EFFECT OF RICE HUSK ASH AND STEEL FIBRE ON THE STRENGTH CHARACTERISTICS OF PAVEMENT QUALITY CONCRETE

A Dissertation Submitted

In The Partial Fulfillment of the Requirement

for the Award of Degree of

MASTER OF ENGINEERING

IN

STRUCTURAL ENGINEERING

Submitted By:

RAJESH KUMAR

Regd.No 821022007

UNDER THE SUPERVISION OF

DR. MANEEK KUMAR
(Professor)
CED,Thapar University
Patiala.

MR.TANUJ CHOPRA
(Asstt. Professor)
CED,Thapar University
Patiala.

DEPARTMENT OF CIVIL ENGINEERING

THAPAR UNIVERSITY, PATIALA-147004

AUGUST (2015)

DECLARATION

I, Rajesh Kumar hereby declare that this thesis entitled, "**EFFECT OF RICE HUSK ASH AND STEEL FIBRE ON THE STRENGTH CHARACTERISTICS OF PAVEMENT QUALITY CONCRETE**" is an authentic record of my own review carried out as requirements for the award of degree **Master of Engineering (Structures)** in the **Civil Engineering Department**, Thapar University, Patiala, under the guidance of **Dr. Maneek Kumar, Professor & Mr. Tanuj Chopra, Asstt. Professor**, Department of Civil Engineering, Thapar University, Patiala during Jan 2015 to August 2015. The matter embodied in this report has not been submitted anywhere for the award of any degree.

(Rajesh Kumar)

Reg. No. 821022007

Date: 30/08/2015

Place: Patiala

CERTIFICATE

This is to certify that the above statement made by student concerned is correct & true to the best of my knowledge and belief.

Dr. MANEEK KUMAR
Professor
Department of Civil Engineering
Thapar University, Patiala

Mr. TANUJ CHOPRA
Assistant. Professor
Department of Civil Engineering
Thapar University, Patiala.

Countersigned by

Dr. NAVEEN KWATRA
Professor & Head,
Department of Civil Engineering
Thapar University, Patiala -147004

Dr. S.S. BHATIA
Dean of Academic Affairs
Thapar University, Patiala-147004

ACKNOWLEDGMENT

A thesis cannot be completed without the help of many people who contribute directly or indirectly through their constructive criticism in the evolution and preparation of this work. It would not be fair on my part, if I don't say a word of thanks to all those whose sincere advice made this period a real educative, enlightening, pleasurable and memorable one.

First of all, a special debt of gratitude is owned to my supervisors, **Dr. Maneek Kumar, Professor and Mr. Tanuj Chopra, Assistant Professor,** Department of Civil Engineering, Thapar University, Patiala for their gracious efforts and keen pursuits, which has remained as a valuable asset for the successful completion of research work. Their dynamism and diligent enthusiasm has been highly instrumental in keeping my spirit high. His flawless and forthright suggestion blended with an innate intelligent application has crowned my task success.

I would like to express my gratitude to **Dr. Naveen Kwatra, Head of department of Civil Engineering,** Thapar University, Patiala for his kind cooperation and encouragement which helped in the completion of work.

I am extremely thankful **to Mr. Ram Simran and Mr. Varinder Sharma** for helping me carry out experimental work.

I would also like to thank Soul of my father to whom I lost during my course study,my mother, sisters, brother, spouse, children,my seniors and my friends for their constant encouragement during the entire course.

Rajesh Kumar

(821022007)

ABSTRACT

The world's second largest road network of almost 3.5 million Km consisting of both paved and unpaved surfaces is in India. Roads in India are presently constructed not with the right choice of material. Bitumen and concrete are the two major types of materials used in road construction in the country. Construction of concrete roads in the country is of very small share. There is growing interest in the construction of concrete pavements, due to its high strength, durability, better serviceability and overall economy in the long run.

The thrust nowadays is to produce thinner and green pavement sections of better quality, which can carry the heavy loads. The high strength steel fibre reinforced concrete is a concrete having compressive strength greater than 40MPa, made of hydraulic cements and containing fine and coarse aggregates; and discontinuous, unconnected, randomly distributed steel fibres.

The present study aims at, developing pavement quality concrete mixtures incorporating waste Rice Husk Ash as partial replacement of Cement as well as addition of steelfibres by volume of concrete. The aim is to design of slab thickness of PQC pavement using the achieved flexure strength of the concrete mixture for different percentage of steel fibres and replacement of cement with Rice Husk Ash and are reported. It is found out the maximum increase in flexure strength and compressive strength is for 10% waste Rice Husk Ash and 1.5% Steel fibre.

Due to this increase in the flexural strength it is possible to achieve a saving in cost of Pavement Quality Concrete construction. In this study it has been observed that with 10% replacement of cement with Rice Husk Ash and addition of 1.5% steel fibres, the maximum saving 2.04% in cost per kilometre has been achieved for the 8.5m wide PQC carriage by calculating the thickness required for the PQC slab as per IRC: 58-2002.

CONTENTS

CHAPTER- 2 LITERATURE REVIEW

PROPERTIES OF RICE HUSK ASH IN CONCRETE

CHAPTER- 3 MATERIALS AND METHODOLOGY

CHAPTER- 4 RESULTS AND DISCUSSIONS

CHAPTER – 6 CONCLUSION AND RECOMMENDATIONS FOR FURTHER STUDY

LIST OF TABLES

LIST OF FIGURES

CHAPTER-1
INTRODUCTION

1.1 OVERVIEW

A pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favorable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the sub-grade. Two types of pavements are generally recognized as serving this purpose, namely flexible pavements and rigid pavements.

1.2 REQUIREMENTS OF A PAVEMENT

An ideal pavement should meet the following requirements:

_ Sufficient thickness to distribute the wheel load stresses to a safe value on the sub-grade soil,

_ Structurally strong to withstand all types of stresses imposed upon it,

_ Adequate coefficient of friction to prevent skidding of vehicles,

_ Smooth surface to provide comfort to road users even at high speed,

_ Produce least noise from moving vehicles,

_ Dust proof surface so that traffic safety is not impaired by reducing visibility,

_ Impervious surface, so that sub-grade soil is well protected, and

_ Long design life with low maintenance cost.

1.3 PAVEMENT TYPES

1.3.1 Flexible Pavement

A flexible pavement structure is typically composed of several layers of material with better quality materials on top where the intensity of stress from traffic loads is high and lower quality materials at the bottom where the stress intensity is low. Flexible pavements can be analyzed as a multilayer system under loading.

A typical flexible pavement structure consists of the surface course and underlying base and sub base courses. Each of these layers contributes to structural support and drainage. When hot mix asphalt (HMA) is used as the surface course, it is the stiffest (as measured by resilient modulus) and may contribute the most (depending upon thickness) to pavement strength. The underlying layers are less stiff but are still important to pavement strength as well as drainage and frost protection.

When a seal coat is used as the surface course, the base generally is the layer that contributes most to the structural stiffness. A typical structural design results in a series of layers that gradually decrease in material quality with depth. Figure 1-1 shows a typical section for a flexible pavement.

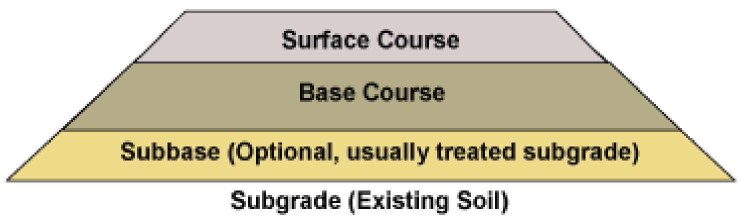


Figure 1.1. Typical section for a flexible pavement.

1.3.2 Perpetual Pavement

Perpetual pavement is a term used to describe a long-life structural design. It uses premium HMA mixtures, appropriate construction techniques and occasional maintenance to renew the surface. Close attention must be paid to proper construction techniques to avoid problems with permeability, trapping moisture, segregation with depth, and variability of density with depth. A perpetual pavement can last 30 yr. or more if properly maintained.

Structural deterioration typically occurs due to either classical bottom-up fatigue cracking, rutting of the HMA layers, or rutting of the subgrade. Perpetual pavement is designed to withstand almost infinite number of axle loads without structural deterioration by limiting the level of load-induced strain at the bottom of the HMA layers and top of the subgrade and using deformation resistant HMA mixtures. Figure 1-2 shows a generalized perpetual pavement design.

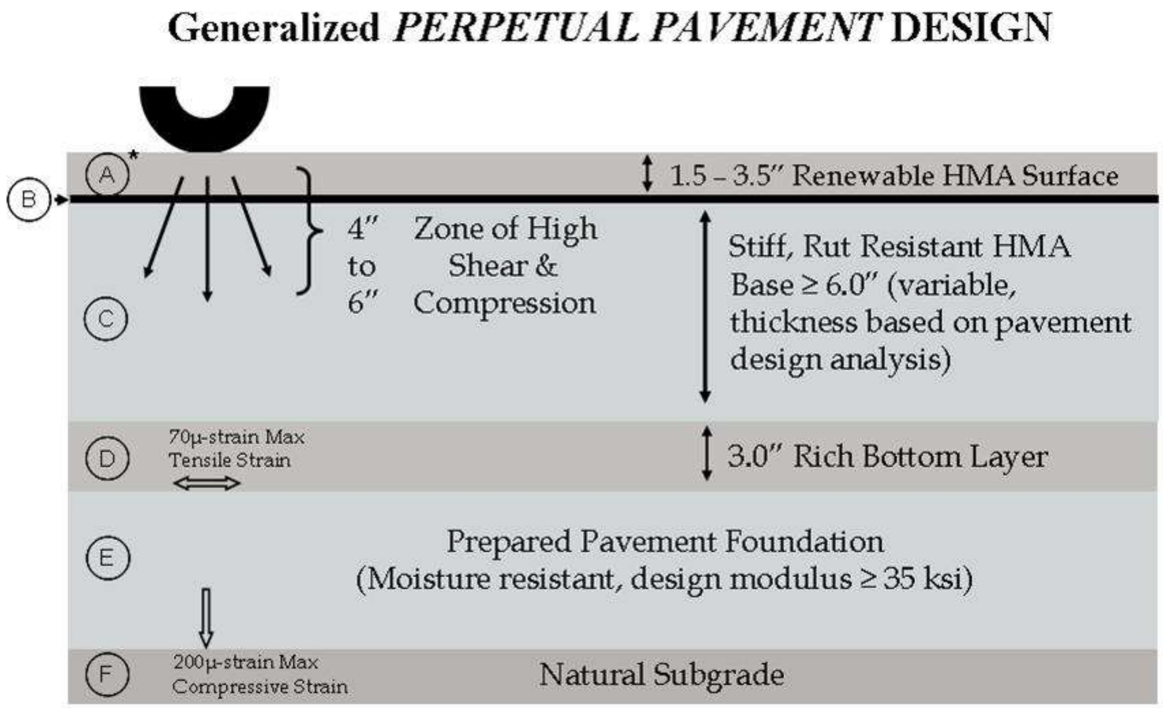


Figure 1.2. Generalized perpetual pavement design.

