim, 2015). Therefore, KFRC is the best mechanical and physical properties, so its suitable for various applications and as alternative to ordinary concrete. The sustainability in concrete material it's important to ensure the environment safe for a long-time life.

Tables 1.1: Comparison of Ordinary and Kenaf Fibres Concrete Bernama (Civiltoday,2023)

Ordinary Concrete	**Kenaf Fibre Concrete**
Concrete does not deteriorate much over time.	Save energy and consumption
Concrete is resistant to extreme heat.	Good thermal insulation
The cost of maintaining concrete is essentially non-existent.	Absorb 20 tonnes of CO_2 per hectare

1.2 Problem Statement

The world todays still lack eco-friendly materials and safe for the environment. As we know the concrete will release carbon dioxide (CO_2). This is because Portland cement is produced by burning at a very high temperature up to 1450ºC and Portland cement also produced by first co-grinding a mixture of 80% limestone and 20% clays. At the same time, the kiln transports calcium and silicon oxide nodules locked together by a calcium aluminate melt, the high temperature will induce a reaction to happen.

Kenaf Fibre will help reduce emissions of carbon dioxide (CO_2) from concrete and these materials should increase it is usage in buildings when the temperature is high. Other than that, unpredictable weather will affect the curing time of concrete by adding some additive with different chemical compositions, its very useful especially in the monsoon season its make short time of curing time. This investigation tries to replace the basic material into the bio-composite materials with characteristic improved for building.

However, kenaf fibre can improve the tensile and flexural properties of concrete while decreasing its workability and compressive strength based on previous study and some research has proven that kenaf can improve the mechanical properties. This research also to be done and prove all the hypothesis about KFRC. At the same time, try to analysis the basic limitations will occur. This research is also to help prove the extent to which kenaf can be used as a fiber in concrete also how can kenaf fiber affect the mechanical and physical properties of concrete.

1.3 Objectives

This research provides two objectives:

i. To prepare KFRC at different kenaf fiber concentration with mixing method.
ii. To characterize surface appearance, water absorption, compressive and flexural strength of KFRC.

1.4 Scope of Study

The core scope of study is to prepare the best composition of concrete mixture in Kenaf Fibre Reinforce Concrete (KFRC). These mechanical and physical properties can determine by the testing. Tests on specimens such as compress and flexural for mechanical characterization. In this research, physical properties will use water absorption and thermal analysis test on samples using Thermogravimetric analysis (TGA).

Basically, to know more quality of Kenaf Fiber Reinforced Concrete we need to measure using a suitable testing. The effects of various kenaf fibre contents and all the materials in concrete will give effect on the mechanical also physical characteristics of the composite material. This entails identifying the ideal fibre amounts and admixtures that offers the ideal compromise between strength, durability, and workability for concrete.

1.5 Significances of Study

This research will be presenting the importance of concrete material in the field of civil engineering and be useful to researchers for the future. This study can also contribute knowledge and as reference sources related to reinforced concrete such as Kenaf Fibre Reinforce Concrete (KFRC). In addition, the results of this study can produce concrete materials that are potentially useful for construction with good performance of concrete. This is because concrete is our basis for the construction of buildings, infrastructure and subsequently a contributor to the economy for country.

CHAPTER 2

LITERATURE REVIEW

2.1 Concrete

Figure 2.1: Fine Aggregate and Cement

Concrete is one of the most widely used in building materials, brittleness and relatively low impact resistance, tensile strength, fire resistance, longevity, and resistance to fracture formation are only a few of the many disadvantages of concrete (Jamshaid et al., 2023). Because of the limitations of concrete, it's the reason why concrete is not suitable for all applications especially in building. Inclusion of materials in the concrete like fibers and steel can improve a certain property of cementitious concrete in a small value.

Since the cementitious is poor ductility, low tensile strength, low cracking resistance and energy absorption (Abbas et al., 2022a), new method has been developed to enhance or reduce their limitations by adding materials that different properties. For example, steel and synthetic or natural fiber. Cement is composed with filler in mass like 85% < clinker < 91%, 3% < gypsum < 5%, 6% < limestone filler < 10%) with 32 MPa of compressive strength at 28 day and replacement for cement can be used to increase the durability of composite by replaced replaced by 30% of metakaolin (MK) and 20% of calcined waste crushed clay brick (CWCCB) and 50% of cement by the calcined clays it was possible to develop a matrix that was free of calcium hydroxide (CH) at 28 days of age (Silva et al., 2010). It's also helping to reduce the immersion of CO_2 to the environment at the same time protected the air from pollutions because the quantity of pozzolanic materials in cement is less.

There are many past studies that shows the fibre and other material in concrete with various aspects of the study reveal the improvement of composite concrete. The Portland cement concrete serves as the discussion's matrix substance also have been utilised as a host matrix for unique applications. Cement can be classified into two types which is Ordinary Portland Cement (OPC) and Portland Pozzolana Cement (PPC). All the composition is difference and properties. This research only focused on the lightweight concrete cause in mix proportions only used fine aggregate.

Another material should include is fine and coarse aggregate. The aggregate is depends on the size, for fine aggregate 4.75 mm from river sand and coarse aggregate is 20 mm and 20 mm (Jain et al., 2023). The aggregates also can be categorized as poorly graded, well graded, and evenly graded based on the distribution of particle sizes. However, Aggregates are classified into fine aggregates with size is less than 4.75 mm and coarse aggregates with size is larger than 4.75 mm in (Iyer, 2020), ductility and strength of concrete form aggregate that we put in the mic concrete.

Water ratio also give impact to the strength of concrete and the quantity should be more than cement. Reductions in the water-to-cement ratio in freshly mixed concrete are typically viewed negatively since they can cause the mixture's workability to be lost (Domagała, 2015). The proper ratios very important to produce the high quality concrete, Reducing the amount of water that contains chloride or sulfate in concrete is crucial since it can seriously harm the material and shorten its lifespan (Golewski, 2023).

Water absorption and water ratios are connected. According to physical definitions, water absorption, based on research, is the amount of water that concrete can absorb at atmospheric pressure. To make sure appropriate longevity, its value ought to fall between 4 and 6%. Moreover, concrete is deemed to be of high grade when the wa is less than 5%. Other evidence indicates that a concrete rate less than 10% is already seen as low (Golewski, 2023).

However, concrete helpful building material is nevertheless fraught with negatives. Ordinary Portland Cement (OPC) is the primary binder in concrete; regrettably, the manufacturing of OPC is the primary source of greenhouse gas (GHG) emissions, primarily CO2, linked to global warming and climate change on Earth. According to these issues, the low volume fly ash concrete (LVFAC) under water immersion conditions has been study. Moreover, the study of natural reinforcement in concrete as replacement to the steel reinforcement is increasingly exciting because of the corrosion issues.

2.2 Composition of Cement

Ordinary Portland Cement (OPC) and Portland Pozzolana Cement (PPC) have been difference properties and composition. The name "Ordinary Portland Cement," or OPC, is frequently used to characterize this type of cement. It is no longer possible to find Type I Portland cement on the market. Portland Composite Cement (PCC) and Portland Pozzolana Cement (PPC) are currently the most popular varieties of cement (Krisnamurti et al., 2018). The basic phase in Portland Cement compositions shows in the Table 2.1.

Portland Pozzolana Cement (PPC) is denser and more impermeable compared to regular Portland Cement (OPC). PPC has a stronger long-term structure and more resistant to the attack of hostile fluids and generates less heat during hydration than regular OPC (Naik et al., 2019). Table 2.2 is showing the chemical composition in Portland Pozzolana Cement (PPC) with difference scope study.

Table 2.1: The Four Major Phases in Portland Clinker (Oye, 2012)

Phase	Mineralogical Term	Cement Chemical Notion	Shortened Cement Chemical Notion	Typical Content (%)
Tricalcium silicate	Alite	$3CaO \cdot SiO_2$	C_3S	50 - 65
Dicalcium silicate	Belite	$2CaO \cdot SiO_2$	C_2S	15 - 25
Tricalcium aluminate	Aluminate	$3CaO \cdot Al2O_3$	C_3A	5 - 15
Tetracalcium aluminoferrite	Ferrite	$4CaO \cdot Al_2O_3 \cdot Fe_2O_3$	C_4AF	5 - 15

The Ordinary Portland Cement (OPC) it is produced by grinding clinker, which is a mixture of gypsum, limestone, clay, and other substances. OPC is ideal for all ordinary building applications and offers exceptional compressive strength. Chemical composition for Ordinary Portland Cement (OPC) shows in Table 2.3 and the ARL-9800XP X-ray fluorescence spectrometer (XRF) was utilized to perform chemical composition analysis of OPC.

Table 2.2: The Chemical Composition in (OPC) and (PPC) (Ye et al., 2023) (Naik et al., 2019)

Chemical Compositions	SiO2	Al2O3	CaO	Fe2O3	MgO	SO3	Others
OPC	23.17%	5.37%	61.86%	3.32%	2.78%	-	3.5%
PPC	21.77%	2.59%	57.02%	0.65%	2.71%	2.41%	-

Form the table 2.2, OPC and PPC have the same chemical composition but have a difference proportion. Pozzolana is a synthetic or natural substance that has reactive silica in it. Although it lacks cementitious qualities, when finely divided at room temperature, it can chemically react with calcium hydroxide to produce compounds (calcium silicates) having cement properties it's the reason why the OPC widely used as building materials.

Clinker, gypsum, and a small amount of other elements make up the majority of OPC. Gypsum, fly ash, volcanic ash, or calcined clay are examples of pozzolanic components, and OPC clinker may be added to PPC it is related to their strength and mechanical properties which is PPC is a more sustainable option than OPC since it has a smaller environmental impact and better resistance to chemical attacks.

Calsium Sulfoaluminate Cement (CSA) is another of the Supplementary Cementitious Materials (SCMs) has properties cementitious with better properties than OPS and PCC. CSA These so-called fast-setting cements are useful for building projects that require quick turnaround times, including fixing congested roads or airports that can only be closed for a short because of (CSA) is produced at 1250 ˚C, which is approximately 200 ˚C lower than an ordinary OPC, and with a 25–30% lower net CO2 release (Pushpan et al., 2023).

High alumina cement is made by either sintering or fusing aluminous and calcareous ingredients, then grinding the resulting clinker in accordance with IS requirements. The only ingredient that can be added while grinding is water. The extremely rapid strength growth of high alumina cement concrete is one of its main characteristics. It can acquire roughly 20% of its maximum strength in a single day (Iyer, 2020).

The OPC is a cement that is often used in studies. In addition, OPC is also easily available Most of the strength is produced by the reaction of C_3S with water, which results in the formation of the nanostructured, weakly crystalline compound known as C-S-H (calcium silicate hydrate), which contains crystalline calcium hydroxide particles. Although the total volume decreases because the water is more densely packed in the generated solids, overall, this hydration reaction produces solids with double the volume of the beginning materials.

