CAPITAL UNIVERSITY OF SCIENCE AND TECHNOLOGY, ISLAMABAD

Sustainable Framework on Hybrid Fiber Reinforced Concrete to Control water losses in Canal Lining

by

Liaqat Ali Khan

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I am thankful to Allah almighty, the Gracious and Beneficent for enabling me to complete the project successfully. This minor effort is dedicated to my respected Parents and Family members, who helped me through each troublesome of my life and yielded every one of the comforts of their lives for my brilliant future. This is likewise a tribute to my best teachers who guided me to go up against the troubles of presence with ingenuity and boldness, and who made me what I am today.

CERTIFICATE OF APPROVAL

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Abstract

Sustainability is one of the major issues of the world today. The demand of sustainable development is increasing day by day in all areas of economic sector like construction, architecture, agriculture, industries, water resource, irrigation etc. Sustainable projects are turned out to be major consideration in the construction sector for having economical and energy efficient structures throughout the life cycle. Water is life for all human activities so sustainable usage of water is very critical. Major portion of our water resources are used to be waste due to irrigation system losses. The main water losses in canal lining are due to seepage, adsorption, evaporation, and operational losses causes by temperature variation, differential settlement, hydraulic pressure etc. With the passage of time the initial micro cracks in canal-lining convert into macro cracks, which ultimately accelerates the water losses by allowing the seepage through these cracks. Seepage loss (20%-30%) is major reason of water loss of unlined canals and (15%-20%) has also been observed even in the cementconcrete conventional sections in lined canal. Concrete lining in canal is considered an effective solution to cater this problem.

The use of fibers for improving the characteristics of concrete is very ancient. Fiber has the potential to resist cracks in concrete and make concrete less impermeable. Recently, hybrid fiber reinforced concrete (HFRC) has gained popularity for its Superior mechanical properties i.e. Compressive strength, Splitting tensile strength and Flexure strength. In current study, the used hybrid fibers are the combination of two different fibers i.e. Jute fiber (JF) and polypropylene fibers (PPF). JF has the capability to improve strength properties of concrete, while Polypropylene fibers include benefits like chemically inertness, zero water absorption and high tensile strength. The mix design ratios of concrete with fibers are 1:2:4:0.6 uses in this research work which improve strength properties and make the concrete impermeable to save water losses in canal. Also, it controls water logging and salinity for sustainable development irrigation system. All this operation may ensure to control the rate of cracking in canal-lining, eventually improving its desired performance.

It is recommended that combination of different other fibers should also be investigated to control the water losses of canal lining as economical resource. There is a need to address the sustainable development frame work to introduce the drawbacks of irrigated canal in order to save water losses for future generation and provide safe irrigation structure to community.

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Abbreviations

A	Aggregate
C	Cement
CCE	Compressive cracked absorbed energy (MPa)
CPE	Compressive pre-crack absorbed energy (MPa)
CS	Compressive strength (MPa)
CTE	Compressive total absorbed energy (MPa)
CTI	Compressive toughness index (-)
FCE	Flexural post-crack absorbed energy (kN.mm)
FPE	Flexural pre-crack absorbed energy (kN.mm)
FRC	Fiber reinforced concrete
FS	Flexure strength (MPa)
FTI	Flexural toughness index (-)
FTE	Total flexural absorbed energy (kN.mm)
HFRC	Hybrid Fiber Reinforced concrete
JF	Jute fibers
JFRC	Jute fiber reinforced concrete
kN	kilo-Newton
LS	Linear shrinkage (mm)
mm	millimetre
MoR	Modulus of rupture (MPa)
MPa	Mega Pascal
NF	Nylon fibers
PC	Plain concrete
PPF	Polypropylene fibers

PPFRC	Polypropylene fiber reinforced concrete
S	Sand
s	second
SCE	Splitting-tensile post-crack absorbed energy (kN.s)
SPE	Splitting-tensile pre-crack absorbed energy (kN.s)
SS	Splitting-tensile strength (MPa)
STE	Splitting-tensile total absorbed energy (kN.s)
STI	Splitting-tensile toughness index (-)
WA	Water absorption (%)
W/C	Water-cement

Symbols

Δ	Deflection (mm)
Δo	Deflection at maximum load (mm)
εo	Strain at the maximum stress (-)

Chapter 1

Introduction

1.1 Prelude

Sustainability is the ability to exist constantly. It has been defined in many ways. According to the report published in UN World Commission of economic Development (WCED), "To meet the need of present without compromising the ability of future generations to fulfill their own needs". Sustainability is one of the major issues of the world today. The concept of sustainable development is increasing day by day in all areas of economic sector like construction, architecture, agriculture, industries, water resource, irrigation, public health etc. Therefore, it has becomes important to assess and control the factors for achieving a sustainable economic development. Sustainability is very important to conserve natural resources on earth for coming generation. Sustainable project turned out to be major consideration in any construction activity due to characteristics of economically, environmentally and energy efficient throughout the life cycle [1]. Achieving sustainability in irrigation system (like canal lining) is very important now a day for supporting human life, economic stability and provides peaceful ecological system to conserve natural resources (water) for coming generation.

Water is life for all human activities so sustainable usage of water is very critical. Our water resources are used to waste due to irrigation system losses. Canal-lining is widely used as a water saving measure. However, cracks may be observed in canal concrete lining which can be converted from micro cracks to macro cracks with passage of time, that permits the seepage through this lining. Pakistan economy mainly depends on agriculture and for better agriculture products depends on reliable irrigation system. A large amount of water is lost due to poor irrigation system in our country causes due to seepage at beds and banks of canals. Seepage is the downward movement of water from a source of supply like irrigation channel or reservoir into soil or substratum [2]. About 20%-30% water losses causes due to seepage in canals [3,4]. About 15%-20% seepage in lined canal has been witnessed even in the cement-concrete conventional sections [5]. One of the major reason for the increase the rate of cracking in concrete canal lining is thermal stresses [6]. Cracks in canal lining can be mostly controlled by improving mechanical properties and linear shrinkages of its concrete [7]. The cracks in canal can be controlled mostly by educating mechanical properties i.e. compressive strength (CS), splitting-tensile strengths (STS), and the flexure strength (FS) of concrete [8]. Seepage is a problem in canal system create twin problem of water logging and salinity, so consequently large land of agriculture has gone out of use, and this practice is continued predominantly in Pakistan. An effective solution to solve these problems is to provide concrete lining in canals. The reduction in rate of cracking can be based on mechanical performance criteria associated with enhanced post cracking behavior of fiber reinforced concrete.

Material investigation is carried out regarding better lining of concrete in canal performance for crack rate control. Fibers in concrete act as crack arrester [9,10]. In current research, hybrid fibers (mixture of two different fibers i.e. polypropylene and Jute fibers) are used that improve strength properties and make the concrete impermeable to save water losses for sustainable development irrigation system. The purpose of current research is to observe behaviors of HFRC for eliminating the cracks in canal lining. PC sample is taken as reference. The Mix design ratio 1:2:4:0.6 for cement, sand, aggregate and water respectively are used for PC and 2-3% (by cement mass) fibers are added for making HFRC. Due to high post cracking absorption capacity and better post crack performance, HFRC can be a good choice in comparison to PC. An enhancement in mechanical properties is unveiled by HFRC over that of PC. Last 20 years research article have focused. Also water absorption, porosity, linear shrinkage was made to be performed to control seepage losses in canal and save water losses. In this study, the strength parameters of HFRC with polypropylene fibers and jute fibers having different fiber length and content are investigated.

1.2 Research Motivation and Problem Statement

Water is life for all human activities so accordingly sustainable usage of water is very critical. Our water resource is going waste due to irrigation system losses. Canal-lining is widely used as a water saving measure. However, there may be observed cracks in canal concrete lining. Pakistan economy mainly depends on agriculture and for better agriculture products depends on reliable irrigation system. A large amount of water is lost due to poor irrigation system in our country causes due to seepage at beds and banks of canals. About 20%-30% water losses causes due to seepage in canals [3,4]. The motivation of the research topic is to control the water losses and provide safe irrigation system to community. Thus the problem statement is as following:

"The seepage from the canal creates twin problems of salinity and water logging consequently a large agriculture land has gone out of use, and this process is continued particularly in Pakistan. Canal-lining is widely used as a water saving measure. Cracking in canal-lining reduced its efficiency up to 70% [11]. One of major reasons for the increase in the rate of cracking in concrete canal-lining is thermal stress [6]. Due to this, the performance of canals is decreased with an increase in water losses. Improving mechanical properties of concrete and controlling its linear shrinkage can limit cracking in canal-lining [7]. So, to attain the high-performance concrete for canal-lining application, the fibers can be utilized in concrete. There is the study regarding polypropylene fiber (PPF) plus jute fiber (JF) reinforced concrete for canal-lining application. JF are to be used to improve

strength properties of concrete, while PPF has the capability to control water loss by make the concrete impermeable".