1.3.3 Rigid Pavement

A rigid pavement structure is composed of a hydraulic cement concrete surface course and underlying base and subbase courses (if used). Another term commonly used is Portland cement concrete (PCC) pavement, although with today's pozzolanic additives, cements may no longer be technically classified as "Portland."

The surface course (concrete slab) is the stiffest layer and provides the majority of strength. The base or subbase layers are orders of magnitude less stiff than the PCC surface but still make important contributions to pavement drainage and frost protection and provide a working platform for construction equipment.

Rigid pavements are substantially 'stiffer' than flexible pavements due to the high modulus of elasticity of the PCC material, resulting in very low deflections under loading. The rigid pavements can be analyzed by the plate theory. Rigid pavements can have reinforcing steel, which is generally used to handle thermal stresses to reduce or eliminate joints and maintain tight crack widths. Figure 1-3 shows a typical section for a rigid pavement.

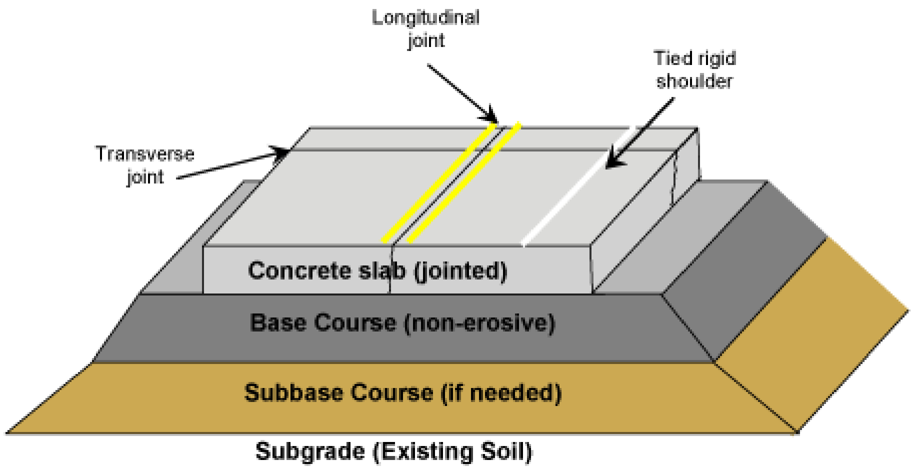


Figure 1-3. Typical section for a rigid pavement.

1.3.4 Continuously Reinforced Concrete Pavement

CRCP provides joint-free design. The formation of transverse cracks at relatively close intervals is a distinctive characteristic of CRCP. These cracks are held tightly by the reinforcement and should be of no concern as long as the cracks are uniformly spaced, do not spall excessively, and a uniform non-erosive base is provided. Figure 1-4. shows a typical section of CRCP.

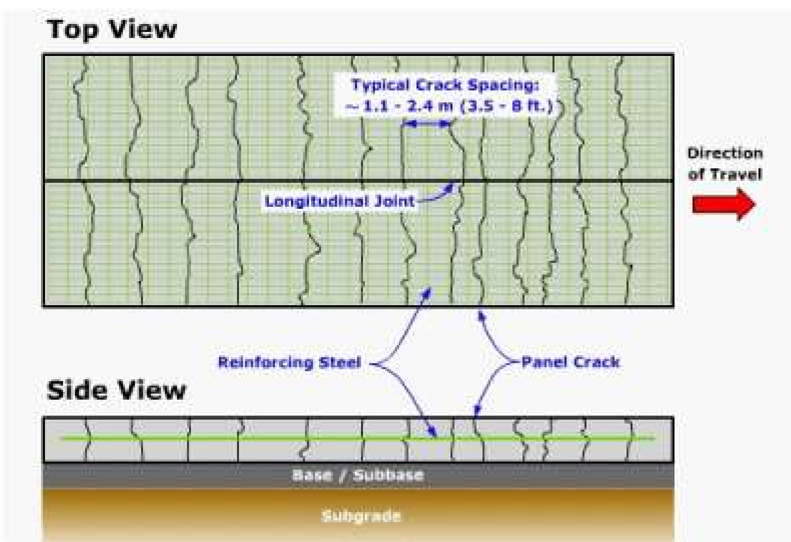


Figure 1.4. Continuously Reinforced Concrete Pavement.

1.3.5 Concrete Pavement Contraction Design (CPCD)

CPCD uses contraction joints to control cracking and does not use any reinforcing steel. An alternative designation used by the industry is jointed concrete pavement (JCP).

Transverse joint spacing is selected such that temperature and moisture stresses do not produce intermediate cracking between joints. Nationally, this results in a spacing no longer than 20 ft. The standard spacing in Texas is 15.0 ft.

Dowel bars are typically used at transverse joints to assist in load transfer. Tie bars are typically used at longitudinal joints. Figure 1-5 shows a typical section of CPCD.

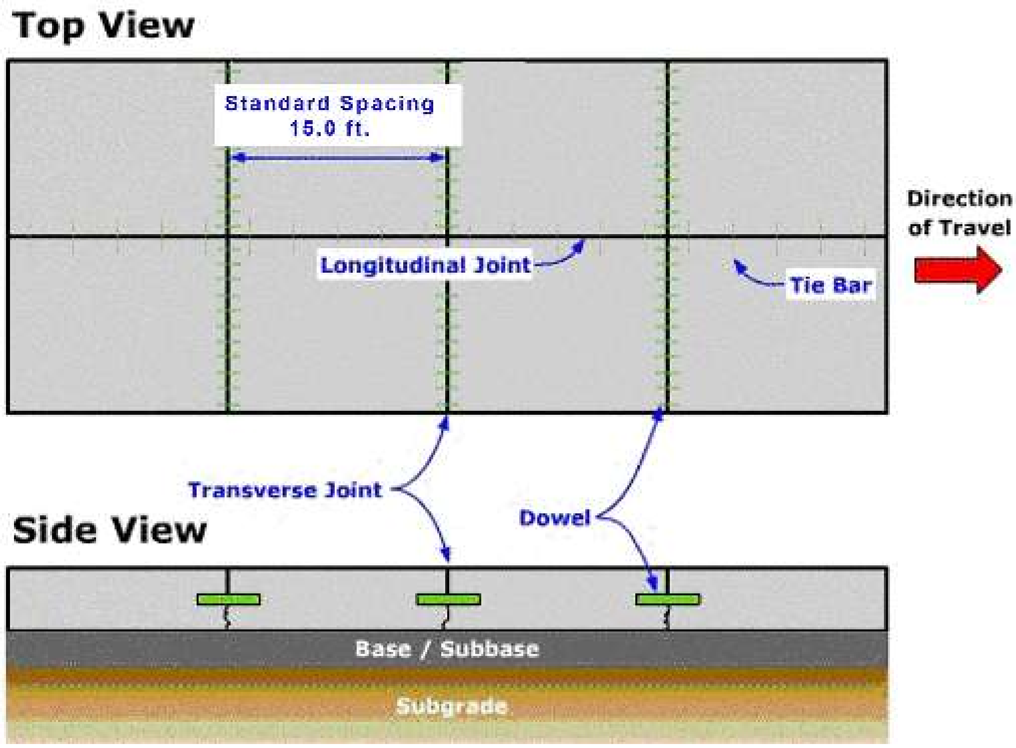


Figure 1.5. Concrete Pavement Contraction Design (CPCD).

1.3.6 Jointed Reinforced Concrete Pavement (JRCP)

JRCP uses contraction joints and reinforcing steel to control cracking. Transverse joint spacing is longer than that for concrete pavement contraction design (CPCD) and, in Texas, it typically ranges from 30 ft. to 60 ft. This rigid pavement design option is no longer endorsed by the department because of past difficulties in selecting effective rehabilitation strategies. However, there are several remaining sections in service. Figure 1-6 shows a typical section of jointed reinforced concrete pavement.