Overall, every step of the manufacturing process to produce Portland cement is well optimised. Limestone ($CaCO_3$), which often makes approximately 90% or more of the raw meal, is the primary raw material component. Smaller amounts of bauxite (Al-hydroxide), quartz (SiO_2), burned shale (Si, Al, Fe), and iron oxide (Fe_2O_3) are also added. Depending on local availability, the origin of the minor constituent materials may change between cement factories (Oye, 2012).

2.2.1 Reinforcement

The strength of reinforced concrete is nearly double that of ordinary concrete. Although not all concrete needs to be reinforced, reinforced concrete is used in footings, slabs, columns, and foundations to prevent structural failure. Because of the concrete's compressive strength and the reinforcing element's tensile strength, reinforced concrete extends the life and durability of structures. Furthermore, the most widely utilized reinforcing material, steel, and concrete have comparable thermal properties. Because of their comparable thermal properties, steel, the reinforcing material, and concrete can expand and contract at comparable rates.

Reinforcing steel, often known as rebar, comes in a variety of shapes and sizes, including TMT and deformed bars, each reinforcing is depend on the applications because every reinforcing material has unique engineering qualities, choices must be made based on the needs of the specific application the types reinforcing bar (Iyer, 2020):

i. Fiber Reinforcement.

ii. Epoxy-coated Reinforcement.

Based on previous study (Iyer, 2020), FR is the concrete added with fiber. Fibers in the mixture, including natural, carbon, asbestos, steel, polypropylene, glass, and polymeric fiber (kevlar, arami). During mixing, fibers should be used an appropriate length-to-diameter aspect ratio and volume percentage are added. Fiber serves as a secondary reinforcement, preventing shrinkage-related cracking and enhancing the concrete's ability to absorb energy. Its help to improve its tensile strength and ductility of concrete, making it an essential part of reinforced concrete constructions.

A fiber dosage of 0.5% to 1% has been found to work well. Once more, the kind of fibers utilized, and their dimensions/sizes will determine this. There are many different forms of fibers, such as straight, crimped, hooked, etc., and their lengths range from 19 to 60 mm. There are also fibers that are shorter than 19 mm, which are known as microfibers. Epoxy-coated, function as variations in the reinforcement's surface condition, which alters the performance of the connection between the reinforcement and the concrete (Ma et al., 2023).

From previously, the epoxy-coated will combine with geopolymer concrete to build strong bond between the surface. The test findings demonstrate that the ultimate bond strength of the epoxy-coated reinforcement (ECR) and geopolymer concrete declined by 7.32% and 14.76%, respectively, when the rebar diameter grew from 14 mm to 16 mm and finally to 20 mm (Ma et al., 2023). In comparison to ECR and geopolymer concrete, the ultimate bond strength between regular threaded reinforcement and geopolymer concrete was slightly greater.

Epoxy-coated also can prevent the corrosion in concrete composite when a substance called epoxy is applied to the steel bars to prevent corrosion and extend the concrete structure's durability. In concrete, C-S-H and CH both contribute to preventing corrosion of the steel reinforcement in reinforced concrete. The C-S-H creates a tangled solid network. Therefore, it plays a physical part in slowing down the pace at which chemically active species enter the system.

In contrast, as CH interacts with CO_2 to precipitate calcite, it can be thought of as a chemical sink for ingested CO_2. This helps to keep the rebars' surrounding pH at a high level and prevents corrosion. The main purpose of reinforcement is to improve the properties of concrete either in physical or mechanical aspect and it is depending on the volume, types of concrete will be combined with it and must be relevant to be used. Since, natural fiber is cheap than other material also low cost, natural fiber has been used as reinforcement for this study

2.2.2 Additive Materials

Additives are commonly used to modify the properties of the cement paste, such as setting time, workability, strength development, and durability. One example of an additive used in concrete is calcium nitrate, which can act as a set accelerator, plasticizer, long term strength enhancer, and antifreeze admixture (Kičaite et al., 2017). There are two types of additives for concrete: chemical and mineral additives. Based on previous study there are four types of materials that has been used as additives in concrete.

i. Liquid Brown (Polycarboxylic).
ii. Calcium Nitrate.
iii. Quicklime CL 90 + SRA (Liquid-types shrinkage-reducing agent).
iv. Metakoalin.

Liquid brown (Polycarboxylic) in (Mohammed et al., 2023), this study prove that the reduction in water content produced incrementally as the additive's amount increased. Compared to combinations containing 300 and 400 kg of cement, the combination containing 350 kg of cement for all three types of additives demonstrated a greater percentage of water-content decrease. The polymer RC 897 showed the highest effect on reducing the water content compared to the other two polymers by 46.7% at a cement content of 400 kg, while the polymer PC180 exhibited the highest effect on reducing the water content of the other two types of polymers by 43.5% at a cement content of 300 kg.

Calcium nitrate as an additive in concrete had been a positive impact on both the early and standard strength of the material, especially at different temperatures. At lower temperatures, calcium nitrate can effectively accelerate the setting time of cement pastes, which leads to the early development of strength in concrete (Kičaite et al., 2017). This is particularly beneficial in cold weather conditions where the setting and hardening of concrete can be delayed.

Every additive gives different effect to the microstructure and compressive strength by various accelerating admixtures, such as calcium nitrate and crystal seeds. Cement pastes' compressive strength is improved by calcium nitrate (Pizon & Lazniewska-Piekarczyk, 2019). Precast facilities can expedite the demoulding process and reuse forms by enhancing the early-stage compressive strength. Crystal seeds are added to cement pastes, the C-S-H phase becomes more fully developed and the compressive strength increases.

The cement pastes are stronger overall and their microstructure is improved by this treatment. When it comes to accelerating concrete admixtures, calcium nitrate and crystal seeds both work well by increasing the compressive strength of cement pastes (Pizon & Lazniewska-Piekarczyk, 2019). Quicklime CL 90 + SRA (Liquid-types) has been study as shrinkage educing agent in concrete and a liquid shrinkage-reducing agent (SRA) based on organic compounds and 5% quicklime were added to an OPC concrete C30/37 mixture to restore it (Augonis et al., 2023).

The impact of quicklime on shrinkage was thought to be contingent upon the composition of the concrete. Therefore, it could be necessary to modify the shrinkage strain component to adapt it to different concrete compositions. The observed shrinkage curve best coincided with the theoretical one produced by the modified B4-mod for the concrete specimen containing 5% quicklime addition. Metakoalin additives can influence temperature, when kaolin is dehydroxylated between 650 ˚C and 850 ˚C, a metastable reaction product known as metakaolin (MTK) is produced.

(Kramar, 2015) state on their study, must not go over 3% of MTK. A flaw in the strength of the concrete occurs in the later stages of its hardening process when 5% or more metakaolin is used. It also becomes less resistant to the effects of sulfate and cold environments. To produced high quality of concrete with better properties, additives materials can be used as accelerated to the concrete, help reduced water in concrete mixtures, as plasticizer and improve shrinkage-reducing concrete admixtures. For this study, additives will prefer Calcium Nitrate, concrete is strengthened and sets faster thanks to these additives, which quicken the cement's hydration rate.

2.3 Natural Reinforcement

Engineers and scientists are attempting to exploit natural resources to benefit people's daily lives because of technological advancement. A plant is utilised in composite materials as a fibre. A warm-season annual fibre crop linked to jute and cotton, kenaf is also grown (Lam & Yatim, 2015). In a four to five months growing season, kenaf can reach heights of 4-5 m and a diameter of 25-35 mm. In the past, kenaf was used as a crop for making cordage to make twine, rope, and sack fabric.

Treatment on kenaf fibre will reduce its high-water absorption characteristic to ensure good performance. This can be done by using a chemical to modify the fibre's hydrophobic characteristic, improving the adhesion between the fibre surface and the matrix. In addition, the treatment can make the fibre's surface rougher, which enhances the tensile capabilities of kenaf fibres as compared to untreated kenaf fibres (Alam et al., 2017).

According to studies done by (Elsaid et al., 2011), Anti-microbial treatments are used to improve the FRC's overall durability and stop the fibres from deteriorating. According to (Lam & Yatim, 2015) study, the chemical treatment, fibres will undergo alkali treatment where the hemicellulose from the fibres was eliminated by the alkali.

Basically, alkali will function as interfacial adhesion between natural fibres and polymer matrix. In addition, NaOH solution is also used as remover for lignin, wax substances, and natural oil on the surface on fibres. Each solution concentration will effect on these fibres. Every industry faces a significant requirement and struggle to switch over to sustainable products to promote sustainable development (Kerni et al., 2020).

2.3.1 Types of Natural Reinforcement

Pineapple leaf fibre, Bamboo, Jowar, Banana, Jute, Hemp, Flax, and Sisal are some natural fibres that work well as reinforcement in polymer and concrete composites. This natural fibre that commonly used in as reinforcement of concrete. There are the six categories into which natural fibres are divided (Kerni et al., 2020):

i. *Reed Fibres*:
These fibres come from grains including rice, corn, and wheat. Waste fibres from maize (Zea mays L.) are lignocellulosic fibres made up of the frequently discarded corn cob, husk, stalk, and stover. Comparing the physico-chemical characteristics of lignocellulosic fibres from various sources.

ii. *Leaf fibres*:
Abaca, sisal, and pineapple. The sisal fibre micro-structure is made up of several individual fibre-cells with diameters of 6-30 µm. The middle lamella is made up of hemicellulose and lignin, connecting the separate fibre-cells. It has a chemical make-up of 54-66% cellulose, 12-17% hemicellulose, 7-14 lignin, 1% pectin, and 1-7% ash.

iii. *Bast Fibres*:
Some examples of bast fibres include jute, flax, hemp, ramie, and kenaf. Hemp fibre, which is part of the bast fibre family and has a multicellular structure, is harvested from the stem of the plant. The hemp plant, which has a height range of 1.2 to 4.5 metres and a diameter range of 12 cm, is primarily farmed in Europe and Asia. These fibres are utilised in clothing, rope, and insulation for gardens.

iv. *Seed Fibres*:
Such as Cotton, Kapok, and Coir. At 1.8 to 4.6 m in height, it starts to develop. It also needs a lot of water and artificial fertiliser. The most common varieties are Pima cotton and upland cotton (Gossypium hirsutism). The use of cotton fibres in the textile industry is crucial.

v. *Core Fibres*:

Some examples of these fibres include kenaf, hemp, and jute. Using Scanning Electron Micrographs (SEM), kenaf has a porous structure with primary and minor. For example, 1.293 0.006 gm/cm^3 is the density of the bast fibre, and 0.09-0.11 gm/cm^3 is the density of the core fibre. A structure with micro-pores the substance is particularly absorbent since it contains around 50% by weight of cellulose.