1.3 Overall Objective of the Research Work and Specific Aim of this MS Project

"The overall goal of the research work is to explore the material for better performance of canal lining to resist the rate of cracking. These cracks may develop due to Temperature variation, differential settlement of foundation, external load, opening of joints etc. However the specific aim of this MS project is to examine the sustainable frame-work on hybrid fiber concrete to control the cracking rate for possible application in canal lining which ultimately reduce the seepage".

1.4 Scope of Work and Study Limitation

In current research work, a sustainable frame work in light of literature are studied to investigate the mechanical properties, control water losses, linear shrinkage control of hybrid fiber reinforced concrete (HFRC) and plain concrete (PC) for possible application in canal lining. In study limitation 20 years research should be focused for relative comparison of PC and HFRC.

1.5 Brief Methodology

The mix design ratio for Plain concrete i.e. (cement: sand: aggregate: water 1: 2: 4: 0.6). The same mix design ratio is used for hybrid fiber reinforced concrete but having 2cm to 5cm long fibers of Jute and polypropylene for 2% to 3% (by mass of cement) to be used. Slump, density, water absorption, linear shrinkage, XRD and flexure strength test have studied. Flexure behavior, energy absorbed and toughness index were examined. Link between material properties and canal lining performance are to be investigated. For these propose sustainable frame work for expected water saving in canal in to be investigated.

1.6 Research Significance

Seepage is a problem in canal system create twin problem of water logging and salinity, so consequently large land of agriculture has gone out of use, and this practice is continued predominantly in Pakistan. There is need to address the sustainable development frame work to introduce the draw backs of irrigation canal in order to save water losses and provide safe irrigation structure to community. Thus a framework is important to be prepared for solving this issue effectively, efficiently and economically.

1.7 Research Novelty and Practical Implementation

There is need to address the sustainable development frame work to introduce the draw backs of irrigation canal in order to save water losses & provide safe irrigation structure to community.

1.8 Scholarly Aspects of Current Research

To the best of authors knowledge on the basis of literature research, no study has been conducted for developing theoretical sustainable framework for possible use of Hybrid FRC to control the cracks in canal lining.

1.9 Project Report Outline

The thesis contains four chapters. These are:

Chapter 1 includes of introduction. It explains the sources of water losses in canal-lining, research motivation, problem statement, overall or specific research aims and scope of work, investigation methodology, research novelty, scholar aspect of current research and project outline.

Chapter 2 contains the literature review of 20 years research articles. It comprises of background, water losses in canal-lining and its reason, available measure to reduce water losses in canal, performance of fiber reinforced concrete, behavior of hybrid fiber reinforced concrete, use of FRC in canal lining, relationship between material properties of canal & their performance, and summary of chapter 2.

Chapter 3 incorporates the discussion on basis of literature review. It covers the knowledge include background, raw materials, the techniques of PC and FRCs mixing and casting, specimen details, testing techniques, critical review for HFRC in canal lining, and summary of chapter 3.

Chapter 4 encompasses of conclusions, recommendations, acknowledgement & references.

Chapter 2

Literature Review

2.1 Background

There are many forms of water losses in canals. In comparison to other forms of water loss, the major water loss in canal have been absorbed are seepage. Concrete are commonly use in canal lining to reduce seepage losses. The efficiency of canal lining can be seriously affected by developing cracks in canal surfaces. These cracks can be improve or control by enhancing the strength properties and make the concrete impermeable to reduce water losses. These properties can be improved by integration of fibers with concrete. In this chapter, the effectiveness of fiber incorporation in concrete and application of HFRCs for canal-lining is discussed in detail.

2.2 Water Losses in Canal and its Reason

Water is life of all human activities so sustainable usage of water is very critical. Our water resource is going waste due to irrigation system failure. Usually concrete are used to reduce the seepage loss in canal lining. The main water losses in canal lining are seepage, adsorption, evaporation and operational losses. The concern of water losses from canal has substantial impact on surface water availability. Current research have recommended for canal lining to reduce the water losses. Mostly these losses occur near outlet of canals and watercourses are due to high velocity, hydraulic and hydrostatic pressure, and maximum retention time, swelling soil and junction points. Concrete linings fail in the form of cracking, rupture, uplifting and opening of joints, cause loss of water. Failure of concrete linings of canal in the form of temperature variation, differential settlement of foundation, external load and opening of joints, causes loss of water. With the passage of time, the initial micro crack develop in watercourse or canal concrete lining exchanges to macro size which causes seepage through that particular lines. The rate of cracking in concrete of canal can be controlled by educating the mechanical properties (Tensile, compression and flexure strength) and make impermeable concrete. Among all these, tensile strength plays an energetic/vital role in controlling cracks in concrete [12].

About (20%-30%) seepage losses is major reason of water loss evidence in unlined canal [4]. About 15%-20% seepage of lined canal may be observed due to conventional section of cement concrete [3,5]. Main causes of concrete lining cracking are material properties, hydrostatic uplift pressure, hydraulic pressure [13]. The more water absorption in concrete canal lining, there was high rate of deterioration and vice versa [14]. So in term of all above researchers it should be concluded that efforts are require controlling water losses in canal.

2.3 Available Measure to Reduce Water Losses in Canal

The major chunk of construction is covered by concrete construction. Concrete is a mixture of cement, sand, crush and water in appropriate ratio. It is good in compression but weak in tension. In order to improve these strengths of concrete, concrete raw materials are commonly available in approach of local farmers; hence it is useful for canal lining to control seepage [15]. The rate of cracking in canal-lining can be controlled mostly by educating mechanical properties i.e. splitting-tensile strengths, compressive strength and the flexure strength of concrete [8]. Arshad et al. [16] reported that the abundance of water leakage through the water ways was most likely because of cracks, disintegrated mortars, and structural failure of lined canals. Karad et al. [17] reported that for provision of minor lining the seepage should be 39% minimized. A more crack resistant concrete can be significantly improved its structural durability [18]. The reasons responsible for cracks involve thermal stress (temperature variation due to freeze and thaw), differential settlement of foundation, external impact loading etc. [6,19]. Many mechanical/ engineering properties (like Abrasion, tensile strength, thermal impact, flexural strength, and fatigue resistant strength) of composites like (concrete, mortar, and cement paste etc.) can be powerfully enhanced by familiarizing fibers with composites [20-23]. So in term of all above investigations it should be concluded that the best performance of concrete lining in canal can reduce the water losses.

2.4 Performance of Fiber Reinforced Concrete (FRC)

The practice of fiber goes back at least 3500 years can be traced back to Egyptian times, when straw was used to reinforced sun backed bricks, Horse hair was used in mortar, Asbestos fiber were used in concrete in the early 1900. In 1950, the concept of composite material came into picture. Steel, glass, natural and synthetic fibers have been used to enhance the special properties of concrete for the past 30 or 40 years. Fiber can be found in form of natural fibers, synthetic fibers, steel fibers, glass fibers etc. In the modern days the cost of construction is increasing with the cost of materials used in it and due to this reason the construction had become unaffordable, thus to reduce the cost of construction materials, the material like fibers which enhance the properties like strength properties, workability, durability, flexural strength ,tensile strength, etc. The steel, glass, etc. fibers can be replaced by natural fibers having low cost and easily available in the market. In our country the fibers reinforcement is not new concept, it is very old from the ancient times as the bamboos were used as a geo synthetic material in Great Wall of China. The fibers used in ancient times were the leaves of trees, vegetable fibers, etc. Many natural reinforcing materials can be obtained at low energy effort and low cost. These composites obtain from natural fibers has been tested for plastering, roofing materials, corrugated slabs and boards etc. and all were reported with their satisfactory results. These natural fibers can avoid superior crack widths that could permit water and pollutant penetration which cause corrosion specially in reinforcing steel. The fibers immerged with concrete fall down their workability. Hence, it require/need to enhancing a better value of slump. Thus, some special admixtures like super plasticizers, air entraining agents can be used to enhance the flow performance of FRC [24-26].

Fibers immerged with concrete are used for different purposes mentioned below [27].

- The main role of fibers are to bridge the crack (both longitudinal and transverse) that creates in concrete which significantly enhance the concrete toughness and ductility.
- Fibers in small volume dosages (1% to 5%) of weight of cement are typically added to concrete, and to be effective in reducing plastic shrinkage and drying shrinkage, so there is extensive enhancement of concrete post cracking behavior.
- Fiber makes the concrete impermeable by reduces the absorptivity of concrete and consequently controls the water bleeding.
- Some fibers show better resistance against abrasion in concrete.
- Impart more resistance to impact load.