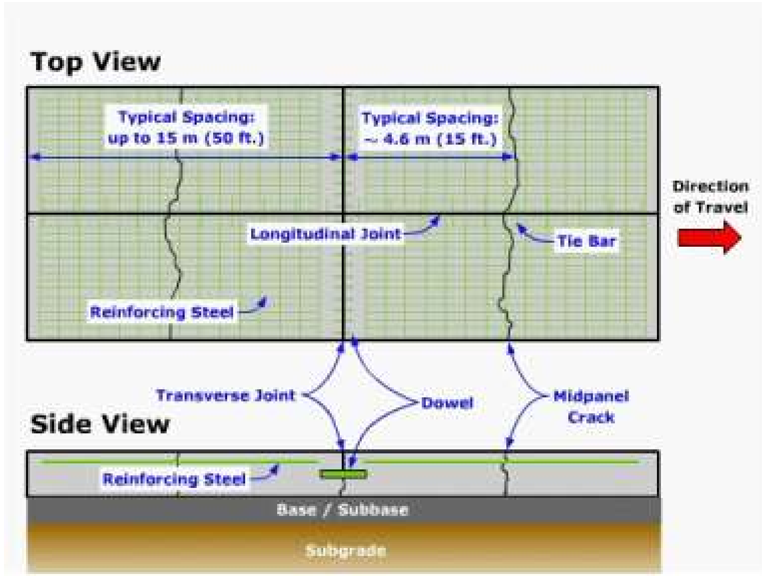


Figure 1.6. Jointed Reinforced Concrete Pavement (JRCP).

1.3.7 Post-tensioned Concrete Pavements

Post-tensioned concrete pavements remain in the experimental stage and their design is primarily based on experience and engineering judgment. Post-tensioned concrete has been used more frequently for airport pavements than for highway pavements because the difference in thickness results in greater savings for airport pavements than for highway pavements.

1.3.8 Composite Pavement

A composite pavement is composed of both hot mix asphalt (HMA) and hydraulic cement concrete. Typically, composite pavements are asphalt overlays on top of concrete pavements. The HMA overlay may have been placed as the final stage of initial construction, or as part of a rehabilitation or safety treatment. Composite pavement behaviour under traffic loading is essentially the same as rigid pavement.

1.3.9 Rigid and Flexible Pavement Characteristics

The primary structural difference between a rigid and flexible pavement is the manner in which each type of pavement distributes traffic loads over the subgrade. A rigid pavement has a very high stiffness and distributes loads over a relatively wide area of subgrade – a major portion of the structural capacity is contributed by the slab itself.

The load carrying capacity of a true flexible pavement is derived from the load-distributing characteristics of a layered system (Yoder and Witczak, 1975). Figure 1-7 shows load distribution for a typical flexible pavement and a typical rigid pavement.

Figure 1.7. Typical stress distribution under a rigid and a flexible pavement.

1.4 COMPONENTS OF CEMENT CONCRETE PAVEMENT

A typical cross-section showing various components of cement concrete pavement is shown in Figure 1-8.

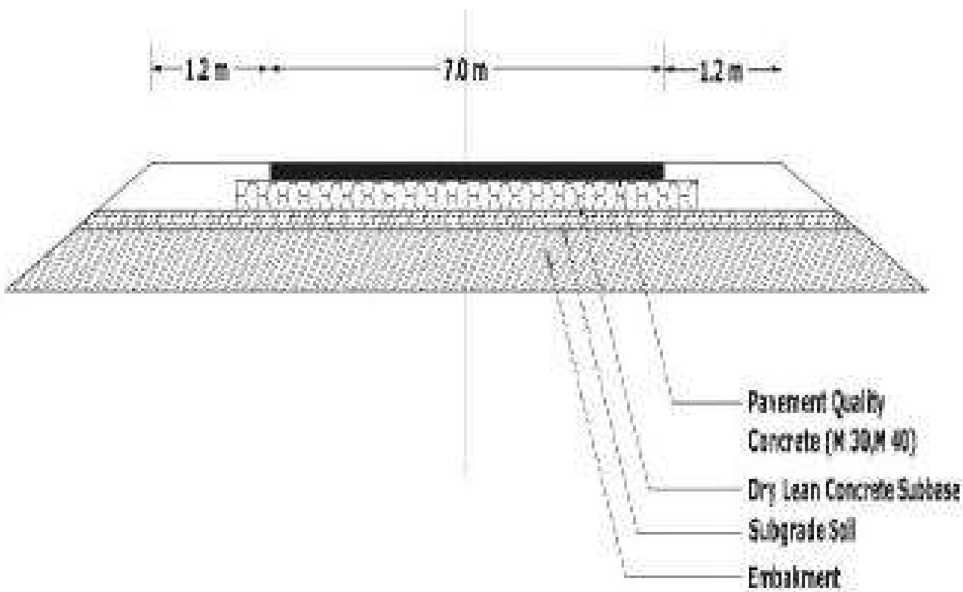


Figure 1.8 Cross-Section Showing Various Components Of Cement Concrete Pavement

1.4.1 Sub-grade

Sub grade is not formally a pavement layer. In order to design and construct a satisfactory pavement over it, its properties and function must be fully understood. Sub grade is the natural soil or made-up ground on which the pavement is built. The load of the whole pavement finally comes on the sub-grade.

The sub grade and sub base for lying of paving concrete slab shall comply with the following requirements: (IRC:15-1991)

a) No soft spots are present in the sub grade or sub base.

b) The uniformly compacted sub grade or sub base extends at least 300 mm on either of width to be connected.

c) It should be properly drained.

d) The maximum modulus of sub grade reaction obtained with a plate bearing test shall be 5.5 kg/cm3.

1.4.2 Drainage Layer

A geo-composite drainage layer is provided over a sub grade for improved pavement drainage. The geo-composite has advantage over natural drainage in maintaining its flow capacity and compressive stiffness under the construction and services beside unequal support. It is a sand/ graded gravel layer.

1.4.3 Sub-base Course/ Dry Lean Concrete (DLC)

It is an important part of modern rigid pavement. It is a plain concrete with a large ration of aggregate to cement than conventional concrete and generally used as a base/ sub base of rigid pavement (Central road research institute, 2010)

1.4.4 Pavement Quality Concrete (PQC)

The IRC specifications of material used for Pavement Quality Concrete (PQC) are discussed as below (MORTH Section 600).

a) Cement

As per technical specifications- M.O.R.T&H Cl. 601.2.1, Ordinary Portland Cement of 43 grade conforming to IS:8112 shall be used.

i) Fly ash up to 20 percent by weight of cement may be used in ordinary Portland cement 53 Grade. No fly ash shall be used in any other grade of Cement other than 53 Grade. The fly ash shall conform to IS:3812 (Part I).

ii) Ground Granulated Blast Furnace Slag (GGBFS) obtained by grinding granulated slag conforming to IS: 12089. GGBFS shall not be sued in any other grade of cement except 53 grade. The content of GGBFC shall be up to 50 percent by weight of Ordinary Portland Cement 53 grade.

iii) Mix design will be done as per IRC: 44. The OPC content shall not be less than 310 kg/m3 in case of blending at site. The curing period may be suitably enhanced by at least about 2 days.

b) Coarse aggregates

The maximum size of coarse aggregate shall not exceed 31.5 mm for pavement concrete. No aggregate which has water absorption more than 2 percent shall be used in the concrete mix. The aggregates shall be tested for soundness in accordance with IS: 2386 (Part-5). After 5 cycles of testing, the loss shall not be more than 12 percent if sodium sulphate solution is used or 18 percent if magnesium sulphate solution is used. The combined flakiness and elongation index of aggregate shall not be more than 35 percent.

c) Fine aggregates

The fine aggregates shall consist of clean natural sand or crushed stone sand or a combination of the two and shall conform to IS:383.

d) Cement content

When Ordinary Portland Cement (OPC) is used the quantity of cement shall not be less than 360 kg/ cu.m. In case fly ash grade I (as per IS:3812) is blended at site as part replacement of cement, the quantity of fly ash shall be up to 20 percent by weight of cement and the quantity of OPC in such a blend shall not be less than 310 kg. cu.m. The minimum of OPC content in case ground granulated Portland blast furnace is used, shall also not be less than 310 kg/m3.

e) Concrete strength

The characteristic flexural strength of concrete shall not be less than 4.5MPa (M40 Grade).

f) *Separation Membrane*

Separation membrane shall be impermeable plastic sheeting of 125 micron thick laid flat without creases. Before placing the separation membrane, the DLC surface shall be swept clean of all the extraneous materials. Overlap of membrane if any shall e at least 300 mm and any damaged sheet shall be replaced immediately.

Fig. 1.9 Laying of separation membrane

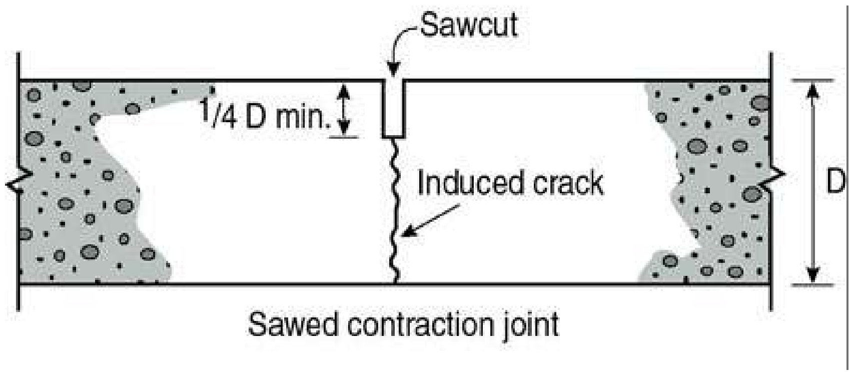
g) *Joints*

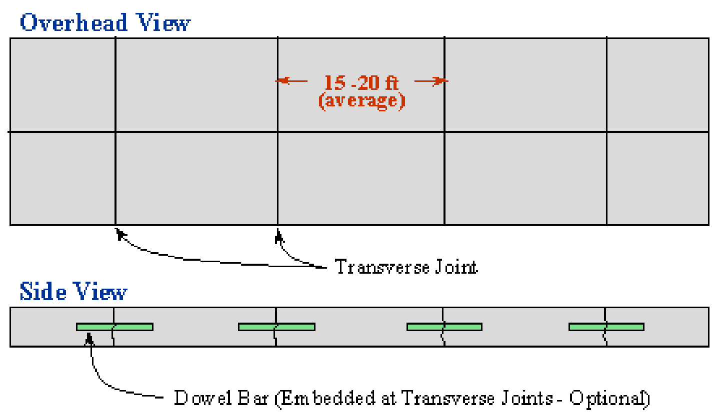
Initial saw cut of 3mm wide, 100mm depth in transverse and longitudinal direction will be provided after initial set (approximately 6-8 hrs). Final saw cutting 10-12 mm wide, 20-25 mm depth will be provided after 14 days of curing at accommodated joint sealant. The staggering of transverse joint with reference to the base will be minimum 0.3 m.