Figure 2.2: (**A**) Sisal plant, its fibers, fabrics; (**B**) Jute plant,its fibers, fabrics; (**C**) Kenaf plant its fibers, fabrics; (**D**) Hemp plant, its fibers, fabric and (**E**) Coir plant, Coir fibers its fabric. (Puttegowda et al., 2018)

Every type of fibres will give different impact on the concrete performance and some fiber will have a negative impact on the hydrations of cement composite. There are so many studies that showed the effect of fibers on the concrete composite (Abbas et al., 2022a). A prior investigation demonstrated that, (Tariq et al., 2023) when applied in the same volume fraction as polypropylene fibers, KF offered superior workability in cementitious mixtures. Comparing the 0.1% polypropylene fiber combination to the fiber-free control mixture, the workability of the latter was 34% higher.

Conversely, KFRC with 0.1% KF had a 29% lower workability than the control combination. Through the reduction of KF's water-absorbing chemical components, fiber pre-treatment mitigated the decrease in mixture workability. To lessen the amount of workability lost, the fibers can also be pre-wetted before to usage in mixes.

2.3.2 Types of Kenaf Fiber

Kenaf fiber is one of the types of natural reinforcement that added into concrete mixtures. Based on their properties, kenaf fiber is more popular as a fiber compared to other plant, it is also multifunction in various applications. Furthermore, plants are desirable because their tall stems can yield long fibers. However, fiber surface treatment should be done before mixing it with concrete. The purpose of the treatment is to change the surface of the fiber and overcome the hydrophilic nature.

One successful technique for lowering these fibers' water absorption and increasing the interfacial adhesion between the fiber surface and the cement matrix is surface pre-treatment through chemical or physical modification (Abbas et al., 2022b). For kenaf fiber appropriate mixing ratios were determined for KFRC with 1.2% and 2.4% fiber percentages. According to the (Elsaid et al., 2011) research, a cement-rich mixture, and coarse aggregates with a maximum diameter of 9.5 mm are needed to retain the workability of the KFRC.

The sisal fibers had a mean tensile strength of 400 MPa and an elastic modulus of about 19 GPa, respectively. The Young's modulus and ultimate tensile strength were not changed by the gage length when the gage length was raised from 10 mm to 40 mm, the strain-to-failure dropped from roughly 5.2% to 2.6%. This study showed the possibility for reinforcing thin cement-based laminates for semi-structural and structural applications using long aligned sisal strands.

The best rheological properties were obtained with 10 mm long jute fibers at a volume percentage of 2.0%, whereas the worst properties were obtained with 30 mm long jute fibers at a volume fraction of 1.0%. The mixtures broke in a ductile way even though all the mechanical parameters declined (compressive strength dropped from 27.5 to 6 MPa and fexural strength dropped from 6.2 to 1.8 MPa). Using 10 mm long kenaf fibers at 2.0% induced optimal fiber dispersion, whereas the minimum dispersed coefcient value was determined for 5 mm long kenaf fbers at 0.5%.

Chemical treatment effects on the behaviour of the fibres and the effects of their addition to concrete have been investigated. According to research conducted by other authors, treating hemp fiber-reinforced concrete with 10% NaOH for 24 hours improved its qualities and decreased its degradability in an alkaline solution (Caroline & Archbold, 2002). One unique approach that stood out for flax fibers was treating them with 1% stearic acid in ethanol for four hours. The elastic modulus was slightly affected by the treatment with this solution, which increased the tensile by 101% (Caroline & Archbold, 2002).

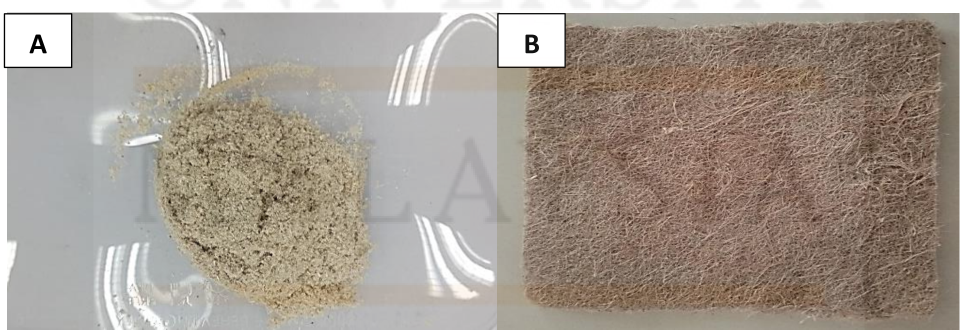

Figure 2.3: (**A**) Coir and (**B**) Kenaf Fiber Mat

The fiber orientation (random or unidirectional), treatment technique, fiber length, and fiber content all determine the compressive, flexural, and tensile strength of KFRCC based on (Abbas et al., 2022b). The volume fractions of the fibers in concrete might vary from 0.25%. to 2% vol. The KFRCC dosage ranges from 0.1 to 2.5 vol.%. Few studies have examined the effects of KF content above 2.5 vol.%, though 10mm to 8mm was the length of kenaf fibers employed in most of the studies.

As this investigation goes on, it is anticipated that the mechanical properties of the kenaf fiber volume will be influenced by both fiber length and content. Used kenaf fiber as natural reinforcement will improve the mechanical properties than other fiber, suitable volume friction should be taken which is the best value is less than 3% to produced high performance concrete composite.

2.4 Recent Development of Kenaf Fiber

Due to the peculiar behaviours of agricultural-based composites, researchers are very interested in their advances for structural uses in the automobile, aerospace, and construction industries (Sreenivas et al., 2020). Kenaf fiber, one of the agricultural fiber that are readily available, is frequently used as a reinforcement in polymer composites to create kenaf reinforced polymer matrix composites (Cement, 2011). The creation of hybrid natural-based composites with kenaf fiber as a reinforcing agent has been researched. To achieve the requisite qualities, matrix resins such as epoxy, unsaturated polyester, polypropylene (PP), and phenolic are utilised (Yusuff et al., 2021).

The findings demonstrated that the produced hybrid composites outperformed the glass mat thermoplastic (GMT) samples in terms of tensile strength and tensile modulus. The same tendency was evident in flexural characteristics as well. This is because the fabrication process uses pressure to compress the hybrid composite and strengthen the bond between the epoxy and the fibers. The GMT sample, however, shows better impact behaviour than the kenaf hybrid sample (Yusuff et al., 2021). Researchers have made advancements to increase the performance of composite materials made of natural resources.

Kenaf fibers offer several functions, scalable manufacturing values, and a variety of value adds for commercial gain. Kenaf fibers are very strong and rigid. However, they have a low density. Recent studies have addressed these long-term objectives by demonstrating that kenaf fibers have qualities that, with appropriate modifications and the inclusion of chemicals, could enable them to replace glass fibers, particularly in applications that don't require as much strength (Uzoma et al., 2023).

Furthermore, as evidenced by Ford Motor Company, kenaf fibers are becoming more and more popular in a variety of engineering applications, especially in the pulp and paper technology and automotive industries, because of their excellent mechanical qualities, short growth life cycle of 150 days, and high economic and industrial value. In response to these long-term goals, recent studies have demonstrated that kenaf fibers have qualities that would enable them to replace glass fibers with certain modifications and the inclusion of chemicals that are beneficial, particularly in applications that no need require as much strength.

2.5 Physical and Mechanical Characteristics

The physical properties of KFRC were examined with several testing, all materials' measurable attributes that are related to their physical or chemical composition. These characteristics, include colour, density, melting point, thermal conductivity, electrical conductivity, and corrosion resistance, can be seen or measured without altering the material's composition. This test will show and analyse how Kenaf fiber influence the physical characteristic on surface of concrete. The physical and chemical characteristics of materials, such as surface roughness, porosity, and crystal habit, can be clarified through examination of morphology (Nicula et al., 2023).

However, mechanical characteristic using tensile strength and flexural, sometimes result in a loss in mechanical strength when used in longer lengths at greater content. Materials' mechanical properties are those that characterize a material's behaviour under mechanical stress or load. In evaluating materials for a variety of purposes, include manufacturing, engineering, and building, these attributes become essential for understanding how a material will behave under different conditions. All new laboratory preparations were evaluated for their mechanical (compressive, flexural, and tensile strengths), thermal (thermal conductivity), and physical (cone slump, air content, pH, and density) qualities based on (Małek et al., 2021).

2.5.1 Water Absorption

Kenaf Fibre reinforced composites have the potential to absorb water depends on their fibet content, orientation, temperature, exposed surface, permeability, voids, and hydrophilicity (Flatt et al., 2012). The movement of water atoms via tiny spaces in concrete. The mechanism of water absorption caused by insufficient wettability and impregnation, this process can been used capillary transport into the cracks and holes that serve as the interface between the fiber and the matrix (Akil et al., 2011).

In sisal fiber concrete, the capillary water absorption curve has been applied. The CH-free and PC composites go through three distinct stages. Composites water absorption has an exponential decline characteristic. For CH free and PC composites, the composites' sportively values were 0.025 cm $min^{-1/2}$ and 0.019 cm $min^{-1/2}$, respectively.

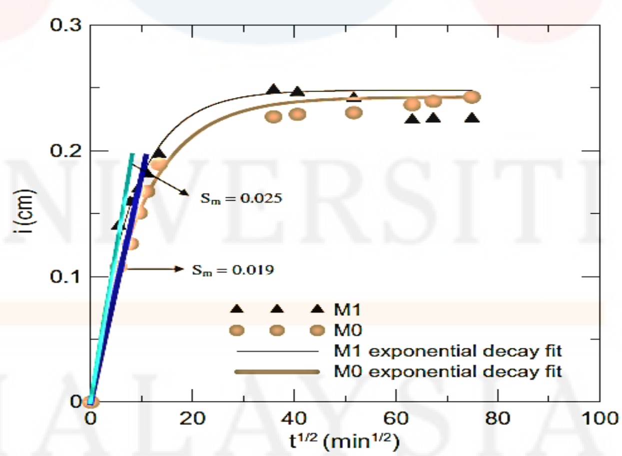

Figure 2.6: Capillary Water Absorption: Cumulative Absorption i vs. $t^{1/2}$; Experimental Points are marked by triangles for CH free and circles for PC composites. The sorptivity S_m is defined by the main linear portion of the curve (Silva et al., 2010).

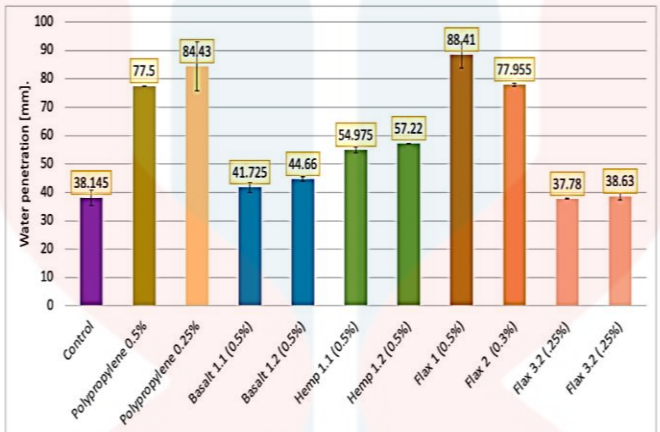

Figure 2.7: Water Penetration (mm) (Caroline & Archbold, 2002)

Form the Figure 2.7 shows the addition of 0.25% flax fibers produced results that were almost identical to the control mix, suggesting that the cement paste would be able to coat the fibers at this amount, making it more difficult for water to permeate the matrix. Compared to control and flax 0.25%, the hemp fiber blends showed up to 50% higher penetration levels. Unexpectedly, mixtures including the synthetic material polypropylene showed higher levels of water penetration, which may be an indicator of decreased fiber-matrix adhesion.