Researches about fiber reinforced concrete are to be continues even today. Fibers training for improve behavior of concrete is very ancient. Concrete having cement, water, aggregate (Coarse and Fine) and discontinuous, uniformly dispersed fibers are known fiber reinforced concrete. In the modern days the cost of construction is increasing with the cost of materials used in it and due to this reason the construction had become unaffordable, thus to reduce the cost of construction materials, the material like fibers which enhance the properties like workability, durability, flexural strength, tensile strength, etc. There are so many natural products which are obtained from the forest but commonly observed thing is Jute (natural) fibers. Natural fibers as reinforcement of composite have the potential to improve the strength properties of concrete [28,29]. The natural fibers can avoid superior crack breadths that can permit water and pollutant penetrates which cause serious corrosion in steel reinforcement. Fiber makes the concrete impermeable and so reduces the permeability of concrete and consequently controls bleeding for water. In concrete fibers act as crack arrester [9,10]. The concrete brittleness and poor crack resistance can be controlled up to some extent by reinforcement of randomly distributed fibers. The cracks from micro- to macro level can be arrested by use of fibers reinforcement. The fibers help to resist the initiation and crack growth from micro- to macro level and provide bridging effect which ultimately enhances the strength and toughness [30]. A stone like material is known as concrete which is attained by a warily balanced mixture of cement, sand, gravel and water. While in fresh state, concrete is a plastic which can be molded into any desired shape but with time it becomes hardened. Concrete develops micro cracks during curing. Cracks propagate in the fibers that are right under the load and these hybrid steel fibers block crack propagation. Due to dry shrinkage problem in concrete, formation of cracks also occurs and by elapsing of time increase in size and magnitude of cracks take place resulting in failure of concrete. To minimize these phenomenon fibers are introduced as a new technique which helps to escalation of concrete tensile strength [31,32].

Concrete which contain fibrous material is known as Fiber Reinforced Concrete (FRC) which improves its structural strength. It incorporates quick isolated fibers which are equally allotted and haphazardly oriented. Fiber reinforced concrete consisting of, cement, water, fine and coarse aggregate, along with discontinuous fibers. The small Piece of reinforcing material which own certain properties and minimize the propagation of cracks are called Fibers which are equivalently disseminated and arbitrarily arranged. This concrete is named as fibers reinforced concrete [33]. The addition of fibers greatly reduced the post cracking behavior in concrete which improves structural integrity and cohesiveness of material [34]. Natural fibers enhance the dynamic properties of concrete, toughness and crack resistance [35]. Strength properties of concrete (Compressive, flexure and tensile strength) with hair fiber reinforced concrete are improved 12.4%, 16.2% and19.1% respectively, and that of WPFRC are increased by 11.7%. 25.5% and 17.5% respectively as compare to PC [36]. An increase of 105% in split tensile toughness was observed with 1% of wheat straw fiber content as compare to PC [37]. Post cracking performance of concrete can be enhances by using Jute fibers as reinforcing material [38]. Using of jute fiber in concrete improved its toughness and flexure strength [39]. On the basis of all mentioned literature it is suggested that fibers in concrete acts as crack arrestor which enhance strength properties of concrete. The demand of high strength increases day by day, using jute fibers can overcome this demand.

2.4.1 Use of Single Fiber Reinforced Concrete (FRC)

There is lots of research available to investigate the single fiber with concrete to improve the special properties with different mix design. For this purpose 20 years research articles have been focused.

Table 2.1: Strength properties of Jute, Nylon, Polypropylene, Glass & Steel Fibers by James et al. [40]

Fiber Type	Tensile Strength (ksi)	Elastic modulus (ksi)	Water absorption per ASTM D 570, Percentage by weight
Jute	36-51	3770-4640	Not Available
Nylon	140	750	2.8-5.0
Polypropylene	20-100	500-700	NIL
Glass	450	9400	Not Available
Steel*	50-435*	29007*	Not Available [41]

* Data from Banthia (2010) [41]

Table 2.2: Advantages of Jute, nylon, polypropylene, glass and steel fibers

Fibers	Advantages	References
Jute	Seven times lighter than steel fibers, high energy absorption capability, high breaking strength, cheaply available.	[42,43]
Nylon	Strong, light weight, better resistive to heat and cold conductance, good tenacity, toughness, and outstanding elastic recovery, zero water absorption, stable, and exceptional capability of abrasion resistance.	[41,9,44]
Polypropylene	Low specific gravity, more ductility, zero water absorption capacity, high elasticity and energy absorption, outstanding capability to oppose friction, bond by mechanical interaction with cement matrix and does not chemically interact with cement, lowest thermal conductivity among the available fibers.	[41,9,45,46]
Glass	Low density, more ductility, light weight, energy efficient.	[47,9]
Steel	High density, more ductility, energy efficient, zero water absorption	[9]

Table 2.3: CS, SS, and MoR of PC, JFRC, NFRC, and PPFRC by Previous Studies

Fiber content	Mix design Ratio	Fiber length (mm)	CS (%)	SS (%)	MOR (%)	References
PCC	-	-	100	100	100	-
JFRC						
0.6 kg/m3	(1:1.74:3.24)	30	119	-	154	[48]
1% a	(1:1.5:3)	40	128	112	144	[49]
4.4 kg/m3	(1:1.5:2.7)	50	106	-	111	[42]
0.25%b	(1:1.5:3)	15	105	105	119	[50]
0.50%b	(1:1.5:3)	15	98	78	90	[50]
0.25% b	(1:2:4)	15	102	101	111	[50]
0.50% b	(1:2:4)	15	88	113	101	[50]
NFRC						
5%a	(1:3.33:1.67)	50	94	108	103	[51]
1%b	(1:1.22:2.8)	45	108	110	113	[52]
1.5%b	(1:1.22:2.8)	45	94	94	93	[52]
1%b	(1:1.5:3)	20	127	112	-	[53]
2%b	(1:1.5:3)	20	107	169	-	[53]
PPFRC						
0.25%a	(1:1.5:3)	24	106	172	-	[54]
1.5%b	(1:1.5:3)	12	134	140	-	[55]
1%b	(1:1.27:2.76)	12	107	119	118	[56]
0.25%b	(1:1.27:2.76)	12	103	107	105	[56]
1 kg/m3	(1:1.36:2.52)	54	104	113	102	[57]
2 kg/m3	(1:1.36:2.52)	38	84	118	115	[57]

* Note: a, content by mass of cement, b, content by volume fraction of concrete.

2.4.2 Behavior of Hybrid Fiber Reinforced Concrete (HFRC)

Hybrid fiber are the mixture of two different fibers i.e. Jute fiber and polypropylene fiber which are use in the current research work which include benefits like low cost, least health hazards, improvement in mechanical properties and flexibility. A recent option for reinforcement in concrete includes the addition of more than one fiber results into hybrid fiber reinforcement. Singh et al [58]. Investigated the properties, such as compressive and flexural strength of HFRC comprehending steel and polypropylene fibers have been investigated. A significant increase in MOR has been seen in the case of HFRC due to absence of voids. To reduce the risk of spelling and deterioration, the use polypropylene and steel fiber can bear satisfactory protection on the concrete behavior [59]. He et al. [60] examine polypropylene with steel. Their results show that steel-polypropylene HFRC increased the MOR up to 11.4%. Wang et al. [61] studied steel-polypropylene HFRC having different length of steel with fixed length of polypropylene fibers. Their results show that with greater length of steel maximum MOR was observed about 49.05%. It has been seen that as the length of the polypropylene fiber increased MOR value decreases up to 5.23% [62]. Sorelli et al. [63] also investigated the steel and polypropylene fibers as HFRC with 0.5% each having equal lengths. They reported the 41% increase in MOR.

Recently, hybrid fiber reinforced concrete (HFRC) has gained popularity for its superior mechanical properties. Hybrid fibers are combination of two different fiber with desired fiber length and fiber content. In current research jute plus polypropylene fibers are selected due to study their characteristic in previously available research. It can be observed that jute and polypropylene fibers have high tensile strengths and elastic moduli and also having low tendency of water absorption. Both fibers are to be mix in concrete to improve the issues in canal lining. The good tensile strength of the selected fibers is likely to be helpful in adjusting the formation of cracks occurred due to tensile stresses by enhancing the tensile strength of FRCs. The smaller capacity of water absorption of selected fibers can also compelled the concentration towards their use for the application of canal-lining as compared to other available fibers. The available type of glass fiber is not considered for the application of canal-lining due to the findings that glass (non-resistant to alkaline effects) fibers were chemically attacked by hydration products, leading to weak glass surface [41].