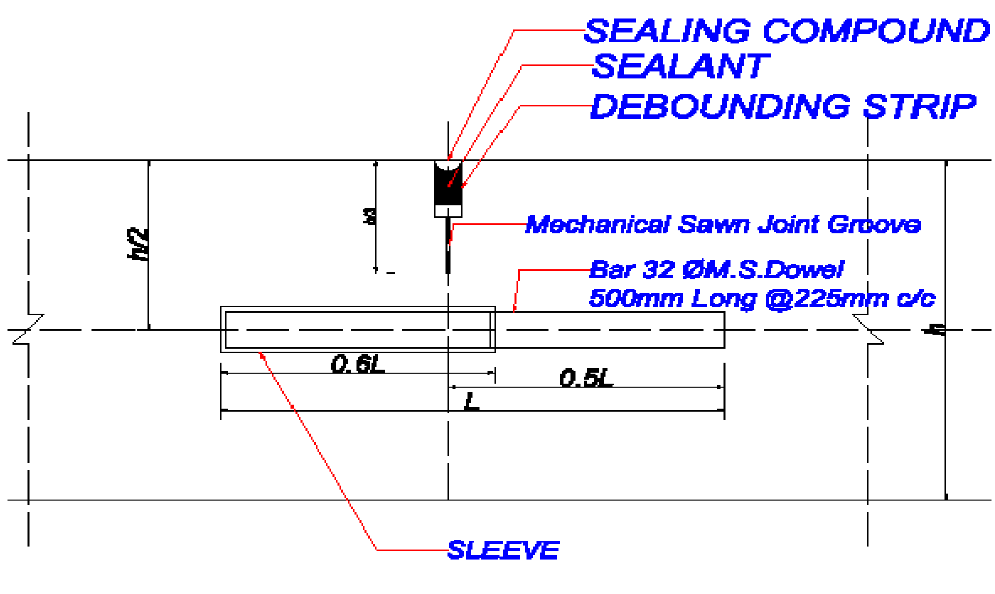
Contraction joints will be provided at every 4.5 m interval except where expansion joints are provided. Transverse construction joint shall be placed when concreting is done after a day’s work. It will be provided at regular location of contraction joints using dowel bars.

Fig. 1.10 Longitudinal joint in Pavement Quality Concrete (PQC)

Fig. 1.11 Saw cut in transverse direction







TRANSVERSE JOINT

Fig. 1.12 Section of Transverse joint in Pavement Quality Concrete (PQC)

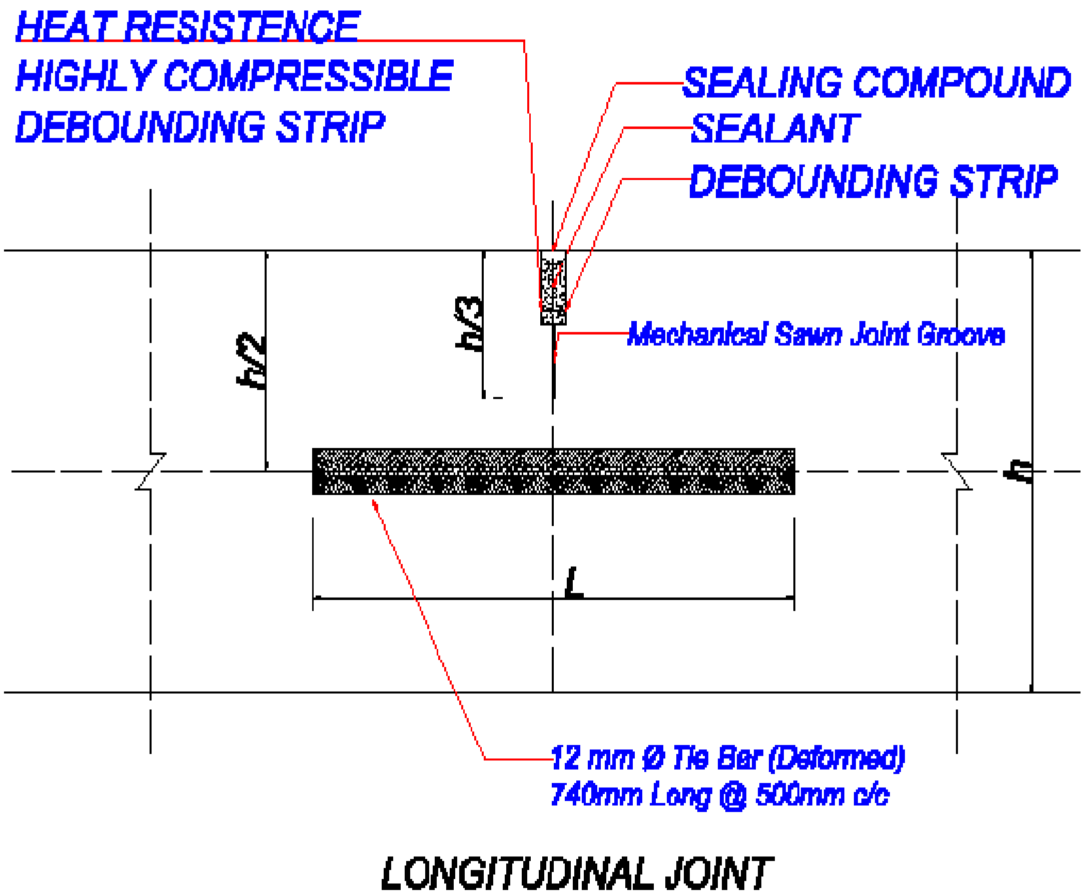


Fig. 1.13 Section of Longitudinal joint in Pavement Quality Concrete (PQC)

h) Dowel Bars

Dowel bars shall confirm to the requirements of IS:432, IS:1139 and IS:1786. The dowel bars shall confirm to Grade S 240 and tie bars to Grade S 415 of IS. It should be mild steel round, free from dirt, loose rust, scale straight and burring restricted slippage in the concrete. Dowel bars will be positioned at the mid depth of the slab with in a tolerance of +/- 20 mm. Dowel bars shall be covered by a thin plastic sheet for at least 2/3 of length from one end for dowel bars in contraction joint or half the length plus 50 mm for expansion joints. The sheet shall be tough, durable and of an average thickness not less than 1.23 mm. For expansion joints, a closely fitting cap 100 mm long cotton waste placed over sheet end of each dowel bar.

Fig. 1.14 Dowel bars in Pavement Quality Concrete (PQC)

i) Tie Bars

The bar should be free from oil, dirt, loose rust and scale. In longitudinal joints shall be deformed steel bars of strength 415 MPa complying with IS: 1786. It should protect from corrosion for 75 mm on each side of the joint by applying bituminous paint. The coating shall be dry when Tie bars are used. It should be perpendicular to the line of joint, with the centre of each bar on the intended line of the joint within a tolerance of +/- 50 mm and with a minimum cover of 30 mm below joint groove.

Fig. 1.15 Tie bars with Longitudinal joint in Pavement Quality Concrete (PQC)

j) Surface Tolerance

Surface tolerance shall be within the limits of +5/-6 mm tolerance limit as per M.O.R.T.H Clause 902.3, surface levels shall be checked on a grid of points spaced at 6.25 m along the length and 3.5 m transversely between 0.5 m from the edges and at the centre of the pavement.

Fig. 1.16 Laying of Pavement Quality Concrete (PQC) with Slip Form Paver

Fig. 1.17 Placing of Dowel bars manually and Laying of Pavement Quality Concrete with paver.

1.5 RICE HUSK ASH

Rice milling generates a by-product known as husk. This surrounds the paddy grain. During the milling of paddy about 78 % of weight is received as rice, broken rice and bran. The rest 22 % of the weight of paddy is received as husk. This husk is used as fuel in the rice mills to generate steam for the parboiling process. This husk contains about 75 % organic volatile matter which burns up and the balance 25 % of the weight of this husk is converted into ash during the firing process, which is known as **rice husk ash (RHA).** Rice husk is burnt approximately 48 hours under uncontrolled combustion process. The burning temperature should be within the range of 600 to 850 degrees. The ash obtained then ground in a ball mill for 30 minutes and its colour normally seen as grey.This RHA in turn contains around 85%-90% amorphous silica. So for every 1000 kg of paddy milled,about 220kg (22%) of husk is produced, and when this husk is burnt in the boilers, about 55kg (25%) of RHA is generated.

Fig. 1.18 Rice husk ash

Rice husk ash (RHA) can be used as a highly reactive pozzolanic material to improve the:

- microstructure of the interfacial transition zone (ITZ) between the cement paste and the aggregate in high-performance concrete. The utilization of rice husk ash as a pozzolanic material in cement and concrete provides several advantages, such as improved compressive strength and durability properties, reduced materials cost due to cement savings , environmental benefits related to the disposal of waste materials and reduced carbon dioxide emissions.

- The cements containing Rice Husk Ash possess excellent resistance to dilute organic and mineral acids.

It is also highly absorbent, and is used to absorb oil on hard surfaces and potentially to filter arsenic from water.