Other studies have been conducted, the water absorption was determined. In the strengthening period, the experiment was carried out on days 14, 28, 56, 90, and 180. In comparison to abaca fiber concrete, conventional concrete had a higher water absorption rate for both grades. 30M1 and 40M3 had 180th-day water absorption values of 3.11 and 2.97, while 30M2 and 40M4 had values of 2.54 and 2.02. The abaca fiber concrete ranks 18.32 and 31.9% lower than 30M1 and 40M3 when the two results are compared. The alkali solution treatment prevented further water absorption by the abaca fiber (Priya & Sudalaimani, 2023).

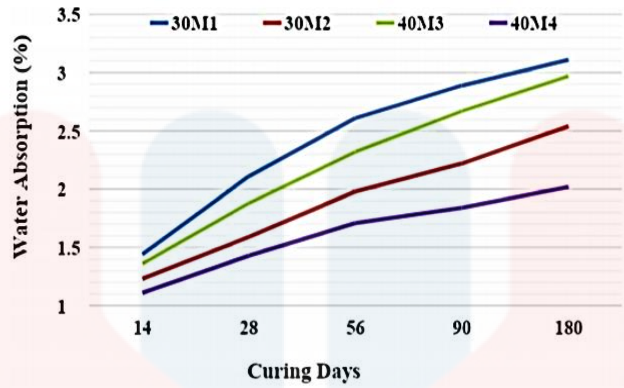

Figure 2.8: Water Absorption of Conventional and Abaca Fibre Concrete (Priya & Sudalaimani, 2023).

Form the three previous studies results that conclude, the amount of fibers in concrete composite will give impact on the water absorption and sorptivity properties. The great values for fibers content should be less than 5% form the mix proportions ratios. This result revealed that fiber should be treated to improve their properties.

2.5.2 Flexural Strength

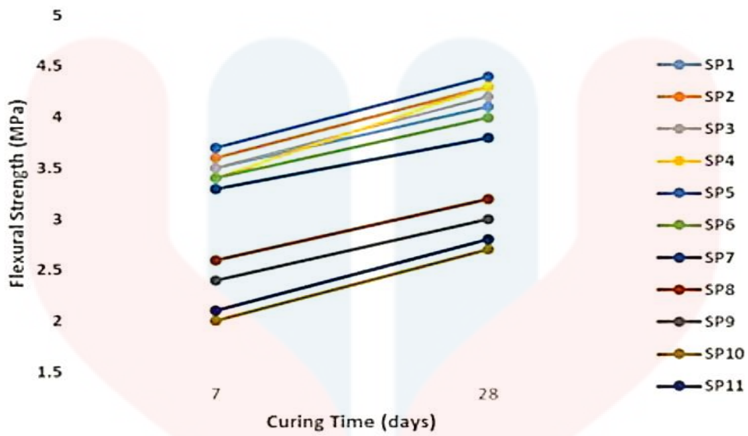

Figure 2.13: Flexural Strength vs. Curing Time (Lam & Yatim, 2015)

Inspection reveals that the KFRC's flexural strength was decreased due to the excessive fibre content in the concrete. Figure 2.13 show the flexural strength of the KFRC prisms was only slightly improved by the inclusion of fibres in the proper quantities. The specimens SP2 to SP5 demonstrate this. According to the results, the fibre length has a minimal impact on the flexural strength of KFRC.

According to Figure 2.13 and Figure 2.14, the failure of the control prisms was caused by the development of a single crack along the middle third of the prism, which resulted in brittle failure of the prism. However, when a comparable break appeared in the KFRC prisms, the kenaf fibres' presence assisted to bridge the crack and the crack is narrower, as demonstrated.

Table 8
Flexural behavior of 28 day KFRC prisms.

Sample ID	Modulus of rupture, f_r				Toughness			
	Mean (MPa)	St. dev. (MPa)	CofV	$f_r/f_c'^{1/2}$ (SI)	(US)	Mean (Joules)	St. dev. (Joules)	CofV
C-1.2-28-f_r-1~5	6.2	0.6	10%	0.84	10.1	9.0	3.3	37%
F-1.2-28-f_r-1~5	5.0	0.7	14%	0.72	8.7	28.9	4.7	16%
C-2.4-28-f_r-1~5	6.8	0.4	6%	0.93	11.2	17.1	6.8	40%
F-2.4-28-f_r-1~4	4.7	0.2	4%	0.81	9.8	52.6[a]	9.2[a]	17%

[a] Two of the four tests were halted prior to reaching the L/150 limit. These tests were not included in the calculation of the mean or standard deviation.

Figure 2.14: Flexural Behaviour of 28 days KFRC Prisms (Elsaid et al., 2011)

The impact of the kenaf fibers on the flexural strength and toughness of KFRC prisms was assessed by flexural tests. The observed load-midspan deflection behavior of the 1.2% KFRC and the 28-day control prisms under test. As is common for FRC, kenaf fibers considerably enhanced the residual flexural strength and toughness of the prisms while marginally reducing the concrete's peak flexural strength. The 2.4% KFRC prisms exhibited similar behavior. The KFRC and control prisms' toughness and modulus of rupture. Evaluating the table reveals that the KFRC prisms' modulus of rupture is smaller than that of the control prisms made of ordinary concrete.

It's probable that some balling of the comparatively long fibers used to make the KFRC caused this decrease in strength. (Elsaid et al., 2011) it shows that the modulus of rupture falls based on the length of natural fibers utilized in a concrete mixture. Measurement of the rupture's normalized modulus. The appropriate ratios of the mixture were determined for KFRC with 1.2% and 2.4% fiber concentrations. Flexural tests reveal that KFRC has a ductile failure mode in comparison to ordinary concrete, with an average measured toughness that is around three times higher than that of comparable control specimens made of plain concrete.

Specimen conditions	Flexural strength (MPa)		
	7 days	14 days	28 days
Reinforced concrete	12.39	14.50	19.58
Reinforced concrete + 5% coir fiber	12.89	14.91	19.80
Reinforced concrete + 5% coir fiber + jute rope	13.50	15.52	20.21
Reinforced concrete + 5% coir fiber + polypropylene rope	13.83	15.73	20.44

Figure 2.15: Flexural Test on Bean Specimens (Tariq et al., 2023)

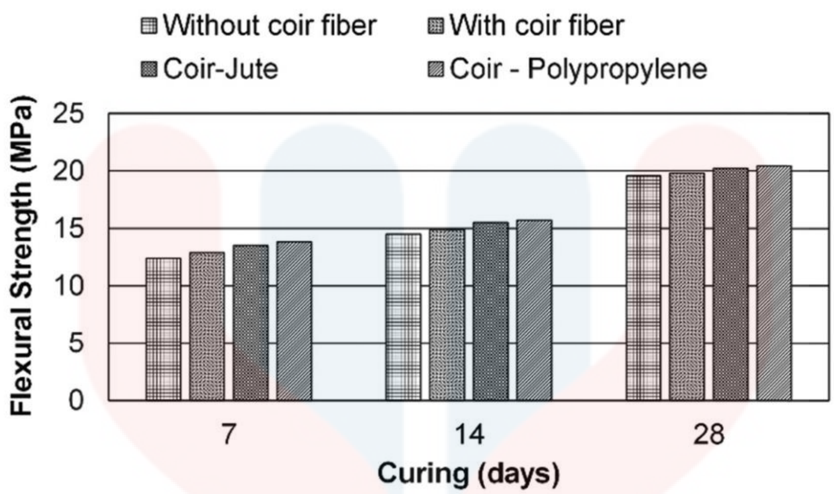

Figure 2.16: Flexural Strength Variation with Curing Time (Tariq et al., 2023)

(Tariq et al., 2023) study, in comparison to the control beam's 19.57 MPa flexural strength, the coir polypropylene beam has a 20.44 MPa flexural strength. When compared to the control beam, the flexural strength of the coir polypropylene beam is increased by roughly 6%. When compared to control samples, the fiber-reinforced steel concrete beams' cracking pattern shift from the end supports to the mid span.

The result reveals flexural strength values in variety length, types, and amount if fibers have been used in concrete mixture. To produced concrete composite with good performance and toughness we need to control the variability of fiber, measured the best amount of fiber and mix proportions of concrete mixture.

2.5.3 Compressive Strength

Compressive test used to determine the maximum amount of compressive load for a material, such as concrete. It can withstand before it fails or fractures. This testing involves subjecting a sample of the material to gradually increasing compressive force until it reaches its maximum load-bearing capacity. The test provides valuable information about the structural integrity and performance of the material under compression. Compressive strength is typically expressed in units of force per unit area which is in pounds per square inch (PSI) or megapascals (MPa) (Lam & Yatim, 2015).

Compressive strength in concrete is commonly determined by applying a compressive force on a cylindrical or cubical specimen until it breaks. The greatest load is then divided by the specimen's cross-sectional area to determine the compressive strength (Lam & Yatim, 2015). This measurement is crucial for figuring out whether concrete is suitable for a variety of uses, such building construction, where it's critical to make sure the concrete can support the weight of the structure without collapsing.

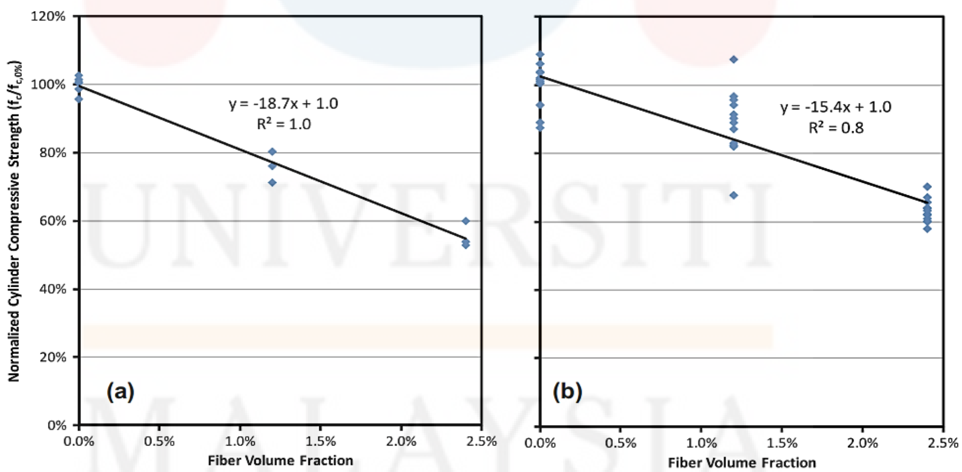

Figure 2.17: Effect of Fiber Content on Compressive Strength of KFRC at (a) 23 h (b) 28 days (Elsaid et al., 2011).