The Steel fiber have good ductile behavior having zero water absorption but having chances of corrosion, so it is not considered due to their corrosive nature which affected the bond the concrete and steel fibers. After that different type of hybrid fiber reinforced composites were developed using fiber hybridization. It has been observed that the performance of multistate hybrid fibers reinforced concrete mixtures is superior to that of concrete mixtures reinforced with single-type of fibers due to positive interaction between them and this phenomenon is commonly known as fiber synergy [8]. The fibers in hybrid fiber reinforced concrete (HFRC) can be classified by their geometrical size i.e. micro and macro fibers [63]. The HFRC having two or more types of fibers has been studied and shows higher compressive strength, tensile strength and energy dissipation capacity [39]. Also, the strength can be enhanced by using optimized content of different types of fibers. Sivakumar and Santhanam (2007) combined the different hybrid fiber combination, i.e. steel-glass, steel-polyester and steel-polypropylene fibers to study the mechanical properties of HFRC. It was testified that adding of steel fiber improves the energy absorption mechanism, i.e. bridging effect while the glass, polyester and polypropylene fibers results in delaying the development of micro-cracks. The reason for improved mechanical properties was due to increased hybrid fibers which provide the bridging effect. Steel fibers can bridge macro cracks and restrict the crack propagation at large scale ultimately enhances the mechanical properties of concrete [64]. The basalt fibers restrict the formation of cracks at meso level. Meanwhile, CaCO3 whiskers can bridge micro cracks and prevent further crack propagation at micro scale [65]". Yoo et al. [66] reported that the restriction of cracks with one dimension and length of fibers is limited at their particular scale, but have no or little effects at other scales. Therefore, it is necessary to combine different types of fiber and still the research is needed form macro-scale to micro scale hybrid fibers at multilevel cracking".

In this study, the strength parameters of HFRC with polypropylene fibers and jute fibers of linear shrinkage and water absorption are investigated. In current research jute plus polypropylene fibers are selected due to study their characteristic in previously available research. The research was conducted to evaluate the effect of Hybrid Fiber Reinforced Concrete (HFRC) on strength of concrete. It can be observed that jute and polypropylene fibers have high tensile strengths and elastic moduli and also having low tendency of water absorption. Both fibers are to be mix in concrete to improve the issues in canal lining. In short hybrid fibers are used to improve multi properties of concrete.

2.4.3 Use of FRC in Canal Lining

"Shrinkage, water absorption, permeability, differential settlement, and tensile strength, etc. are certain factors which causes the rate of cracking in concrete canal-lining [6]". "Fang et al. [7] investigated the feasibility of polypropylene fiber (PPF) in concrete canal-lining. For this purpose, the effect of PPF on concrete crack resistance and shrinkage were analyzed experimentally. The properties of PPFRC were compared to that of standard PC. It was reported that, incorporation of PPF in concrete enhanced its splitting-tensile, axial-tensile strengths, frost resistance, toughness, and impermeability. Also PPF in concrete effectively prevented and suppressed the crack formation in concrete. It was concluded that PPFRC could progress the performance of canal-lining".

"The rate of cracking in canal lining can be controlled mostly by improving compressive, splitting tensile strength and flexure strength of concrete. Natural fibers have attained the attention because of the low cost, less health hazard, and flexibility. Artificial fibers also include many advantages like greater strength, low water absorption and less density in nature. Jute fibers are good in energy absorption and also have high tensile breaking strength. Polypropylene fibers also include benefits like chemically inertness, zero water absorption and high tensile strength. Nylon fibers have good toughness, tenacity and zero water absorption. Detail studies on the suitability of FRC with some other fibers for canal-lining application have not been carried out up to now. Therefore, mechanical properties of FRCs along with the water absorption and linear shrinkage are studied [8]".

2.5 Link between Canal lining Performance and Material Structural Properties

"The main causes for canal lining concrete cracks are water absorption, shrinkage, tensile strength, permeability, differential settlement and brittle failure of concrete [8]. Here it can be discussed briefly one by one.

a) An increase the water absorption consequently raises its rate of deterioration in concrete canal lining.

b) Shrinkage cracks can be escaped if tensile stresses develop by shrinkage is less than internal tensile strength of concrete. It shows that concrete tensile strength play a vital role to avoid cracks occurs due to shrinkage.

c) The differential settlement causes due to the bending stress in concrete structure. The cracks appears due to differential settlement can be controlled if the flexure stresses (Bond strength) of concrete exceeds is bending stresses. So flexure stress play very important role for control the differential settlement.

d) Brittle behavior of concrete is also one of the major causes that impart rate of cracking in concrete. So it is prime necessary to increase the post cracking absorption and toughness of concrete in order to achieve ductile failure. Ductility is very appropriate structural property that reflects the ability of structural member to undergo large deflection prior to failure. It is the ratio of ultimate deflection to first deflection. So a sustainable framework in canal lining has been successfully achieved by overcome all these deficiencies.

So its are very essential to explore materials in terms of the superior structural properties (specifically tensile strength, and flexural strengths and toughnesss of materials) along with less water absorption and less shrinkage to avoiding the rate of cracks in canal-lining. Post cracking performance of concrete can be enhances by using Jute fibers as reinforcing material. PPF are useful to make concrete impermeable by enhancing tensile strength of concrete.

2.6 Expected Canal Lining Performance for Sustainable Water Saving

The sustainable development of irrigated canal introduces the salinization and waterlogging problems may occur due to intensive seepage from ground water in agricultural areas. All these faced problems can be controlled by adopting remedial measures or executing protective measures. There is a need to formulate a framework on HFRC for possible application of canal lining in concrete.

According to author opinion on basis of detailed literature review on the suitability of concrete with HF for possible application in canal lining have not performed so far. There is a need to formulate a framework on HFRC for possible application of canal lining in concrete. The efficiency in lining of can be upgraded by control or monitor its cracking. Water losses in form of seepage or some other sources in canal lining cannot be controlled unless avoid or minimize its crack formation. The initial micro cracks can be converted into macro cracks with some passage of times and consequently leads to seepage through these particular effected portions. These cracks can be importantly controlled by improving its concrete tensile strength. On above of all mentioned literature it is suggested that fiber in concrete acts as crack arrestor which enhance strength properties of concrete, the demand of high strength increases day by day and using of jute fibers can overcome this demand. Also improving mechanical properties, linear shrinkage and water absorption can be ultimately controlled its rate of cracking in canal concrete and mostly expected to achieve sustainable goal by conserve water losses.

2.7 Summary

There are three limited study by Cui [6], Fang et al. [7] Plus Zia and Ali [8] on PPFRC for application in canal lining. Water losses in form of seepage or some other sources in canal lining cannot be controlled unless avoid or minimize its crack formation. The initial micro cracks can be converted into larger cracks and consequently leads to seepage through these particular effected portions. These cracks can be importantly controlled by improving its concrete tensile strength. Also improving strength properties of concrete, LS and WA can be ultimately controlled its cracking in canal concrete and mostly expected to achieve sustainable goal by conserve water losses. Increasing CS, TS and MOR can be found while decreasing the linear shrinkage (LS) and water absorption (WA) has been observed for HFRC. As compared to PC, an enhanced post-crack energy absorption and toughness indices are observed for HFRCs. HFRC outperforms all the investigated materials in upgrading CS, SS, MOR, CTI, STI, FTI, SPE and FTE. So HFRC was recommended a best solution in canal to escape from cracks and to save water losses.

Chapter 3

Discussion

3.1 Background

Natural fibers have attained the attention because of the low cost, less health hazard, and flexibility. Jute fibers are good in energy absorption and also have high tensile breaking strength. As stated in the previous chapter that comprehensive studies of FRC with hybrid fibers for appropriate application in canal are still not studied so far. Therefore, mechanical properties of FRCs along with the linear shrinkage and water absorption are studied. In this chapter, raw materials, the techniques of PC and FRCs mixing and casting, specimen details, testing methodologies are examined in detail in this chapter.

3.2 Critical Review of HFRC in Practical Application

The rate of fracturing and destruction in concrete lining could be interconnected to dissimilar aspects like contraction and expansion effect due to temperature, soil swelling, settlement of underneath soil, porousness etc. The study concluded that when the concrete strength is diminished and fractures arise due to bending stress. That all happens due to the concrete observed spalling effect and initiate to decline at the similar spell. Concrete matrix is going to become more brittle due to this effect. However, the inclusion of fibers into the concrete matrix curtailed the impacts that happen in the concrete. So, flexure strength is required to counter these stresses. The adding of fibers also enriched the flexural properties of the concrete, as the HFRC fibers prevent the fracturing progression that happened in the concrete. HFRC critically affects its flexural and toughness. Cracking pattern and propagation was much different for HFRC in comparison with plain concrete. The PP fiber was found to delay the pre-cracking of micro crack while steel fibers were helped in delaying post-cracking of macro cracks. These two fibers grip the particle in the concrete when loading was applied. HFRC is very cheap solution for control cracks in canal lining, that are caused due to temperature effect and release of energy. The concrete lining can show significantly enhancement by decreasing its cracks and its defects. To improve structural properties of concrete natural and artificial fibers can enhance the mechanical properties. Ductility of the samples decreases as the addition of fibers. This is important for significant improvement in the beams strength. While the current research conducted on HFRC with 2-5% fiber content by mass of cement. Modulus of rupture has no significant difference and density was decreased up to 5%, respectively as compared to those of PC. Low MOR was due to W/C ratio. It is worth noting that the cracked HFRC beam took a load of 1.32 kN and had undergone a maximum deflection of 26 mm. In this study as compared to PC, HFRC shows relatively higher values of flexure strength. The decrease of values for WA and LS are also seen. HFRC can be a good choice in comparison to PC due to high post cracking absorption capacity.