1.5.1 Reactions In The Production of RHA Concrete

Silicon burnt in the presence of Oxygen gives Silica. The highly reactive silica reacts with Calcium hydroxide released during the hydration of cement, resulting in the formation of Calcium Silicates responsible for strength as shown in Fig. 1.19.

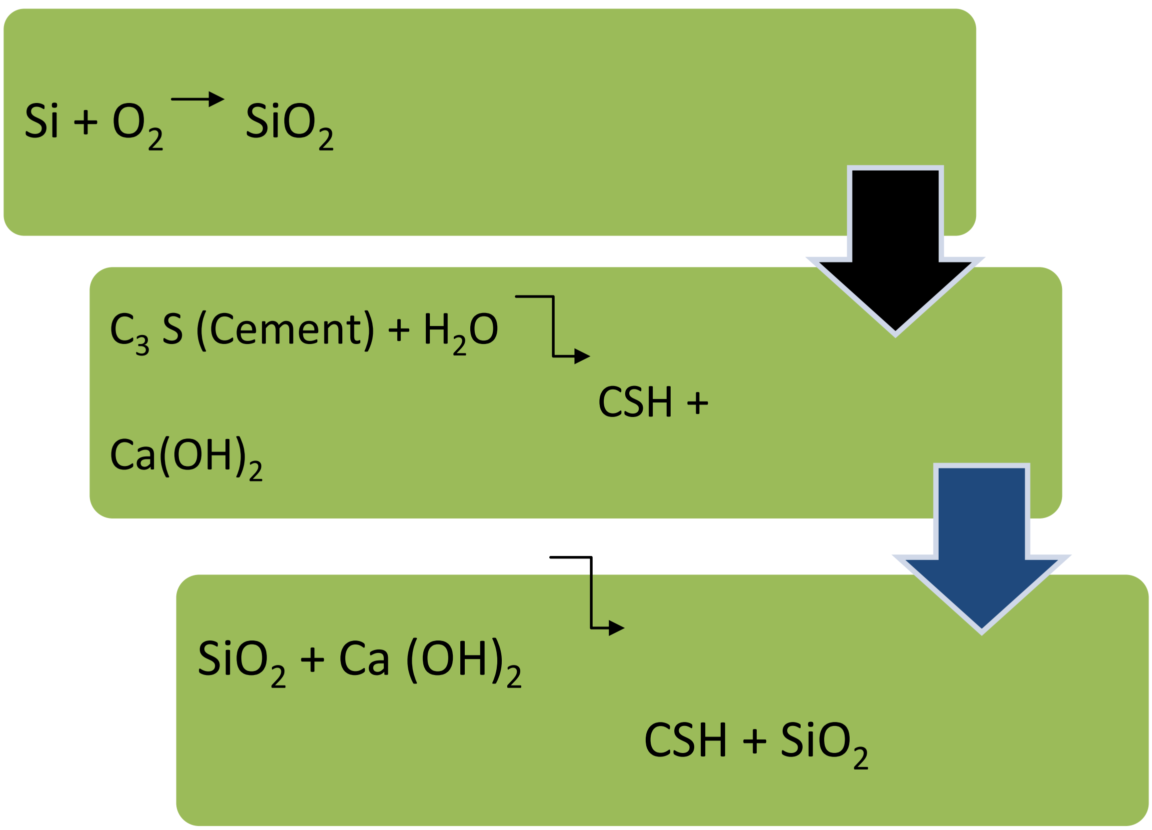


Fig. 1.19 REACTIONS IN THE PRODUCTION OF RHA CONCRETE

1.5.2 Properties of RHA

1.5.2.1 Physical Properties of RHA

Table1.1 Physical Properties of RHA

Property	Value		
	(Khani et al., 2009)	(Habeeb et al., 2010)	(Kishore et al., 2011)
Specific Gravity	2.15	2.11	2.27

1.5.2.2 Chemical Properties of RHA

Table 1.2 Chemical Properties of RHA

Constituents	Percentage		
	(Khani et al., 2009)	(Habeeb et al.,2010)	(Givi et al.,2010)
Silica (SiO_2)	89.61	88.32	87.86
Alumina (Al_2O_3)	0.04	0.46	0.68
Iron oxide(Fe_2O_3)	0.22	0.67	0.93
Calcium Oxide (CaO)	0.91	0.67	1.30
Magnesium oxide (MgO)	0.42	0.44	0.35
Sodium oxide (Na_2O_3)	0.07	0.12	0.12
Potassium oxide (K_2O)	1.58	2.91	2.37
LOI	5.91	5.81	-

1.5.3 Rice Husk Ash Production. {Khani et al. (2009)}

The quality of RHA as an additive for cement and concrete depends on its reactivity. The reactivity of RHA depends on amorphous silica content available and on the porous structure of the ash. To produce the best pozzolanas, the burning of the husk must be carefully controlled to keep the temperature below 700°C and to ensure that the creation of carbon is kept to a minimum by supplying an adequate quantity of air.

Fig.1.20 RICE HUSK ASH PRODUCTION.

At burning temperatures below 700°C an ash rich in amorphous silica is formed which is highly reactive. Temperatures above 700°C produce crystalline silica which is far less reactive. The presence of large quantities of carbon in the ash will adversely affect the strength of any concrete or mortar produced using RHA cements. Where possible, the carbon content of the ash should be limited to a maximum of 10%.

1.5.4 Basic Incinerators

- There are several designs of small simple incinerators, normally made of fired clay bricks, which are capable of burning ash at temperatures below 700°C and without excessive quantities of carbon.The temperature is monitored by a pyrometer (an industrial instrument for measuring high temperatures) and rapid cooling is necessary if the temperature rises above 650°C.Incinerators of this type are normally used in banks of three or four to produce approximately one tonne of ash per day.
- Small incinerators have a number of advantages:

  1.They are simple and inexpensive to construct.

  2.Easy to operate .

  3.Will produce ash of an acceptable quality.
- Small incinerators have a number of disadvantages:

  1. Their output is rather small
  2. They also require constant supervision
  3. They make no use of the energy value of the husk

Rice husk has an energy value about half that of coal and is therefore an important potential energy source.

1.5.5 RHA Furnace (Khani Et Al., 2009)

- In order to supply typical RHA, a special furnace was designed and constructed in the Amirkabir University of Technology. This furnace was manufactured in the pilot size, capable of controlling the conditions of combustion. The furnace was designed and manufactured in order to control the temperature and the rate of burning. Therefore, the furnace can be used to produce rice husk ashes with various un-burnt carbon contents.

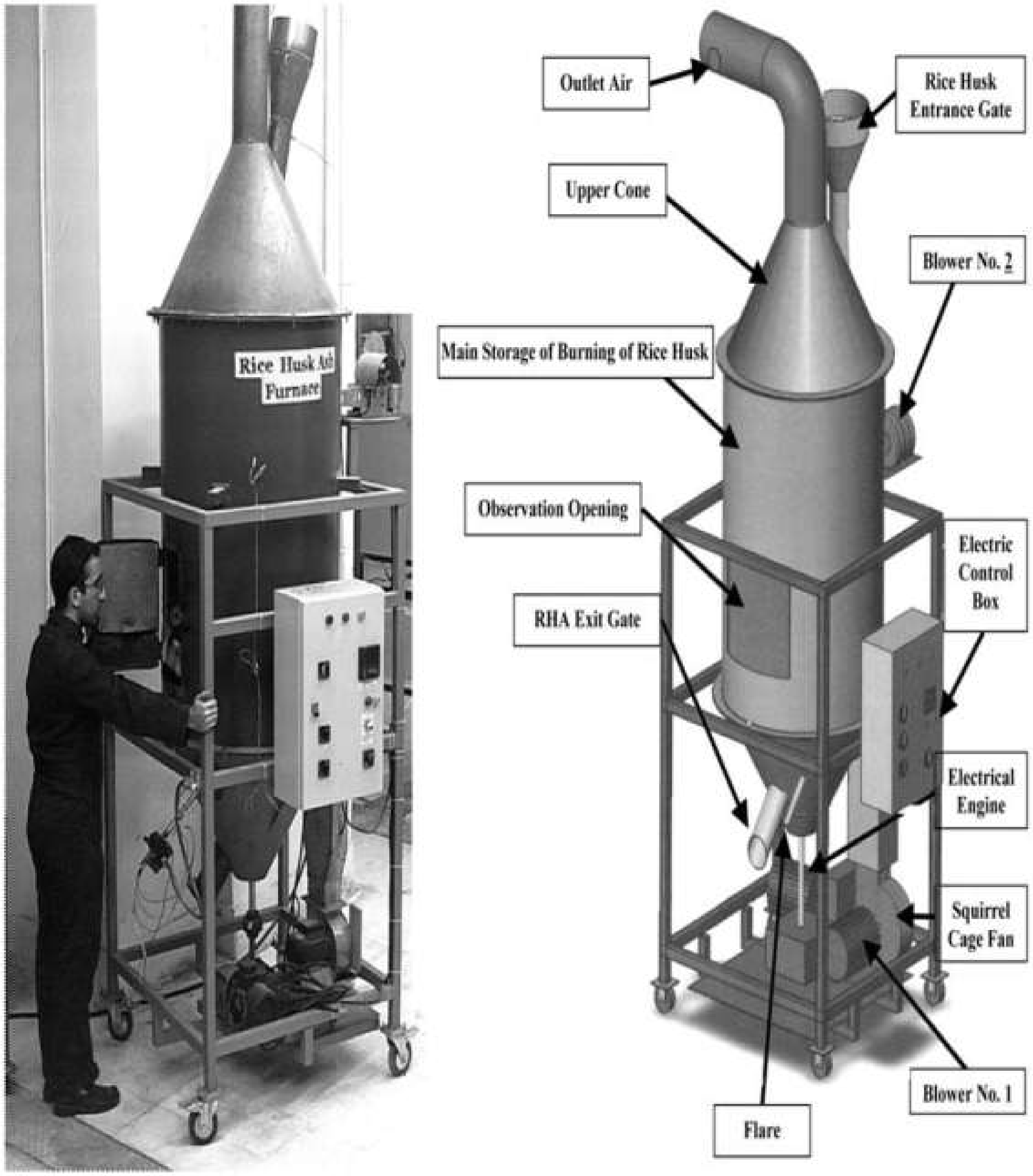


Fig.1.21 RHA Furnace

1.5.6 Process

Fig.1.22 Process

- Ways for supplying required air for combustion.The hot air is blown into the main storage of ash through a porous plate. Simultaneously,the air is injected from another blower through pipes of air transfer.The air blowers can directly control the combustion procedure. Temperatures can be measured by thermocouples at the fire zone, in air inlet and outlet zones.The measured temperature in the fire zone shows directly the temperature of the ash.
- **Advantage** - No control is required during burning process.