Table 3
Twenty-three hours compressive strength of KFRC cylinders.

Sample ID	Compressive strength		
	Mean (MPa)	St. dev. (MPa)	CofV (%)
C-1.2-23-f_c-1~3	22.8	0.8	4
F-1.2-23-f_c-1~3	17.2	1.0	6
C-2.4-23-f_c-1~3	27.2	0.3	1
F-2.4-23-f_c-1~3	15.1	1.0	7

Figure 2.18: 23 Hours Compressive Strength of KFRC Cylinders (Elsaid et al., 2011)

Table 4
Twenty-eight days compressive strength of KFRC cylinders.

Sample ID	Compressive strength		
	Mean (MPa)	St. dev. (MPa)	CofV (%)
C-1.2-28-fc-1~6	54.6	4.3	8
F-1.2-28-fc-1~12	48.5	8.1	18
C-2.4-28-fc-1~6	53.0	3.0	6
F-2.4-28-fc-1~12	33.4	2.4	7

Figure 2.19: 28 days Compressive Strength of KFRC Cylinders (Elsaid et al., 2011)

According to the results of the compressive strength tests, the 28-day compressive strength of KFRC was virtually unaffected by the addition of kenaf fibers up to a volume fraction of 1.2%. On the other hand, greater fiber concentrations 2.4% are linked to a higher volume fraction of kenaf fibers in the concrete and an increase in the water-cement ratio required for workability, which results in a measurable drop in compressive strength.

Furthermore, compared to plain concrete with a similar compressive strength, KFRC's compressive elastic modulus was found to be significantly lower. This was mainly because the KFRC mixtures contained smaller diameter and comparatively smaller amounts of coarse aggregates than conventional concrete.

Mixture ID	Vf (%)	Compressive Strength (MPa) 7 Days	28 Days
C0	0	17.40	22.30
K1	1	12.60	16.50
K2	2	11.30	15.20

Figure 2.20: Compressive Strength of Kenaf Fiber concrete mixtures (Syed Mohsin et al., 2018)

Form the figure 2.20, (Syed Mohsin et al., 2018) at days 7 and 28 the inclusion of kenaf fiber reduced the concrete's compressive strength. On the 28th day, the findings showed that K1 and K2 had decreased by 17.5% and 24.0%, respectively, in relation to the concrete's 20 MPa design strength. This is because the concrete that had kenaf fibers added to it became less dense. It's also possible that this is because the cubes did not completely dry out and solidify after seven days of curing in water. The density of the concrete will decrease even more when the amount of kenaf fiber added is increased; hence, the fiber content will cause the compressive strength to decrease.

Specimen condition	Compressive strength (MPa)		
	7 days	14 days	28 days
Control specimen	9.88	10.54	12.91
With 5% coir fiber	9.29	9.79	13.82

Figure 2.21: Compression Test on Cylindrical Specimens (Tariq et al., 2023)

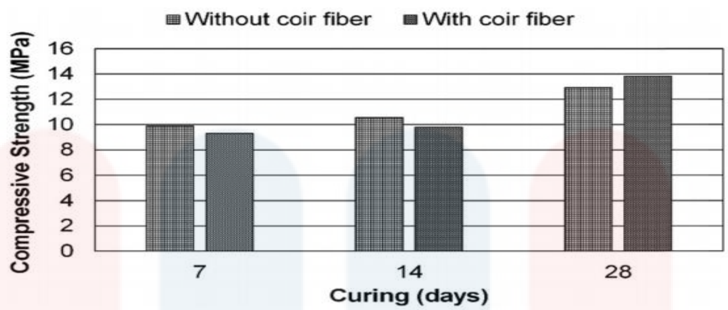

Figure 2.22: Compressive Strength Variation with curing time (Tariq et al., 2023)

Based on the figures 2.21 and 2.22, Coir fiber's rough surface provides a strong interfacial connection with the cement matrix. (Tariq et al., 2023) stated when compared to control concrete specimens, the fiber-reinforced concrete beam's compressive and flexural strengths are higher. Coir concrete achieves 13.82 MPa of compressive strength, while control concrete achieves 12.92 MPa.

When compared to control concrete, the compressive strength of coir concrete is approximately 6% higher. For conclusion, the compressive strength of concrete is approximately affected by fiiber and types of fiber. The interfacial between concrete and fiber should be taken as important to make sure the concrete is good mechanical properties. This is because rough surface fiber will provide strong bonding between reinforcement and matrix.

CHAPTER 3

MATERIALS AND METHODS

3.1 Preparation of Specimens

This research prepared a several specimens of Kenaf Fibre Reinforce Concrete (KFRC) with cubic and rectangle shape. Cement is another essential component of this concrete. Firstly, preparation of concrete as control used 1:3 ratio cement and sand (1 part of cement while 3 parts of fine aggregate include Kenaf core) without kenaf core. Mixed concrete by hand (manually) because of the small amount have been used for 100 g/ml.

3.1.1 Mixing, Casting and Compacting

Table 3.1: Mix of Proportion Concrete and KFRC

Type of concrete	Cement (wt%)	Fine aggregate (wt%)	Kenaf core (wt%)	$Ca(NO_3)_2$ (wt%)
C0	25	74	-	-
Kfrc 1	25	74	0.30	12.5
Kfrc 2	25	74	0.50	12.5
Kfrc 3	25	74	0.75	12.5

Figure 3.1: Samples prepared day 17 curing time.

After 24 to 48 hours, concrete dries sufficiently. The concrete is poured, the curing process can take up to 28 days. The new surface can sustain vehicular traffic and the movement of equipment across it after 7 to 10 days. At the same time, steam curing also occurs, this steam curing occurs due to the water in the concrete evaporating. However, the curing time can be reduced to three days if high-early strength concrete is used, and the temperature is above 30º C (room temperature).

For this research, the curing time is 7 days, 14 days, and 28 days. Preparation for rectangle and cubic mould. Concrete will dry in the mould. To make it simple to remove the hardened, the interior of the mould needs to be properly. The size of cubic mould is 4x4x4 cm and rectangle mould is 2x17 cm. The cubic and rectangle mould is made from foil aluminium. After that, air is taken out of freshly laid concrete during compaction. Concrete that has been properly compacted has a higher density and is stronger and more durable.

3.2 Characterizations of KFRC

3.2.1 Visual Observations

The visual inspection is conducted after all the samples is dried. After 7 days, observations direct and indirect. This method to evaluate on the surface of the PC and KFRC. Form this method can determine the difference between surface and chemical composition PC and KFRC

3.2.2 Water Absorption Testing

According to ASTM C 140 Water Absorption ("Water Absorption," 1955). Testing for water absorption is a crucial method for assessing the resilience and water resistance of concrete. The general procedures for carrying out a concrete water absorption test are as follows:

i. Prior to the test, the samples should be weighed.
ii. Drying: The sample is dried to a constant weight.
iii. Initial Weighing: The sample will weight.
iv. Immersion: The sample is immersed in water for a specified amount of time.
v. Final Weighing: After 24 hours, the sample will remove from the water, dry and weigh again.
vi. Calculation: The absorption (in percent) represents the weight growth as a proportion of the starting weight. Concrete's water absorption is quantified as a percentage of the sample's initial weight.

Water Absorption (%) =

$$\left(\frac{m2-m1}{m1}\right) \times 100\% \qquad \text{Equation 3.1}$$

Where:

m1: The mass of the dry concrete

m2: The mass of wet concrete

3.2.3 Flexural Strength Test

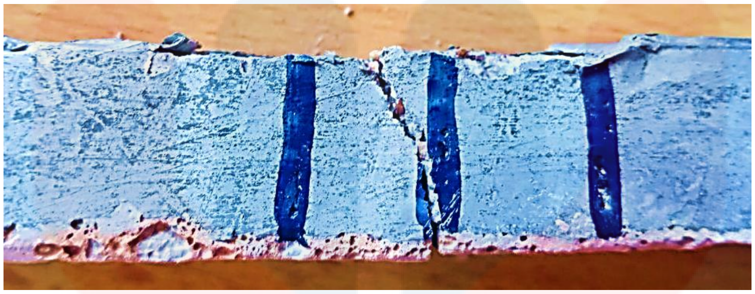

Figure 3.2: The crack occurs in the midpoint of KFRC3.

The procedure of flexural test refers to standard ASTM C293/C293M(ASTM C293/C293M, 2002). Using three-point load to perform the flexural test on concrete. The specimen is supported by the flexural test machine's supports during the test, and a load is applied at the middle of the supporting span. Calculating the modulus of rupture involves considering the distance between the line of fracture and the nearest support, specimen width, failure point depth, supported length, and maximum load.

The modulus of rupture =

$R = 1.5\ (Pl/bd^2)$ Equation 3.2

Where:

R = modulus of rupture, psi.

P = corrected load on beam, lb.

l = span between centers of lower supports, in.

b = average width of beam, in.

d = average depth of beam, in.

3.2.4 Compressive Strength Test.

Figure 3.3: Compressive Testing of KFRC3 for 14 Days

The general procedures for getting ready for a test of concrete's compressive strength is must refer to the standard ASTM-C39-C39M-01 (Method, 2000) or other related standard for concrete. Testing will be taken after curing time 7 days, 14 days, and 28 days. Place the specimen vertically on the platform of the compression testing device Universal Testing Machine (UTM) 0500-11213. Make sure there are no substantial flaws in the samples of compressive strength.

3.3 RESEARCH FLOWCHART

3.3.1 Research Flow

The research flow chart will be divided into three stages. Stage 1 is material preparation and stage 3 are for analysis, evaluation and comparison of the obtained experimental data as shown in Figure 4.1.