It may be noted that researches have different input parameters like mix design ratio, water cement ratio, aggregate size, fiber length, and fiber content/volume. So there is a need to address these issues properly to have the good results i.e. to investigate the properties of HFRC with different fiber length, fiber contents and other parameters. In short, it can be said that hybrid fibers (JF + PPF) have the potential to improve that strength property and make the concrete impermeable to concrete.

3.2.1 Raw Materials

Ordinary Portland cement, locally available sand, well graded aggregates, potable water and uniform length of hybrid fibers are used for preparation of PC and FRC. 12mm are the maximum size of aggregate (which passes through sieve 12mm and retained on 10mm sieve) [21,28,29].

3.2.2 Preparation of Hybrid Fiber on Large Scale

Preparation and mixing of fibers into the required length (5cm) of jute and polypropylene fibers was a time consuming and require labors task. Finally, Hybrid fibers were loosed and saturated in water for 30-40 minutes to soften the fibers for eliminates dust. Fibers were then t manually make straight and combed with a steel comb. Long wet fibers should be dry in the open atmosphere. Finally fibers were combed and cut into desired length with knife carefully [21,28,29].

3.2.3 Mix Design Concept

For the PC, the mix design ratio of 1:2:4 for cement, sand and aggregates respectively with a water cement ratio of 0.60. The mix design for fiber reinforced concrete was the same as that of the PC except that (1) the water cement ratio was 0.70 because of the addition of fiber to make SFRC workable and (2) 5 cm long hybrid fibers of 5% by weight of cement were added and the same amount (weight) of aggregates were deducted from the whole weight of aggregates. All tested materials were taken by weight of cement. All materials were put in the mixer pan along with the water, and the mixer was revolved for four minutes. A uniform layer of fibers was spread in the concrete mixer, followed by spreading of aggregates, sand and cement. The first layer of fibers was concealed under the dry concrete materials with the help of a shovel. Then, one more layer of fibers followed by layers of aggregates, sand and cement were spread. Approximately, three quarters of the water (according to a water cement ratio of 0.60 which was the same as that of PC) was added, and the mixer was revolved for 4 minutes. Then the rest of the water was added and the mixer was again revolved for four minutes. The HFRC was not workable at this stage, so additional water was added thrice with an addition of 0.05 water cement ratio to make the HFRC workable. A slump test for the HFRC was also achieved before pouring it into moulds. Mix design ratio are 1:2:4:0.6 for both, but there is different fiber content and fiber length to examine the satisfactory result. The specimens were properly oiled and made properly tight to acquire smooth finish and avoid slurry leakage from concrete mixes. Each specimen was cast by pouring concrete into molds in three layers after subsequent tamping of 25 times per layer as per ASTM standards. Proper label were marked for PC for HFRC sample for identification. Cylinders and Beams having the dimension as per ASSHO specification were prepared for PC and HFRC sample. This test was achieved in the same manner as performed for that of plain concrete. The slump test for SFRC was 5mm, but the HFRC was workable using a new pouring technique. Each specimen was cast by pouring concrete into molds in three layers after subsequent tamping of 25 times per layer as per ASTM standards. Proper label were marked for PC for HFRC sample for identification. Cylinders and Beams having the dimension as per ASSHO specification were prepared for PC and HFRC sample. This test was achieved in the same manner as performed for that of plain concrete. HFRC should be pour into the moulds and up lifted to a height of about 100 150 mm and then let fall and drop to the floor for self compaction of the fibre concrete and to eliminate air voids from the HFRC. All samples should be cured for 28 days afore testing. To evaluate a sustainable framework on basis of experimental behavior of PC and HFRC are require in future research. It includes to cast 9 PC and 36 HFRC sample to study the mechanical properties and some other properties. Mix design ratio are 1:2:4:0.6 for both, but there is different fiber content and fiber length to examine the satisfactory result. The mix design ratio is selected from the previous study (Khan et al. [36]). A layer procedure for the mixing of fiber reinforced concrete was adopted for the FRC mix design are also reported for uniform mixing and to avoid balling effect. [21,28,29].

3.2.4 Investigated Properties of HFRC

3.2.4.1 Workability

The property of fresh mix concrete to which it can be easily mixed, transport and resistant to segregation during placing and finishing. It can be achieved by mixing moderate amount of fresh water to concrete for observe the slump. The ASTM C143/C143M-15a slump cone test was performed for both PC and FRC to check the workability of fresh mix concrete. The reason for test was to compare the behavior of fresh and FRC for same mix design. The slump cone apparatus was made thoroughly cleaned and well-oiled before workability test [66].

3.2.4.2 Density of HFRC

Density is the mass per unit volume of concrete sample. Densities of PC and HFRC are calculated by physical balance. An increase or decrease in mass of specified volume of PC and HFRC was noted accordingly.

Table 3.1: W/C ratio, Slump and calculating Density for PC and HFRC [41].

Matrix	W/C ratio	Slump (mm)	Density (kg/m3)
PC	0.60	50	2315
HFRC	0.80	05	2244

The measurement of W/C ratio, slump test and density is shown in table 3-1. It has been observed that slump of HFRC was reduced 10 times than that of PC. The reason for this decrease in slump may be due to saturated surface dry condition. The water absorption by surface of aggregates and molds is more than that of ideal condition. Standard density test as per ASTM C138/C138M-16 was performed to measure the density of specimens for PC and SFRC. Density of HFRC has been reduced up to 71 kg/m^3. The percentage reduction in the density if HFRC is 3.12% in comparison of PC. The reduction in density is due to the accumulation by replacement of fibers by concrete composites [41].

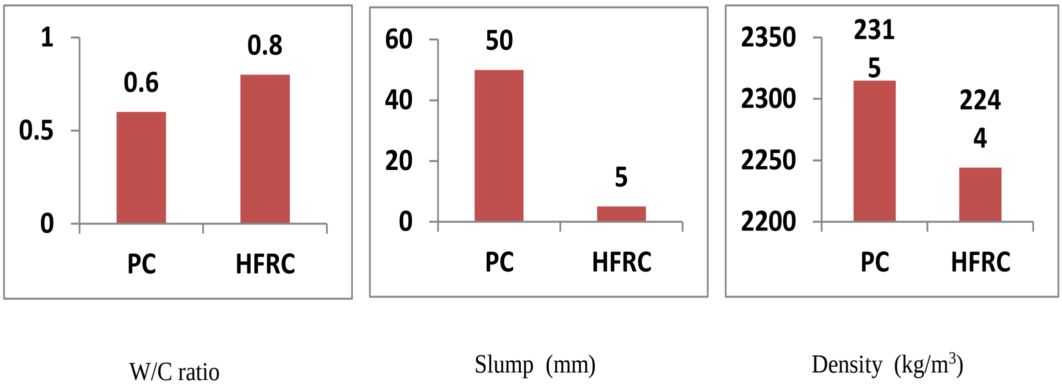

FIGURE 3.1: W/C ratio, Slump test and Density (mass/vol:) for PC and HFRC [41].

3.2.4.3 Water Absorption Test

It is define the transportation of waters in spongy solids acting in capillaries due to surface tension. It is the ratio of absorbed mass of water by to the total sample of mass. WA test is accomplished as per C642-13 ASTM standards. Beam lets specimen of size (450x100x100) mm made for flexure strength test was used to hear about water absorption [68]. Half beam lets sample was selected having no apparent cracks for clear result observation. Table 3-2 shows water absorption of PC and SFRC of 6% and 4.5% respectively. The possible reason for decrease the water absorption of sample which are due to zero water absorption of PPF [8].

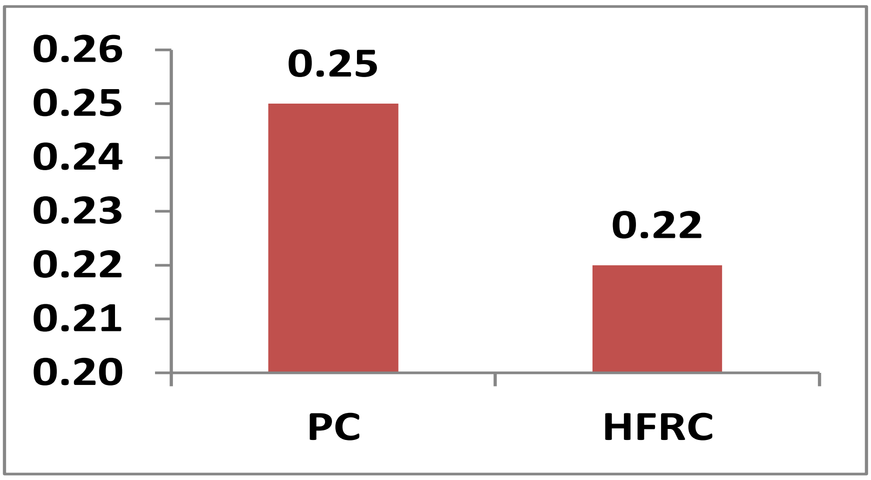

FIGURE 3.2: Comparison of WA of PC and HFRC by [8].