1.5.7 Factors Influencing Ash Properties

(A) Temperature:

- The ash patterns were denoted as RHA-Temp.-Min. respectively.The figure 1.23 shows that silica in the rice husk initially exists in the amorphous form, but will not remain porous and amorphous, when combusted for a prolonged period at a temperature above 650°C, or during less than a few minutes at 1100°C, under oxidizing conditions. It means that the reactivity of rice husk ash is generally decreased by the increase of burning temperature and the heating duration.Burning rice husks at temperature below 650°C produces amorphous crystals of rice husk ashes.Combination of 650°C temperature and 60 minutes burning time seems to present the optimized solution resulting in non Crystallize RHA. Khani et al. (2009).

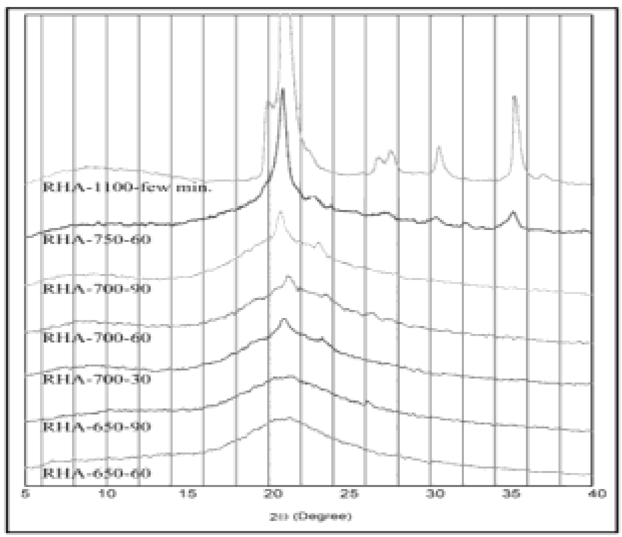


Fig.1.23 Results of XRD on rice husk ash samples and cement .

(Khani et al.,2009)

- Nair et al. (2008) reported an investigation on the pozzolanic activity of RHA by using various techniques in order to verify the effect of incineration temperature and burning duration. He stated that the samples burnt at 500 or 700 °C and burned for more than 12 hours produced ashes with high reactivity with no significant amount of crystalline material. The short burning durations (15 – 360 minutes) resulted in high carbon content for the produced RHA even with high incinerating temperatures 6 of 500 to 700 °C.

- Rukzon et al. (2010) reported that RHA with cellular microstructure and highly pozzolanic activity is formed, when rice husk is burnt at temperatures lower than 700 ^{0}C.

(B) Geographical Region

- Chemical variations in husk composition (and consequently ash composition) are influenced by such things as the soil chemistry, paddy variety and climate. A variation in colour was found in ash from husks burnt in different regions, with ash produced from husks from Northern India resulting in a much darker ash than husks from the US. Differences in mineral composition of ash can be attributed to fertilizers applied during rice cultivation.

1.5.8 Applications of Rice Husk Ash

- **Cement and concrete-** It is an active pozzolan which when combined with lime in the presence of water results in a stable and more amorphous hydrate (calcium silicate). This is stronger, less permeable and more resistant to chemical attack (Owens, 1999).
- **Steel industry-** Rice husk ash is used by the steal industry in the production of high quality flat steel used for automotive body panels (Sugita, 1993).
- **Oil absorbent-** Husks burnt slowly over a period of six months have been found to be effective as oil absorbent and are marketed in California under the trade name 'Greas weep'.
- **Soil ameliorant-** RHA help break up clay soils and improve soil structure. Its porous nature also assists with water distribution in the soil. .RHA was found to increase the pH of the soil, and so was recommended for use with plants which require alkaline soil, or in situations where acid irrigation water is present.
- **Silicon chips-** The Indian Space Research Organization has successfully developed technology for producing high purity precipitated silica from RHA and this has a potential use in the computer industry . Consortiums of American and Brazilian scientists have also developed ways to extract and purify silicon with the aim of using it in semiconductor manufacture.

- **Refractory bricks-** Refractory bricks are used in furnaces which are exposed to extreme temperatures, such as in blast furnaces used for producing molten iron and in the production of cement clinker.
- **Light weight insulating material -** There is anecdotal evidence of RHA being used in the manufacture of lightweight insulating boards in developing countries. Research at the University of Arkansas has also focused the manufacture of insulation from RHA. The material produced is very low density and so lightweight it floats.

1.6 STEEL FIBERS

In early 1990s Steel fibres have been used in concrete. Earlier the fibres were round and smooth and the wire was cut or chopped to required lengths. The use of straight, smooth fibre has largely disappeared and modern fibres have either rough surfaces, hooked ends or are crimped or undulated through their length. Modern commercially available steel or by the melt-extraction process which produces fibres that have a crescent-shaped cross section. Steel fibres have been successfully used for pavement applications in many hundreds and thousands of square meters of concrete for roads and highways. Steel fibre Reinforced Concrete (SFRC) has extra strength in flexure and impact as compared to plain recycled concrete. Steel fibres distributed in the concrete delay the growth of cracks thus improving the ductility of the matrix. The ability of steel fibres in improving the properties of concrete depends on the bond characteristics, aspect ratio of the fibre, surface friction and tensile strength of the fibre. Common application of SFRC include paving applications such as in airports, highways, bridge decks and industrial floors, which endure significant cyclic loading during their service life. All these properties are the requirements needed for recycled concrete pavement for highways, bridge deck and runways or taxiway to maintain high quality and smooth riding surface without irregular depressions. The fatigue performance of SFRC is one of the important parameters to be considered in the design.

Fatigue is a process of progressive and permanent material damage under repeated loading. Fatigue failure takes place under the influence of repetitive or cyclic load, whose peak values are considerably smaller than safe loads estimated on the basis of static load tests. In concrete, these changes are mainly associated with the progressive growth of internal micro cracks, which result in a significant increase of irrecoverable strain. At the macro-level, this will manifest itself as changes in the material's mechanical properties. Fatigue loading is usually divided into two categories i.e. low-cycle and high cycle loading. Low-cycle loading involves the application of a few load cycles at high stress levels. On the other hand, high cyclic loading in characterized by a large number of cycles at lower stress levels.

1.7 STEEL FIBRE REINFORCED CONCRETE

1.7.1 Definition

Fibre reinforced concrete represented by combination of four different phase, like cement, water, coarse aggregate, fine aggregate and a dispersion of discontinuous, steel fibre. It can also contain admixtures and pozzolans which are commonly used with the conservative concrete. All admixtures under the ASTM specifications for use in concrete are desirable for use in Steel Fibre Reinforced Concrete (SFRC).

1.7.2 Fibre Content

Various amount of fibre is added in concrete which is generally measured as a fraction of total volume of mortar. Practically four ranges of Volume fractions (Vf) can be identified as shown in Table 1.3

1.7.3 Types of Fibres

Fibre is manufactured from various materials in various shapes and sizes. The numerical parameter representing a fibre is its aspect ratio i.e. I/d ratio which means fibre length divided by diameter. Typical aspect ratio is used which have ranges from 30-150 for length dimensions of 1.0 to 76.2 mm. Various properties of commonly used steel fibres as shown in Table 1.3.

Table 1.3 Typical Practical Ranges of Fibre Reinforcement of Concrete

Approx. Vol. Fraction of Fibre	Matrix	Example
Vf < 0.5%	Concrete	PP in pipe caps
0.5% < Vf < 3%	Concrete(Smaller size agg.)	Pavements, Joints
3% < Vf < 8%	Mortar	Cement sheets,repairs
8% < Vf < 20%	Paste,Slurry	Asbestos cement sheets, Slurry

1.7.4 Properties of Fibre Reinforced Concrete

The properties of fibre reinforced concrete is regulate by fibre-matrix bond characteristics, volume fraction, material properties of fibre, type, geometry and matrix proportion in fresh as well as in hardened state. Steel fibres are uniformly distributed throughout the concrete mix as comparison to rebar or welded wire reinforcement, both which are specially located in a single plane. The foremost motive of the use of steel fibre is to modify micro and macro cracking. Steel fibres control the growing of cracks at their initial stages.

Table 1.4 : Physical and Mechanical Properties of Fibres

Fibre	Diameter (µm)	Specific Gravity	Young's modulus (KN/mm2)	Tensile Strength (KN/mm2)	Elongation at break (%)
Asbestos	0.02-20	2.55	165	3-3.5	2-3
Glass	9-15	2.60	70-80	2-4	2-3.5
Steel	5-500	7.84	200	1-3	3-4
Polypropylene	20-200	0.91	6-7	0.5-0.7	20
Rayon	20-200	1.5	7-8	0.4-0.6	10-25
Polyethylene	20-200	0.95	0.14-0.42	0.7	10
Cotton	-	1.5	5	0.42-0.7	3-10

1.8 APPLICATION OF FIBRE REINFORCED CONCRETE

Steel fibre reinforced concrete (SFRC) is concrete containing dispersed steel fibres. The most important regulation of steel fibres in concrete is to control and retard the tensile cracking of the composite material. The steel fibre reinforced concrete improves the strength characteristics like flexural strength, split tensile strength, strain capacity, flexural toughness, compressive strength and crack arrest properties which lead to use in highway and airfield pavements, overlays and bridge deck slabs. Some of the practical applications of steel fibre reinforced concrete include usage in thin shells and walls, concrete pipes, highway pavements, partially pre-stressed composite concrete beams, airport runways, high velocity passages, blast resistance structures, water retaining structures, marine structures etc.