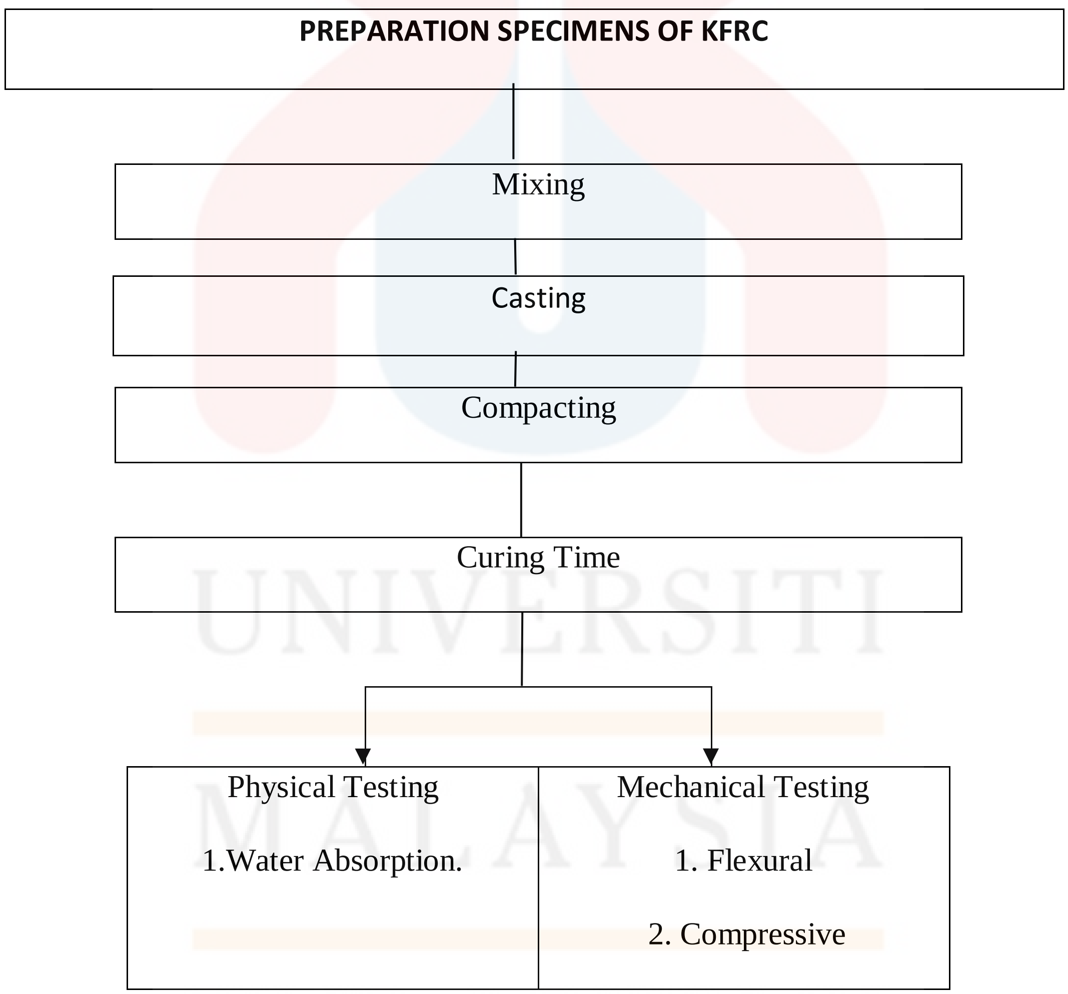

Figure 0.4 Research flow for Kenaf Fibres Reinforced Concrete

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Surface Appearance

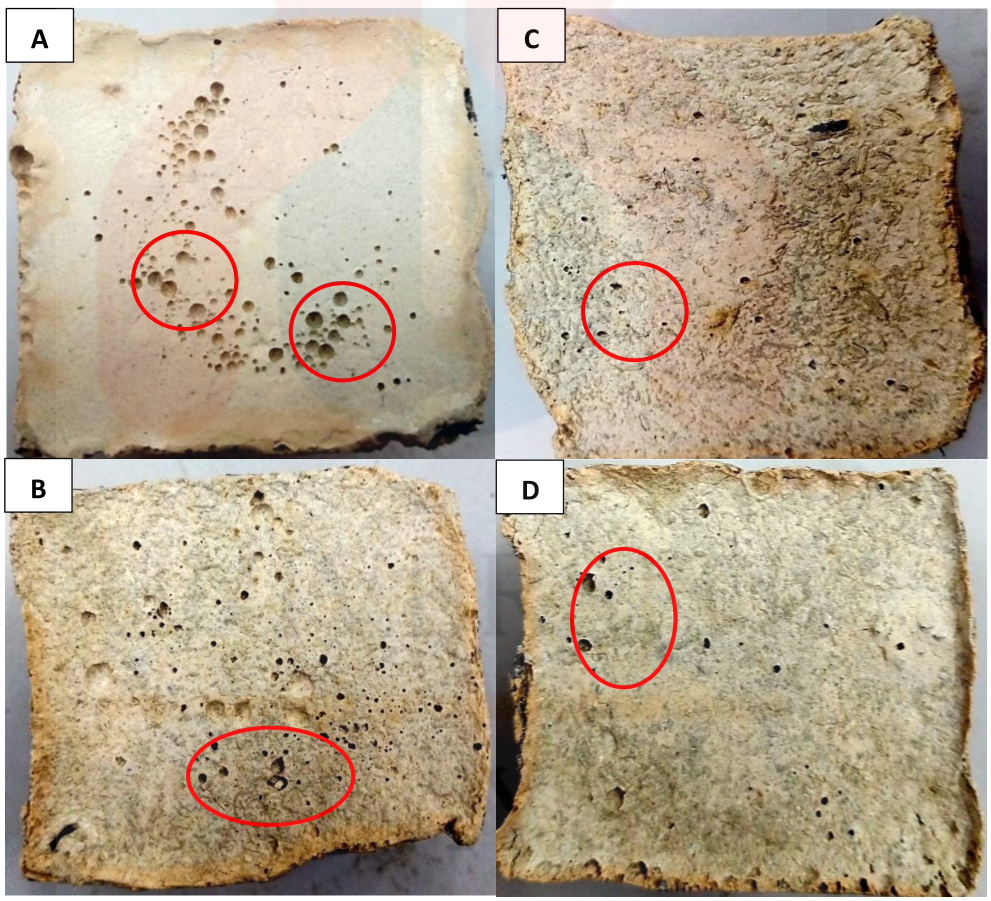

Figure 4.1: Void surface for 14 days (A) C0, (B) KFRC1, (C) KFRC2, (D) KFRC3

Figure 4.1 shows the porosity on the concrete surface, for plain concrete and KFRC1 have more porosity compared to the KFRC2 and KRC3. Based on the visual observations, porosity occur because of the unproper of compacting process and made the air bubbles in the concrete while casting it means the concrete is not mix well. This is also can influenced by the difference amount of kenaf fiber in every composition it means that added kenaf fiber either can make concrete mixture compact or not. Which is plain concrete (0%) KFRC1 (0.01%), KFRC2 (0.02%) and KFRC3 (0.03%). The porosity can influence the mechanical properties and the performance of concrete composite.

Since the porosity is related to the voids in materials, its means in the concrete matrix's air holes' existence. In (Gwon et al., 2023), it was believed that every mixture included both intrinsic fiber holes and entrained air bubbles produced during the comparatively lengthy mixing time of 30 minutes. Overall, with both plant types of fiber, the NFRCCs had a larger air content for a given fiber length when the volume fraction was increased. This resulted from both the increased volume of fiber and the increased quantity of entrained air bubbles, which increased porosity.

Nevertheless, the combinations with longer fibers (except from the 10-mm-long jute fibers) had less air content than those with shorter fibers at a constant fiber volume fraction. This is probably because the same fiber volume fraction, there are less lengthy fbers, which leads to a decrease in entrained air bubbles. (Azzmi & Yatim, 2018), To ensure optimal adhesion of fiber and aggregate in the concrete matrix, the fiber length indicated is twice the size of the coarse aggregate. Kenaf fibers can readily clump together. Therefore, long fiber is not appropriate.

This porosity can impact the quality of the mixing process and is a result of incorrect compacting techniques and air bubbles in the concrete during casting. Concrete mixture compactness is also influenced by the quantity and types of kenaf fiber added to the mixture. Concrete composite performance and mechanical attributes may be influenced by porosity.

Due to entrained air bubbles and increased fiber volume, KFRC had a higher air content for a given fiber length when the volume fraction was raised. When the fiber volume percentage remained constant, combinations with longer fibers had less air content than those with shorter fibers. In the concrete matrix, the surface of fiber should be treated to guarantee the best possible adherence of fiber and aggregate.

4.2 Water Absorption

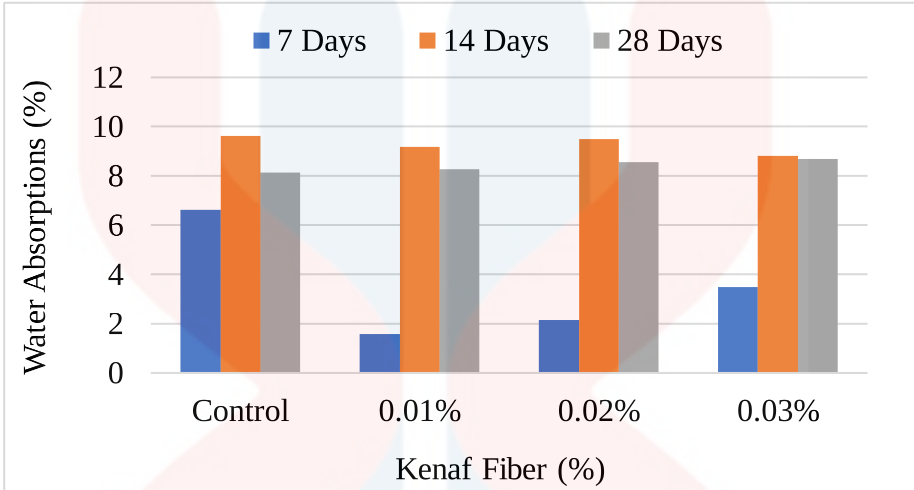

Figure 4.2: The average of Water Absorption of Control and KFRC

Figure 4.2 shown the percentage of water absorption each specimen with difference volume frictions of kenaf fiber. From the graph, comparison between Control and KFRC3, which have higher water absorption values of 8.12% and 6.99% than KFRC1 and KFRC2 have the lowest values, at 6.34% and 6.73%. The association between the volume of kenaf fiber and the materials' rate of water absorption is also demonstrated by the data.

The amount of kenaf fiber will alter the rate of water absorption which impacts the physical properties of concrete. The porosity of the concrete surface has an impact on this situation as well. Additionally, fiber may not function well if it has a high-water absorption rate.

Because of adding kenaf fiber it can have both positive and negative effects, the right amount of kenaf fiber should not be added more 0.03% depends on the requirements of study. Instead, an increase in the volume of space within the materials was noticed, indicating the presence of more porous microstructures.

Table 4.1: Water Absorptions and weight of Control, KFRC1, KFRC2, KFRC3

Specimens	Weight (g)	Mean weight (g)	Water Absorption (%)	Mean Water Absorption (%)
Control	115.51		6.62	
	119.37	114.06	9.62	8.12
	107.32		8.14	
KFRC1	118.46		1.57	
	86.86	106.37	9.17	6.34
	113.79		8.28	
KFRC2	119.26		2.15	
	110.92	113.79	9.49	6.73
	111.2		8.56	
KFRC3	118.73		3.49	
	112.86	115.15	8.81	6.99
	113.85		8.68	

Table 4.1, the average of weight and water absorption rate of concrete. From the table, the higher the rate of water absorption in the concrete composite, the greater the weight of each sample. Where control and KFRC3 are heavier than KFRC1 and KFRC2, 114.06 g, 115.5 g and 106.37 g, 113.79 g respectively. Inclusion of fiber will be affected the physical properties of concrete but its is depends on how much amount of fiber will be used, types of fiber the volume of mix proportion of concrete.