Table 3.2: Water Absorption [8]

Parameter	PC	HFRC
WA %	6.0	4.5

3.2.4.4 Linear Shrinkage Test

Linear shrinkage (LS) is taken as percentage increase/decrease in the length of the specimen (ASTM C531-00; OPSS LS-435 standard). The Test concrete beamlets (OPPSS LS-435 standard) of size (450x100x100) mm. The decrease in linear shrinkage may be due to the random distribution of fibers and the presence of less number of voids. An increase in LS (contracting of hardened samples) is due to the loss of capillary water So, the specimens having larger values of WA shows larger values of LS due to increase in loss of capillary water [69-71]. The specimens having larger values of WA shows larger values of LS due to increase in loss of capillary water. This test result of linear shrinkage (reduction in length for PC and HFRC is shown in table 3-3, The value of 0.25 and 0.22 for PC and HFRC respectively are perceived for linear shrinkage. The decrease of 13.6% linear shrinkage of HFRC was found as compare to PC. The decrease in LS of HFRC may be due to randomly dispersion of HF. An escalation in LS (contracting of hardened samples) is due to the loss of capillary water. So, the specimens having larger values of WA show larger values of LS due to increase in loss of capillary water [8].

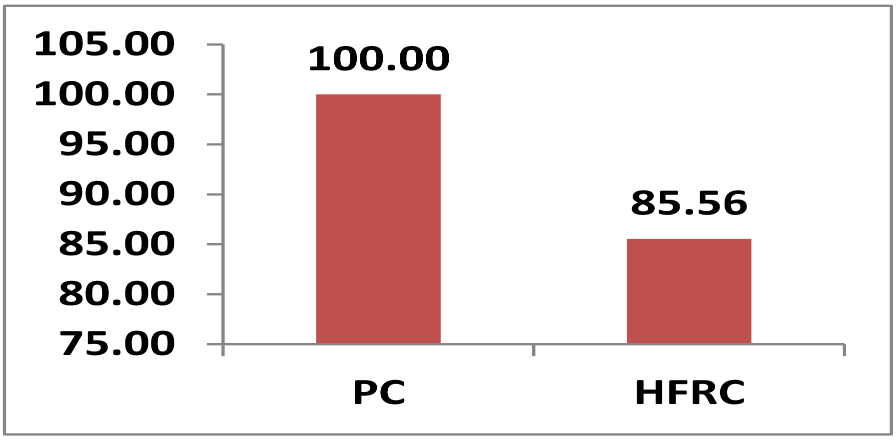

Figure 3.3: Comparison of LS (% decrease) of PC and HFRC by [8].

TABLE 3.3: Linear shrinkage for PC and HFRC [8]

Parameter	PC	SFRC
WA %	0.25	0.22

Note: LS is reported to the nearest 0.001% of gauge length (ASTM C157/C157M-08)

3.2.4.5 Compressive Strength Properties

Compressive strength of concrete is the strength of hardened concrete measured by the compression test. It is measured by crushing cylindrical concrete specimens in compression testing machine. It is the measure of the concretes ability to resist loads which tend to crush it. Servo-hydraulic machine are used for testing via ASTM standard C39 / C39M-17 to find out a) CS of concrete b) Compressive behavior c) CPE d) CCE e) CTE and f) CTI. To find out compressive strength of concrete the cylinder of size 300x150mm were used. It should be perform after 28 days of mixing and hardening, and is measured in Mega Pascals (MPa). For uniform distribution of load prior to testing each cylinder is confirmed by overlaying with plaster of Paris[72].

Table 3-4 shows the CS, CPE, CCE, CTE, and CTI of PC and HFRC. The best reason for comparatively greater value of CS 0.1 MPa of HFRC may be the better compaction of concrete. At maximum stress The values of strain (o) 0.012 and 0.021 are of PC and HFRC, respectively. Due to high elongation capacity of HF it hold the mixture together by creating a strong bond even at time of breaking and thus it avoid to cracks formation and result a huge value of strain in HFRC. Another reason can be the slippage of HF due to relatively less bond strength. The increase in CCE, CTE and CTI of HFRC may be due to the adding of fibers, which improves the post-crack energy absorption capabilities of concrete. Also it provide significant amount of resistance against stresses after the crack propagation [8].

TABLE 3.4: Compressive properties of PC and HFRC samples with MD ratio of 1:2:4 [8].

intended Properties						
Specimen	CS (MPa)	εo (-)	CPE (MPa)	CCE (MPa)	CTE (MPa)	CTI (-)
PC	13.2	0.012	0.06	0.09	0.15	2.50
HFRC	13.3	0.021	0.05	0.26	0.31	6.20

Note: CS = Compressive strength, o = Strain achieved at the maximum stress, CPE = Compressive absorbed pre-crack energy, CCE = Compressive cracked absorbed energy, CTE = Compressive total absorbed energy, CTI = Compressive toughness index

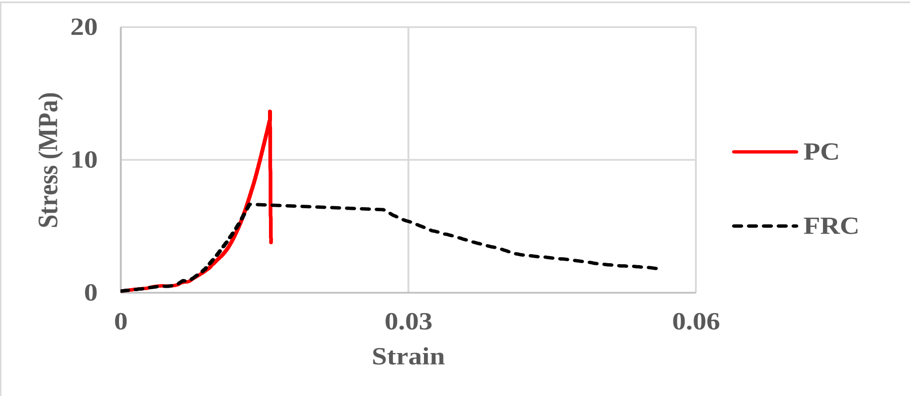

FIGURE 3.4: Stress-strain curves of PC and HFRC for compressive strength test [73].

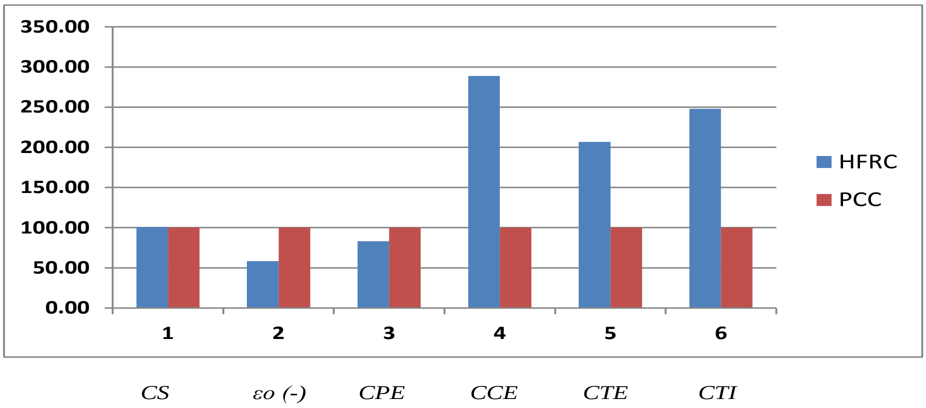

FIGURE 3.5: Comparison of compressive strengths, compressive pre-crack absorbed energies, compressive total absorbed energies, and compressive toughness indices of PC and HFRC [8].

3.2.4.6 Splitting-tensile Strength

Cylindrical samples of PC and HFRC are tested via using ASTM standard C496/ C496M-11. Servo hydraulic machine is used for this purpose. Results are taken from the following test include a) STS b) ST behavior c) ST pre-crack d) ST post crack energy e) SP Toughness index [74].

The tensile strength of concrete is one of the basic and important properties which greatly affected the extent and size of cracking in structure. Moreover the concrete is very weak in tension due to its brittle nature. Hence it is not expected to resist the direct tension, so concrete develop cracks when tensile forces exceed its tensile strength. Therefore it is necessary to determine the tensile strength of concrete to find out the load at which the concrete members may occur. STS is the method to determining the tensile strength of concrete using a cylinder which splits across the vertical diameter. Figure 3-6 displays the Load-time curves under splitting-tensile loading. Figure 3-7 shows the situation observed of PC and HFRC specimens during the testing at first crack, cracks appeared at peak loads and cracks developed at the ultimate loads which are known as SPE, SCE and STE respectively. Ratio of STE to SPE is known as STI [8].