1.9 OBJECTIVES OF THE PROPOSED PROJECT

The main objective of the proposed work is to study the effect of steel fibres on strength characteristics of Pavement Quality Concrete. Additionally, the effect of partial replacement of cement by RHA had also been proposed to be studied.

CHAPTER -2

LITERATURE REVIEW

PROPERTIES OF RICE HUSK ASH IN CONCRETE

2.1 INTRODUCTION

We have studied the literature review of various properties of concrete when cement is replaced by RHA in different percentage. Basic properties that are under study are – compressive strength, splitting tensile strength, slump workability and super plasticizer content, water absorption and flexural strength.

Study of the literature review of various properties of concrete cement is replaced by RHA in different percentage is discussed below.

2.2 COMPRESSIVE STRENGTH

- Zhang et al. (1996) presents an experimental study on the effects of the incorporation of rice-husk ash (RHA) in cement concrete on the compressive strength of concrete , and the results are compared with those obtained with the control Portland cement concrete and concrete incorporating silica fume.(Table-2.1)
- Fifteen 50.8 X 50.8 X50.8 mm cubes were casted.

Specification - Three types of mixes were made –

1. CC0 (controlled concrete mix with 0%RHA and 0%SF)
2. CR10 (mix containing 10% RHA)
3. CSF10 (mix containing 10% SF)

Table 2.1 Mixture Proportions for Concrete. (Zhang et al., 1996)

Mix no.	RHA content (%)	Silica fume content (%)	W/C or W/C+RHA or W/C+SF	Quantities (kg/m^3)						
								Fine agg.	Coarse agg.	SP
CC0	0	0	0.30					708	1153	6.9
CR10	10	-	0.30					699	1137	9.6
CSF10	-	10	0.30					706	1149	7.9

- Coarse agg. Used are crushed limestone of avg size 19mm. Fine agg. Used is local natural silica sand . Super plasticizer used is Sulphonated Naphthalene Formaldehyde Condensate Average particle size of RHA – 7 µm , SF – 0.1µm, cement - 13 µm .

Table 2.2 Properties of Concrete. (Zhang et al., 1996)

Mix no.	Type of concrete	W/C or W/C+RHA or W/C+SF	Fresh concrete				Hardened concrete					
			Tempe - rature (ºc)	Slump (mm)	Unit weight kg/m³	Air cont-ent (%)	Unit weight (1-day) (kg/m³)	Compressive strength (Mpa)				
								1d	7d	28 d	90 d	180d
CC0	Control	0.30	25	150	2472	2.4	2467	41.4	52.1	61.0	70.6	76.5
CR10	10%RHA	0.30	25	120	2458	2.4	2466	41.4	57.9	70.8	78.9	81.7
CSF10	10%SF	0.30	25	110	2472	1.7	2471	44.4	64.8	78.9	77.8	80.8

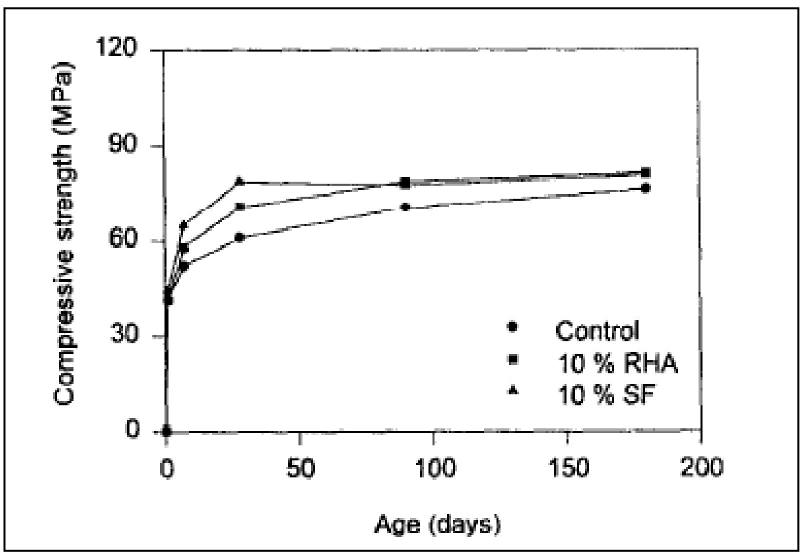


Fig.2.1 Compressive strength development of concretes versus age. (Zhang et al., 1996)

- Fig.2-1 curves shows that the RHA and the control concrete had similar one-day strengths, but the RHA concrete had Somewhat higher strength than the control concrete thereafter up to 180 days. Compared with the silica fume concrete, the compressive strength of the RHA concrete was lower up to 28 days, but similar at 90 and 180 days.

- **Habeeb et al. (2010)**

  Habeeb et al. (2010) investigates the effect of grinding time on compressive strength of rice husk ash (RHA).

Specifications – High workability concrete (200 – 240 mm slump). Target strength of 40 MPa for the control mixture. A total of 13 concrete mixtures were casted and results were seen for 1, 3, 7 and 28 days . F1, F2, F3 represents the grinding time that is 180min, 270 min and 360 min respectively.

Table 2.3 Concrete mixture proportioning. (Habeeb et al., 2010)

MIX	CEMENT (kg)	RHA F1/F2 /F3 (kg)	WATER (L)	F.A (kg)	C.A (kg)	W/BINDER
CM	39	207	750	994	0.53	0.53
05RHA	59	207	750	994	0.53	0.53
10RHA	352					
15RHA	332					
20RHA	313	78	207	750	994	0.53

OBSERVATIONS

- The 5% replacement level achieved slightly lower values of compressive strength at early ages for up to 7 days excluding 05F3 . Therefore 5% replacement used is not adequate to enhance the strength significantly. The maximum strength is obtained by replacing 10% cement by RHA and grinding it for about 360 min.The strength values when RHA was replaced by 15% were found to be similar to 5%replacement except that at the age of 7 days, the strength was higher than the control for all RHA mixtures. 20 % replacement is avoided as it would lead to inc. in water demand and super plasticizer content exceeds the permissible value.

Table 2.4 Strength development of RHA concrete (Habeeb et al., 2010)

Mixture	RHA content (%)	Compressive strength (Mpa)			
		1day	3day	7day	28day
CM	0	19.1	26.7	30.2	39.6
05F1	5	17.9	25.3	30.0	40.2
10F1	10	19.4	28.1	34.3	48.4
15F1	15	18.2	25.1	31.3	42.4
20F1	20	17.3	24.5	29.8	40.6
05F2	5	17.2	26.3	29.8	40.7
10F2	10	20.3	28.2	35.0	50.2
15F2	15	18.0	25.2	30.8	42.9
20F2	20	17.8	24.5	30.5	41.0
05F3	5	18.3	25.4	31.1	42.2
10F3	10	19.9	29.6	36.7	51.8
15F3	15	19.3	26.1	32.7	44.4
20F3	20	18.1	25.2	32.1	41.7

- **Relation between strength and RHA level of replacement**

(a) RHAF1

(b) RHAF2

(c) RHAF3 (Habeeb et al., 2010)