In (Katman et al., 2022), coir fibers provide concrete more rigidity, which keeps moisture from penetrating through and allowing the specimens to survive the crack. Other authors have also claimed in a few publications that the cement-based material was not more workable when coir fiber was added; as a result, more water was needed than in the case of the cement-based material without coir fiber. All types of natural fiber give a different effect on concrete,

Compare to the (More & Subramanian, 2022) study, The water absorption was found to be 2.79%, 2.84%, and 2.8%, respectively, with the addition of 2.0% coir, 1.5% jute, and 1.5% sisal fibers. The porosity was shown as 4.3%, 4.38%, and 4.27% simultaneously. Because 1.5% jute, 1.5% sisal, and 2.0% coir were added, the porosity was shown to be 4.65%, 4.86%, and 4.53%, respectively.

(Nazari et al., 2022) has been mentioned by increasing the fiber loading percentage from 0.5% to 3%, the natural cellulosic fiber-reinforced concrete's overall water absorption capacity ranged from 4.25% to 9.25% when the fiber loading grew from 0.5% to 3%. The porosity and crystallinity of the various natural fiber types tested in this study were found to be higher in coconut and sugarcane fibers than in jute and sisal fibers. As a result, the concrete samples reinforced with these kinds of fibers had a comparatively greater capacity to absorb water.

There are holes and pores in the concrete matrix because of the natural fibers in the concrete deteriorating due to reactions with the absorbed water and moisture. The concrete's strength is impacted by these holes and pores inadvertently. Considering these characteristics, appropriate coatings can be supplied to enable the efficient use of natural fibers. The addition of kenaf fiber to the concrete may have increased void and pore, which in turn may have contributed to the increased water absorption. Therefore, more emptiness and pore are present when the kenaf fibers grow.

4.3 Flexural Strength

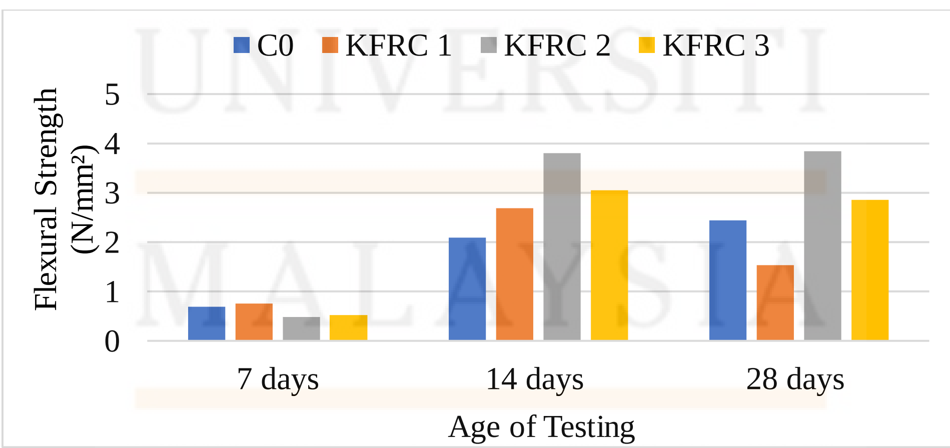

Figure 4.3: Flexural Strength of C0, KFRC1, KFRC2 and KFRC3

Table 4.2: The values of Flexural Strength

Specimens	Age of Testing			
	7 Days (N/mm²)	14 Days (N/mm²)	28 Days (N/mm²)	Mean (N.mm²)
C0	0.685	2.085	2.439	1.73
KFRC1	0.754	2.692	1.533	1.65
KFRC2	0.481	3.808	3.839	2.70
KFRC3	0.526	3.049	2.853	2.14

Figure 4.3 shown the flexural strength of C0 and KFRC with different age of testing and volume of kenaf fiber. Based on the age of time, the strength of the concrete increases with the number of days, especially if kenaf fiber is added. For volume of kenaf fibre it should be used ideal values to get the best mix of composition of concrete. This is because, kenaf fibre will give impact on the mechanical strength of concrete composite and related to the composition of mixtures.

Table 4.2 shown the difference values of C0 and KFRC with significant values. Form the table 4.2, the highest value is observed on days 14 and 28, as indicated by their respective averages of 2.909 and 2.666. This indicates that it takes a long time for concrete to dry and become usable in 14 until 28 days. Even when accelerator chemicals like calcium nitrate were added to the concrete to speed up the drying process, the concrete could not be totally dry by the 7^{th} days because of the significant volume friction of kenaf fibre need to be sure if added.

The greats of volume friction should be added into the concrete is 0.02% and 0.03% which is refer to KFRC2 and KFRC3. Compared to the other study, at 28 days, 1 year, and 2 years. The first breaking load of 4·8 kN was obtained for all three specimens, and the corresponding deflection was approximately 2 mm (Sivaraja et al., 2010). Nevertheless, when comparing the three specimens' yielding points, the concrete specimen reinforced with coir fibers after a year of curing yields the highest value. However, at the final phase, each of the three specimens exhibits the identical performance.

The flexural strength measured the stiffness of concrete composite, it is also can determined the modulus of elasticity. Based on the graph, the best composition of concrete composite is KFRC 2 and KFRC 3. This is because, the higher values of flexural strength it means the concrete is stiffer and the lower of flexural strength it means the concrete is more flexible.In (Gwon et al., 2023), their dispersion coefficients did not show a consistent change at 30 mm of fiber length. The dispersion coefficient of kenaf fibers dropped sharply even with 30-mm-long fibers at a 1% volume fraction when compared to utilizing 0.5% fibers due to the less uniform distribution and local aggregation of the fibers.

In terms of flexural characteristics, the highest value of Kenaf Fiber 0.75% performs better than standard and other mix concrete proportions. More load was needed to deflect the KFC-2 (0.75% and 25mm) specimens because to the larger load applied to them (Azzmi & Yatim, 2018).

Figure 4.4 shown the crack happen start in the midpoint of concrete until it is break into two pieces. Compared to regular concrete, KFC's cracking time is longer. When matrices receive ultimate loading, the fiber minimizes microcracks and keeps them together. The brittle nature of typical concrete is lessened by the energy absorption by fiber and particles (Azzmi & Yatim, 2018).

Based on the (Nazari et al., 2022) bending strength increased with a fiber loading percentage increase of up to 1.5%. When the fiber loading was increased above 1.5%, there was a noticeable drop in the bending strength of the concrete. In comparison to concrete samples reinforced with coconut and sugarcane fibers, samples reinforced with sisal and jute fibers had a better bending strength. When fiber loading exceeds 1.5%, there may be a subsequent decline in bending performance due to an increase in porosity and weak regions at the fiber-concrete interface.

In comparison to ordinary concrete without fibers by (Chaichannawatik et al., 2018), For SFRC, SGFRC, and GFCR, the flexural strength increased by 5%, 7%, and 9%, respectively. The addition of fibers appears to change the failure mode from brittle to ductile and improve post-cracking load and energy absorption capacity when compared to regular concrete. Adding extra fibers helps delay the progression of the cracks by bridging the gaps and transmitting force.

4.4 Compressive Strength

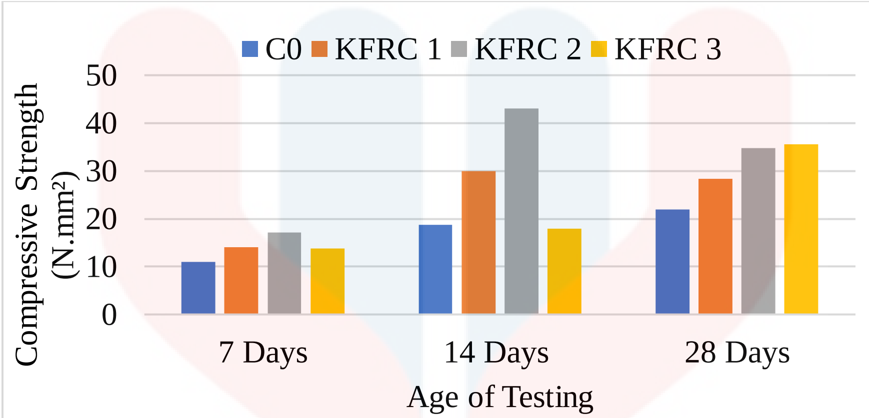

Figure 4.4: Compressive Strength of C0, KFRC1, KFRC2.KFRC3

The figure 4.4 shown, the compressive strength of C0 and KFRC in different age of testing period. The figures showed that as the amount of kenaf fiber in concrete increased, so does the value of compressive strength (N/mm). The specimen with the highest value on day 14 which is KFRC2 showed a slight decrease on day 28 according to the graph. When compared to C0, KFRC1, and KFRC2, KFRC 3 has so far demonstrated the best performance in concrete. The specific values of compressive strength showed in table 4.3, the higher values are referred to mean. KFRC2 and KFRC1 is higher than C0 and KFRC3 which is 31.59 and 24.06.

Table 4.3: The values of Compressive Strength

Specimens	Age of Testing			
	7 Days ($N.mm^2$)	14 Days ($N.mm^2$)	28 Days ($N.mm^2$)	Mean ($N.mm^2$)
CO	11.034	18.773	21.986	17.26
KFRC1	13.999	29.893	28.31	24.06
KFRC2	17.066	42.987	34.718	31.59
KFRC3	13.754	17.884	35.592	22.41

This is due to its continually increasing worth. After then, KFRC2 similarly saw a constant increase, although it was less than that of C0. KFRC2 at day 14, it is possible to experience errors during preparation that create an imbalance in the mix proportion. This means that KFRC2, KFRC3 and KFRC3 have higher fracture toughness than C0. therefore, the presence of kenaf as a fiber has an impact on the compressive strength of concrete.

(Shah et al., 2022) has been investigate about concrete reinforced with sisal, coir, or a mix of sisal and coir has seen a specific % improvement in compressive strength. Form that, the compressive strength has been influenced by both the natural fiber length and the fiber concentration. The SFRC and CFRC have increased with the usage of short fiber (10 mm in length) and a 1% concentration. However, the HFRC has increased at different concentrations than the SFRC and CFRC.