Table 3-5 shows Splitting-tensile tests of HFRC healthier outcomes in terms of enhanced SS, SPE, SCE, STE, and STI as matched to PC. It may be due to unsystematic scattering of fibers that provide bridging effect against initial develop cracks and also resistant to shear forces. It can be suggested that HFRC should be a best selection due to presence of high tensile strength of PPF in controlling crack of canal concrete causes due to tensile stresses. There are always the possibilities of some local defects being present in any object. Tensile strength can be necessary in concrete to avoid the shrinkage cracks of canal lines. It can be seen that concrete tensile property can play an important role to avoid cracks occur due to shrinkage. When an object is put under tensile stresses it tends to expands. All the fibers or region of an object experiences an equal force. Any weak regions in such a case may give up and undergo deformation [8].

Table 3.5: Splitting tensile properties of PC and HFRC samples with MD ratio of 1:2:4 [8].

intended Properties					
Specimen	SS (MPa)	SPE (KN.s)	SCE (KN.s)	STE (KN.s)	STI (-)
PC	2.1	12973	0	12973	1.00
HFRC	2.2	13978	353	14331	1.03

Note: SS = Splitting-tensile strength, SPE = Splitting-tensile absorbed pre-crack energy, SCE = Splitting-tensile post-crack absorbed energy, STE = Splitting-tensile total absorbed energy, STI = Splitting-tensile toughness index.

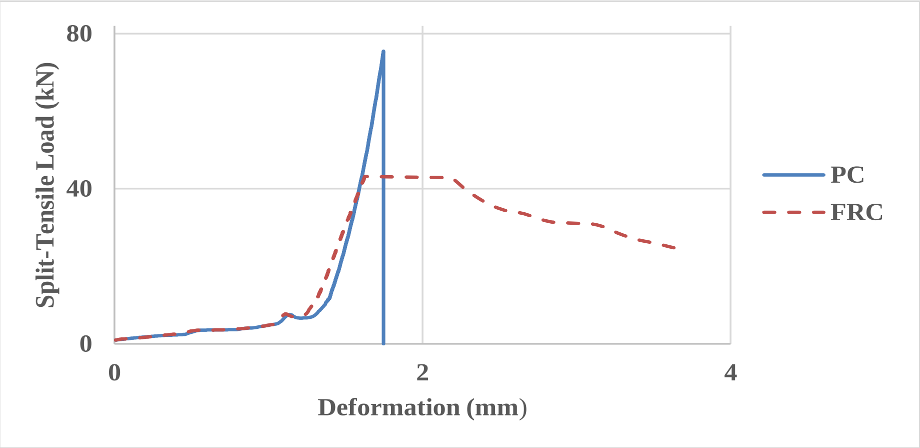

Figure 3.6: Load-time histories of PC and HFRC from the test of SS [73].

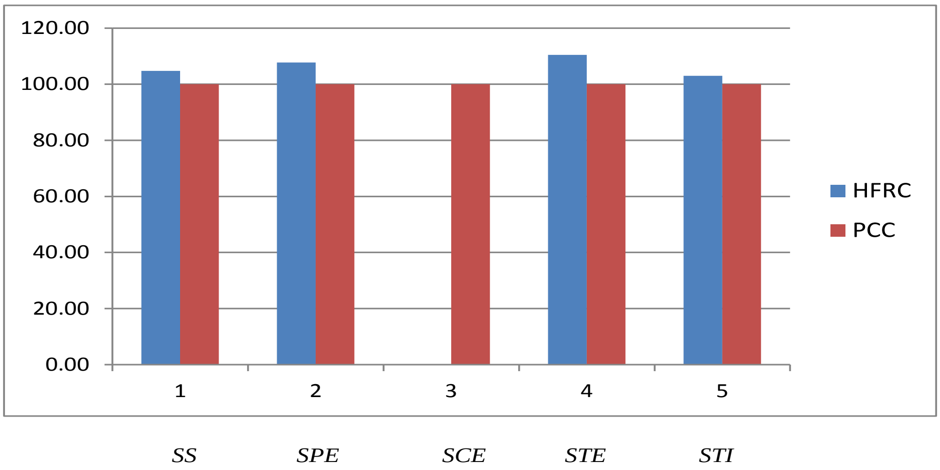

Figure 3.7: Comparison of the splitting-tensile strengths, splitting-tensile pre-crack absorbed energies, splitting-tensile total absorbed energies, and splitting-tensile toughness indices of PC, and HFRC [8].

3.2.4.7 Modulus of Rupture (MOR)/Flexure Strength Properties

Modulus of rupture is a measure of tensile strength of concrete beams or slabs. Flexure strength identifies the amount of stress and forces an unreinforced concrete slabs, beams or other structures that can withstand such that it resists any bending failure. MOR is also known as flexure strength, bend strength or fracture strength. In order to test the flexure strength of a concrete beam, its span length should be at least three times the depth. The flexure strength is expressed as the modulus of rupture (MOR) in psi (MPa). Servo hydraulic machine is used for testing beams using three points loads by ASTM standard C293/C293M-16. The test was performed to examine a) MOR, b) Flexure behavior c) Pre-Cracking energies d) Post cracking energies e) Toughness index. Flexure pre-crack absorb energy (FPE) is the area under the load deflection curve at first crack appear of flexure strength test. In case of PC beam, load at first crack was considered as peak load. Flexure absorbed crack energy (FCE) is taken as the area beneath the load deflection curve from the first crack to ultimate load [75]. Flexural total energy absorb (FTE) is taken as the area under the flexure load deflection curve from zero point to ultimate load. The load-deflection curves is shown in Figure 3-8 displays for flexure strength test of PC and HFRC. The ratio between FTE to FPE is considered as flexural toughness index (FTI) [8].

Table 3-6 shows the MOR, o, FPE, FCE, FTE, and FTI of HFRC and PC. The MOR of HFRC enhances as compare to PC by an amount of 0.26 MPa respectively due to resist the impact loading. The deflections (o) at the peak load of PC and HFRC are 0.99 mm and 1.0 mm respectively. Due to randomly spreading of fibers in HFRC there was an increasing value of FPE which significantly helps to resist the crack propagation. The FCE, FTE and FTI of HDRC was also observed to increase as compare to PC. The possible reasons for increase in pre crack energy of HFRC is due to presence of properly mixed fibers and better compaction of fresh mix concrete. The bridging effect of JF and PPF resist the cracks which improved the result of post crack energy absorption of concrete. On basis of better performance of flexure strength of PPF it can be suggested that HFRC is good for controlling cracks causes due to some external impact loading and differential settlement [8].

TABLE 3.6: Flexure properties of PC and HFRC samples with MD ratio of 1:2:4 [8].

intended Properties						
Specimen	MOR (MPa)	Δo (mm)	FPE (KN.mm)	FCE (KN.mm)	FTE (KN.mm)	FTI (-)
PC	2.68	0.99	4.09	0.00	4.09	1.00
HFRC	2.94	1.00	4.11	3.29	6.89	1.91

Note: FS = Flexure strength, o = Deflection at the maximum load, FPE = Flexural absorbed pre-crack energy, FCE = Flexural post-crack absorbed energy, FTE = Flexural total absorbed energy, FTI = Flexural toughness index.

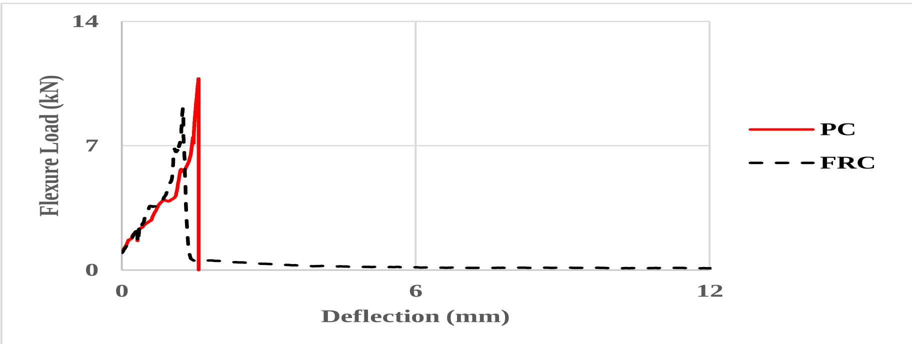

FIGURE 3.8: Load-deflection curves of PC and HFRC from flexure strength tests [73].

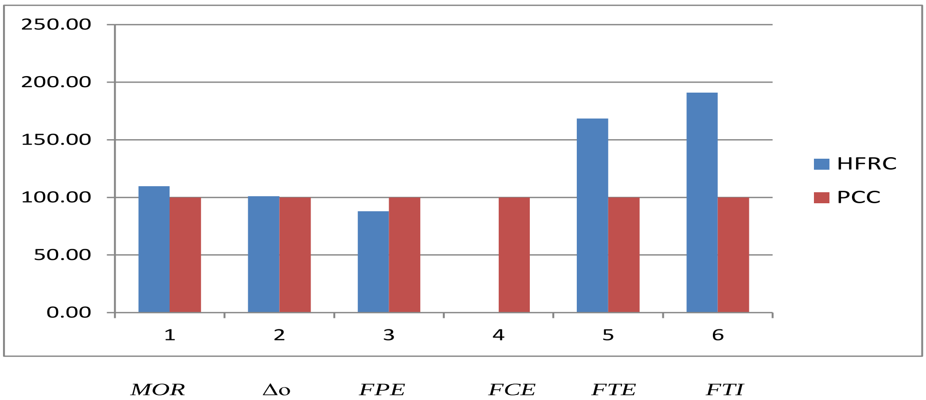

FIGURE 3.9: Comparison of the Flexure strengths, Flexural pre-crack absorbed energies, Flexural total absorbed energies, and Flexural toughness indices of PC and HFRC [8].