HFRC has used a length of 20 mm and a concentration of 0.5% to boost the compressive strength. The results indicate that SFRC and CFRC have improved more when using 10 mm with 1% fiber concentration, whereas HFRC has improved more when using 20 mm with 0.5% fiber concentration. Utilizing a short fiber with a 10 mm length has demonstrated increased compressive strength of concrete reinforced with sisal and coir fibers,

It has been observed that adding coir fiber to concrete up to a 2% reinforcement level increases its compressive strength; however, adding more results in a decrease in strength in (Katman et al., 2022). It has been noted that adding coir fiber to concrete increases its compressive strength up to a 2% reinforcement level.

This is in line with the observation that the presence of fibers tends to force the aggregates into the pores to guarantee sufficient bonding, but that bulkiness from higher fiber content distorts the bonding and reduces its strength. In addition, the overall concrete specimen tends to become weaker due to the establishment of a weaker transition zone around the fibers.

Similarly in (More & Subramanian, 2022), adding coir fiber improved the compressive strength by up to 2% of the volume amount. It was discovered that the ideal Coir fraction was 2.0%, resulting in a 15.92% increase in compressive strength above regular concrete. The ideal jute fraction was determined to be 1.5%, which resulted in a 13.68% increase in compressive strength over regular concrete. Likewise, a 14.18% improvement in compressive strength was achieved through choosing 1.5% as the ideal Sisal fraction.

Compared to (Poongodi et al., 2020), the 0.5% Coir Fiber and 0.5% Banana Fiber combinations had demonstrated comparatively higher strength in all curing periods of both the planned concrete, when compared to the other three hybrid combinations that were chosen. After 28 days, the hybrid fiber with 0.5% CF and 0.5% BF had a compressive strength that was higher than 10% of the control concrete.

The incorrect and unequal distribution of fibers within the concrete can give impact to the results, the poor homogeneity of the concrete matrix also can made decrease in compressive strength after a specific dosage. The volume percentage and kind of fiber added to the concrete had an impact on the compressive strength, according to the data.

Whereas the balling impact of the high-volume percentage of naturally added fibers to the concrete reduced the strength in the case of artificial fibers and the inappropriate distribution of fibers in the concrete also affected its compressive strength. In comparison to the control mix, the compressive strength of all the fiber-reinforced concrete mixtures was higher made the workability of concrete is significantly impacted when natural fibers are added.

Other study had mentioned that in the compressive strength significantly decreased beyond this point. Comparing 0.5% jute and sisal fiber reinforcement to plain concrete, an improvement in compressive strength of 11.6% to 20.2% was noted. Moreover, concrete reinforced with 0.5% coconut fiber had a 9% improvement in compressive strength (Jamshaid et al., 2022). Similar trends can be seen in the behavioural variations between concretes containing various cellulosic fiber types and the mechanical characteristics of those fibers.

The concrete samples supplemented with the matching fibers also demonstrate the inherent strength of jute and sisal fibers over coconut and sugarcane fibers. When the fiber loading was increased to a maximum of 2%, samples of natural fiber reinforced concrete displayed an increase in compressive strength.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The objective of this research is to be prepared KFRC at different kenaf fiber concentration with mixing method and to characterize surface appearance, water absorption, compressive and flexural strength of KFRC. The amount of kenaf fiber affects the physical properties of concrete, with higher water absorption rates affecting the porosity of the surface. The right amount of kenaf fiber should not exceed 0.03%, as it can have both positive and negative effects. Coir fibers provide concrete with more rigidity.

The flexural strength of concrete composites increases with the age of day and volume of kenaf fiber, particularly when added. The higher values indicate stiffer concrete and lower values indicate more flexibility. The cracking time of KFC is longer compared to regular concrete, as fibers minimize microcracks and reduce the brittle nature of concrete. Increase in fiber loading percentage results in an increase in bending strength. The addition of fibers improves post-cracking load and energy absorption capacity, changing the failure mode from brittle to ductile.

However, the presence of kenaf fiber impacts the compressive strength of concrete. The compressive strength is influenced by both the natural fiber length and the fiber concentration. The ideal Core fraction is 0.01%-0.02%. However, incorrect, and unequal distribution of fibers within the concrete can impact results. Also, the volume percentage and type of fiber added to the concrete also affect its compressive strength. In conclusion, the presence of kenaf fiber in concrete has a significant impact on its compressive strength.

5.2 Recommendations

This study needs to be continued with additions to some improvement because of this study is very useful in the future. This is because, this study can be applied in all aspects, and it is important to increase the number of studies on concrete composite. Natural fiber needs to be studied more deeply because it can be used as a reinforcement material in concrete and is easier also cheaper to obtain when compared to materials such as steel.

In addition, I suggest to the future researcher to adding characterization for physical and mechanical properties. For example, thermal and surface morphology. To reveal KFRC properties in more detail. I am also suggested to doing a better treatment or alternative to improve its properties so that kenaf can stick firmly together with cement and aggregate.

Not only that, its damp and water-absorbing properties are also limitations for kenaf to be used as a building material. Lastly, I suggest improving the ratio in mixing concrete and use better equipment than before. I also recommend that laboratory machines and tools be improved and increased to help students do laboratory work better.

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APPENDIX A

1. Cement/Aggregate Ratios.

Simples	Calculations Ratios (1:3) (wt%)
C0	Aggregate: 0% Fibre of 3% Sand: 1:3 = 100% $\frac{100\%}{4} = 25$ Cement: Sand: Fibre = 25%: 75%: 0%
KFRC 1	Aggregate: 0.01% Fibre of 3% Sand: 1:2.99:0.01 = 100% Cement: Sand: Fibre = 25%: 74%:0.30%
KFRC 2	Aggregate: 0.02% Fibre of 3% Sand: 1:2.98:0.02 = 100% Cement: Sand: Fibre = 25%: 74%:0.50%
KFRC 3	Aggregate: 0.03% Fibre of 3% Sand: 1:2.95:0.03 = 100% Cement: Sand: Fibre = 25%: 74%: 1.30 %

2. Water Absorption Test.

7 Days Curing Times	
Samples	**Calculations W.A (%)**
C0	$\frac{116.51 - 109.27}{109.29} \times 100\%$ = 6.62%
KFRC 1	$\frac{119.46 - 117.61}{117.61} \times 100\%$ = 1.57%
KFRC 2	$\frac{120.26 - 117.73}{117.73} \times 100\%$ = 2.15%
KFRC 3	$\frac{199.73 - 115.69}{115.69} \times 100\%$ = 3.49%

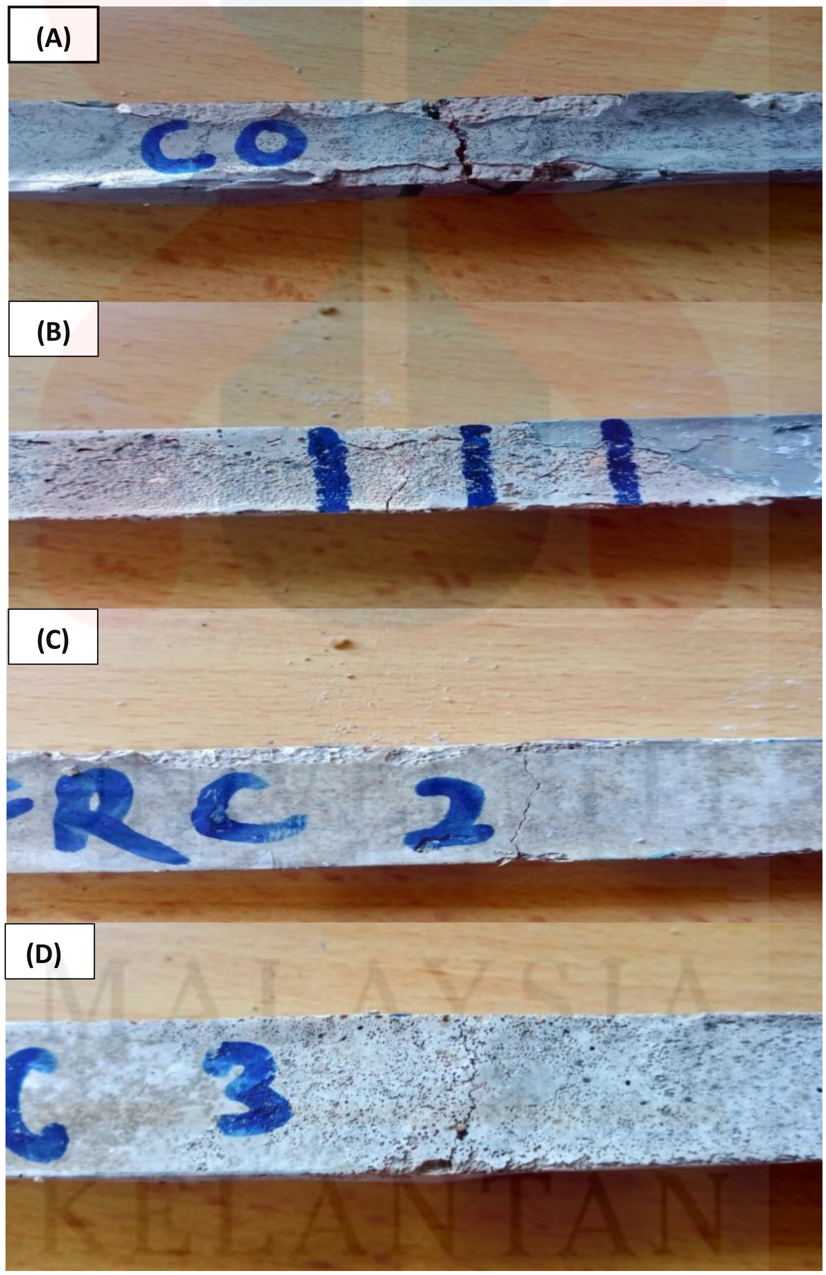
14 Days Curing Times	
Samples	**Calculations W.A (%)**
C0	$\frac{120.37-109.81}{109.81}\times 100\%$ $= 9.62\%$
KFRC 1	$\frac{87.86-80.48}{80.48}\times 100\%$ $= 9.17\%$
KFRC 2	$\frac{111.92-102.22}{102.22}\times 100\%$ $= 9.49\%$
KFRC 3	$\frac{113.86-104.64}{104.64}\times 100\%$ $= 8.81\%$

28 Days Curing Times	
Samples	**Calculations W.A (%)**
C0	$\frac{108.32 - 100.17}{100.17} \times 100\%$ =8.14%
KFRC 1	$\frac{114.79 - 106.01}{106.01} \times 100\%$ = 8.28%
KFRC 2	$\frac{112.2 - 103.35}{103.35} \times 100\%$ = 8.56%
KFRC 3	$\frac{114.85 - 105.68}{105.68} \times 100\%$ = 8.68%

APPENDIX B

1. Flexural Test (Samples)

(A) Concrete, (B) KFRC1 with 0.01%, (C) KFRC2 with 0.02%, (D) KFRC3 with 0.03%



APPENDIX C

1. Compressive Test (Samples)

   (A) Concrete, (B) KFRC1 with 0.01%, (C) KFRC2 with 0.02%, (D) KFRC3 with 0.03%