TABLE 3.7: Comparison with previous studies for expected water saving in canal

Sr. No.	Reference	Fiber	Conclusion
1	[07]	PPF	Incorporation of PPF in concrete enhanced its splitting-tensile, axial-tensile strengths, compressive strength, frost resistance, toughness, and impermeability in canal concrete.
2	[06]		Shrinkage, water absorption, permeability, differential settlement, and tensile strength, etc. are certain factors which causes the rate of cracking in concrete canal-lining.
3	[08]	PPF, JF and NF (individually)	The rate of cracking in canal-lining can be controlled mostly by improving compressive, splitting-tensile strengths, and the flexure strength of concrete.
4	Current Research	Hybrid fiber = PPF + JF	Improve Structural properties of concrete Increase frost resistance, less water absorption and make concrete impermeable of canal lining.

3.3 Sustainable Frame Work for Expected Water Saving in Canal

Pakistan is an agriculture country and its economy mainly depends on agriculture and so for this on irrigation system. Our water resources are going waste due to irrigation system losses. The main losses in canal lining are seepage, adsorption, evaporation and operation losses causes by temperature variation, differential settlement, hydraulic pressure etc. Seepage is a problem in canal system create twin problem of water logging and salinity, so consequently large land of agriculture has gone out of use. An effective solution to solve these problems is to provide concrete lining in canals. This research provides an idea to introduce the problem of salinity and water logging system arises due to poor management of our irrigation system. There is a need to formulate a sustainable framework on HFRC for possible application of canal lining in concrete. Water losses in form of seepage or some other sources in canal lining cannot be controlled unless avoid or minimize its crack formation and consequently increases efficiency of canals. The initial micro cracks can be converted into macro cracks with the passage of time and consequently leads to seepage through these particular effected portions. These cracks can be importantly controlled by improving its concrete tensile strength. Also improving mechanical properties, linear shrinkage and water absorption can be ultimately controlled its rate of cracking in canal concrete and mostly expected to achieve sustainable goal by conserve water losses.

3.4 Summary

The proportion of concrete, sand and aggregates for PC and HFRCs is 1, 2, and 4 with a w/c proportion of 0.6. In addition to that, 5% fiber content, by mass of cement, and fiber length of 50 mm are utilized in the case of FRCs. Sample made should be testing with ASTM standards are followed for the execution of slump, density, compressive, splitting-tensile, modulus of rupture, water absorption, and linear shrinkage tests. Any observation during experimental work should be carefully noted and to address the sustainable development frame work to introduce drawbacks of irrigated canal in order to save water losses for future generation to make the irrigation system more reliable and sustainable.

Chapter 4

Conclusion and Recommendation

4.1 Conclusion

In this research behavior of JF and PPF are studied in form of HFRC for possible improvement in concrete canal lining. The material strength properties of concrete, WA and LS during different loadings, mode of failure and the outcomes of the different tests have been explained in chapter 03. It is found that HFRC outperforms all the investigated materials in upgrading most of the properties. The studies in last few decades on hybrid fiber reinforced cement composites with emphasis on HFRC are discussed for preferable alternatives. A sustainable frame work for investigating the properties of HFRC was also carried out. The methods for preparation of hybrid fibers and mixing of HFRC were improved. The workability of HFRC was a major problem because of the presence of fibers. Further improvements can be made by using a mechanical method for preparation of hybrid fibers and a chemical agent for high workability. It was noted that HFRC beams did not break into two pieces as it happen in PC and had taken a maximum deflection of roughly 26 mm. The static properties of HFRC was not increased or decreased significantly with the note that HFRC beams did not break into two pieces as did beams of normal concrete and had taken a maximum deflection of roughly 2 cm. It has the potential to be used for main structural members due to its increased ductility. It is concluded that HFRC has the potential to be used for lining of canal due to its improved ductility but pouring HFRC requires special attention for taking better results. Here sustainable result can be achieve which can be discussed one by one in following,

- An effort is required to control water losses in canal lining; therefore for better efficiency of canal it should be necessary to provide concrete lining to control the water losses. By Providing concrete lining in canal, the water logging, seepage losses, silting and maintenance cost of canal can be significantly decreased and consequently, flow velocity, cropping intensity and conveyance efficiency can be increased.

- Fibers in concrete acts as crack arrestor which enhances strength properties of concrete. The demand of high strength is increasing day by day, using of jute fibers can overcome this demand. Ductility of the samples decreases as the addition of fibers. This is important for significant improvement in the beams strength.

- Hybrid fibers are used to improve multi properties of concrete. JF are used to improve strength properties of concrete, while PPF has the capability to avoid water loss by make the concrete impermeable and durable.

- It is very essential to discover materials in terms of the superior mechanical properties (specifically tensile strength, and flexural strengths and toughnesss of materials) along with less water absorption, impermeable and less shrinkage to avoiding the rate of cracks in canal-lining. Post cracking performance of concrete can be enhances by using Jute fibers as reinforcing material. PPF are useful to make concrete impermeable by enhancing tensile strength of concrete.

- Due to high post cracking absorption capacity and better post crack performance, HFRC can be a good choice in comparison to PC.

- It should require convincing the locality to use the fiber in concrete to control the crack due to thermal effect and shrinkage etc. It may be noted that researches have different input parameters like mix design ratio, water cement ratio, aggregate size, fiber length, and fiber content/volume. So there is a need to address these issues properly to have the good results i.e. to investigate the properties of HFRC with different fiber length, fiber contents and other parameters.

- HFRC is very economical cure for control cracks in canal lining; arise due to temperature effect and release of energy. The concrete lining can show significantly improvement by decreasing its cracks. To improve structural properties of concrete natural and artificial fibers can play tremendous role.

- 40% to 50% of seepage losses can be controlled by providing lining in concrete and consequently water logging becomes negligible. Conveyance efficiency of canal increases ultimately 70% to 90% resulting into significant improvement in cropping intensity.

- Conveyance efficiency of canal increases ultimately 70% to 90% resulting into significant improvement in cropping intensity.

- As a result of proposed lining of the HRFC concrete canal, water logging, seepage losses, silting and maintenance cost of canal can be significantly decreased, consequently, flow velocity, cropping intensity and conveyance efficiency can be increased.

- Also lined canal can reduced the maintenance cost and increases life of canal for long period. The critical review observed that initial investments over canal lining seem to be very high, but canal lining is a sustainable step which proves to be very economical in terms of long term benefits in our country Pakistan.

- Achieving sustainability in irrigation system (like canal lining) is very important now a day for supporting human life, economic stability and provides peaceful ecological system to conserve natural resources (water) for coming generation.

4.2 Recommendation

Following are recommendations for future studies.

- There is need to Investigate different fiber lengths and contents in FRC. All natural fibers need to be appropriately tested and results should be published in a systematic style. Also give an idea that an appropriate fiber should be used for a particular purpose.
- Use of self-compacted concrete for seepage control in canal.
- Dynamic testing of canal concrete lining due to high hydraulic pressure should be performed through prototype testing.
- To evaluate Theoretical investigation of PC & HFRC, It is recommended to cast 9 PC & 36 HFRC sample to study the mechanical properties and some other properties of canal lining. Mix design ratio should be 1:2:4:0.6 for PC and HFRC, but different fiber content & fiber length should be used to examine the satisfactory result.

Specimen Size for Testing	PC	HFRC				Properties of Concrete		
	(1:2:4:0.6)	(1:2:4:0.6) JF 5cm PPF 5cm JF 2% PPF 3%	(1:2:4:0.6) JF 5cm PPF 5cm JF 3% PPF 2%	(1:2:4:0.6) JF 2cm PPF 3cm JF 3% PPF 2%	(1:2:4:0.6) JF 3cm PPF 2cm JF 2% PPF 3%	Mechanical Properties	Other Properties	
Compression 100x200 mm cylinders						Compressive strength, CE_{max}, CE_{total} ,CTI	SEM & XRD	
Split Tensile 100x200 mm cylinders						Load-deformation curve, STS, SE_{max}, SE_{total} , STI	SEM & XRD	
Flexure Strength 100x100x450mm Beam lets						Load-deflection curve, MoR, FE_{max}, FE_{total} FTI	SEM & XRD	Linear Shrinkage & Water Absorption Test

Table 4.1: Work plan of Different PC and HFRC samples

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