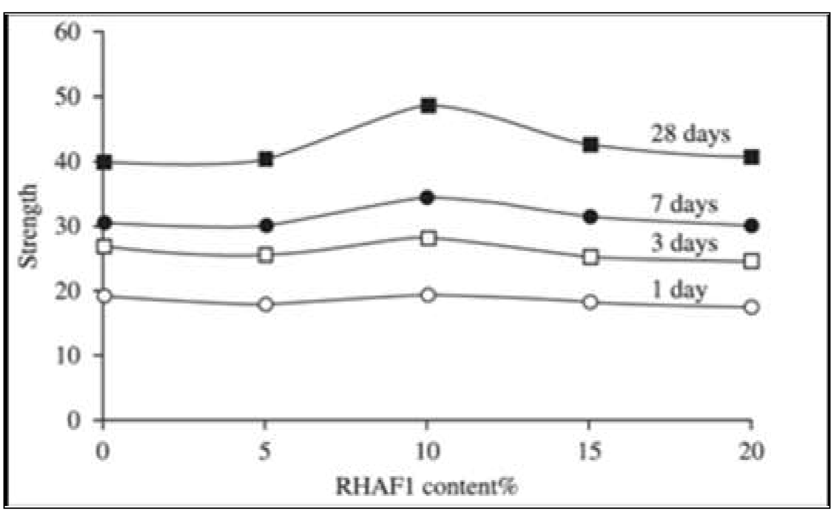


Fig.2.2 Relation between strength and RHA level of replacement (a) RHAF1

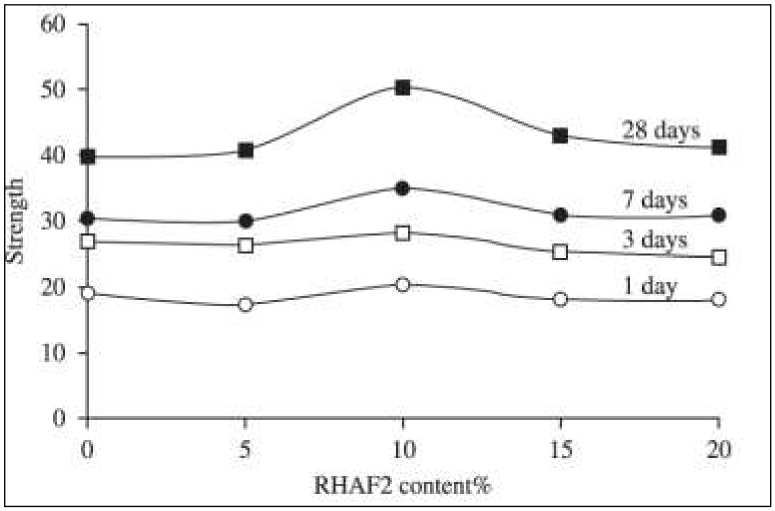


Fig.2.3 Relation between strength and RHA level of replacement (b) RHAF2

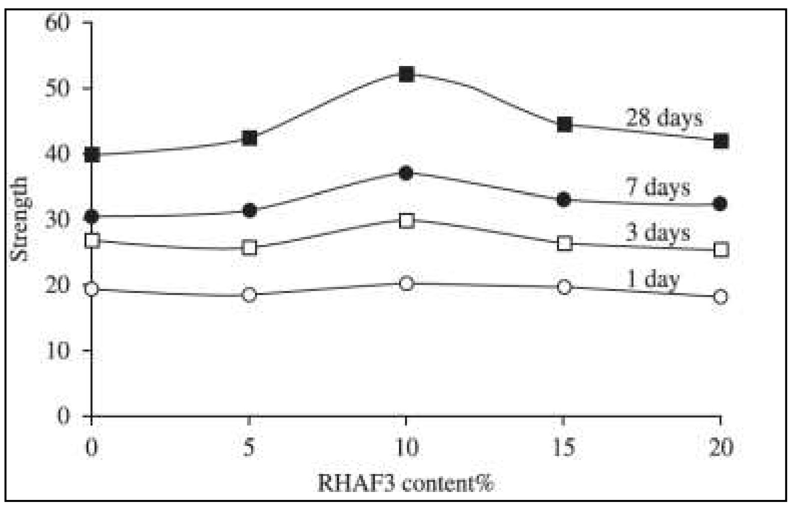


Fig.2.4 Relation between strength and RHA level of replacement (c) RHAF3

2.3 SPLITTING TENSILE STRENGTH

- **Khani et al. (2010) studies** the splitting tensile strength of concrete by partial replacement of cement with agro-waste rice husk ash.

Specifications – A total of 4 concrete mixtures were made – one corresponding to a control concrete (CTL) and three others with 7%, 10% and 15% RHA replaced with cement by weight.(Table 2.5) Slumps were kept constant at 70 ± 10 mm. Cylinders for testing were casted of size 150 X 300 mm.

Table 2.5 Mixture proportion of RHA-blended concretes.

(Khani et al., 2010)

	RHA (kg/m^3)	cement (kg/m^3)	Aggregate (kg/m^3)		water (kg/m^3)
			fine	coarse	
CTL	0	420	815	995	189
7%RHA	29.4	390.6	815	995	189
10%RHA	42	378	815	995	189
15%RHA	63	357	815	995	189

OBSERVATIONS

- Concrete containing RHA has a greater splitting tensile strength than that the control concrete at all ages. As the amount of RHA increases, the tensile strength increases up to 20%. At 90 days the 15%RHA concrete had a tensile strength of 5.62 MPa compared with 4.58 MPa for the control concrete.

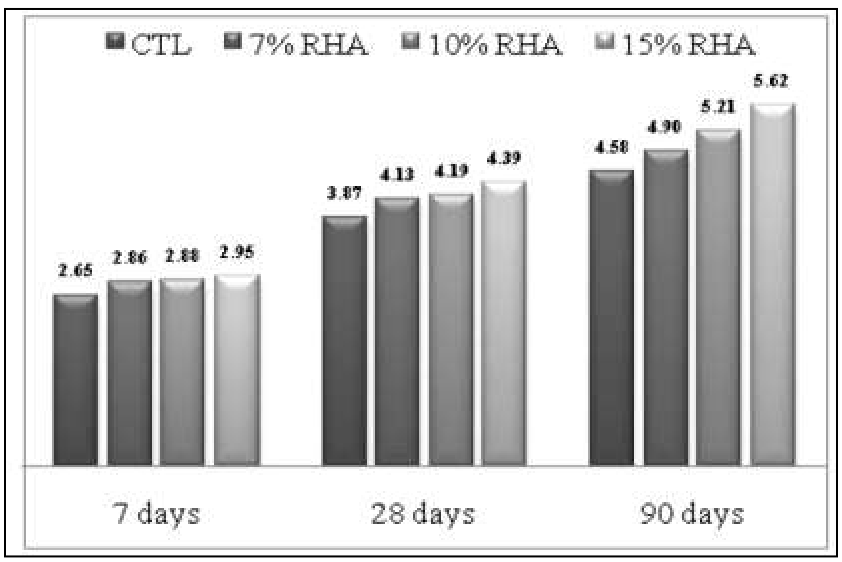


Fig.2.5 Tensile strength (MPa) at various ages for control (CTL) & RHA mixtures . (Khani et al., 2009)

- **Uduweriya et al. (2010**) investigated the results of splitting tensile strength of three different replacement percentages of RHA in concrete (10%, 20% and 30% by mass of cement) were compared with the concrete that does not contain RHA. **(Table 2.6)**

Specifications – Concrete cylinders of 150 mm diameter and 300 mm height were casted . Concrete with W/C ratio of 0.75 is used.The average particle size of RHA is 18 μm**.** The fine aggregates that used for the experiment were natural river sand. The coarse aggregate that used for the experiment were crushed granite with maximum size of 20 mm.

Table 2.6 Results of Splitting Tensile Strength. (Uduweriya et al., 2010)

SAMPLE NO.	REPLACEMENT (%)	SPLITTING TENSILE STRENGTH (N/mm^2)
1	**0**	**1.86**
2	**10**	**2.60**
3	**20**	**3.01**
4	**30**	**2.56**

OBSERVATIONS

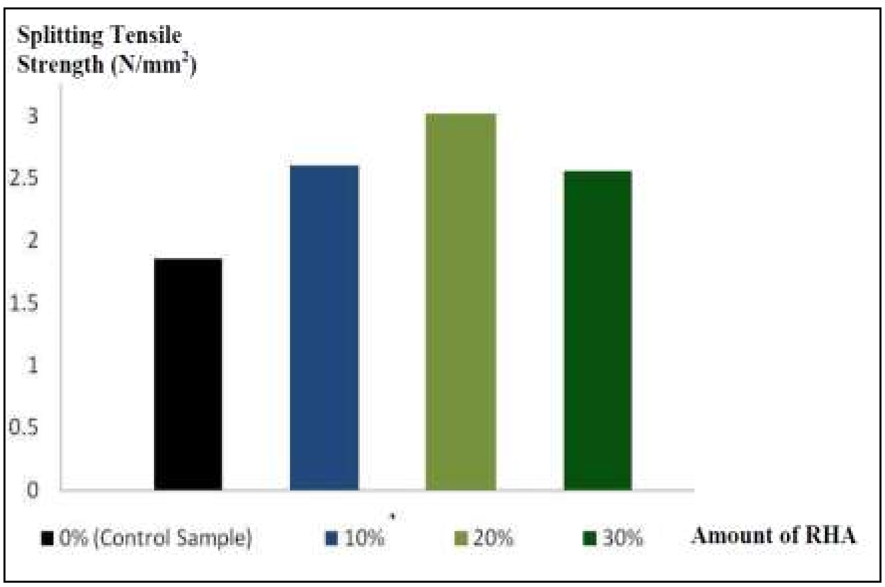


Fig.2.6 Variation of Splitting Tensile Strength. (Uduweriya et al., 2010)

- Fig.2-6 shows there is significant increment in the tensile strength in concrete containing RHA. The maximum tensile strength is resulted with 20% replacement .Therefore tendency of cracking of concrete containing RHA can be considered as low compared to the normal concrete

2.4 WORKABILITY,FRESH DENSITY AND SUPERPLASTICIZER CONTENT

- **Bui et al. (2004**) investigated the workability of concrete and super plasticizer content to be added when cement is replaced by RHA in gap graded concrete.

Specifications – Two kinds of an ordinary Portland cement were employed, i.e. PC30 and PC40.24 concrete mixtures were made, 12 mixtures for each of the two kinds of PC.Three levels of the water to binder ratio were investigated, i.e., 0.30, 0.32 and 0.34.The mixtures with water to binder ratio of 0.30 were made with a binder content of 550kg/m^3 concrete. The binder content of all other mixtures was 500kg/m^3. Rice husk ash was used to replace 10%, 15% and 20% by mass of PC.

Table 2.7 Properties of the cements. (Bui et al., 2004)

No	Properties	Test results	
		PC30	PC40
1	Normal consistency (%)	26	29
2	Setting time (minute)		
	(a) initial	95	85
	(b) final	190	175
3	Volumetric density (g/cm^3)	3.14	3.15
4	Residue on 75μm sieve (%)	10	4
5	Blaine specific surface area (cm^2/g)	2700	3750
6	Compressive strength (MPa)*		
	(a) 3 days	16.2	22.6
	(b) 7 days	27.1	35.6
	(c) 28 days	38.5	47.7

* 40 × 40 × 160mm prisms; cement:sand = 1:3; W/C = 0.5.

Table 2.8 Mixture proportions of gap-graded concrete blended with RHA(kg/m3) (Bui et al., 2004)

W/B	Cement PC30	Cement PC40	RHA[a]	Water	SP[b]	Fine sand (0/0.6)	Crushed basalt (9.5/19)
0.3	550	–	–	165	5.60	550	1283
	495	–	55	165	5.80	546	1273
	468	–	82	165	6.10	543	1267
	440	–	110	165	6.30	540	1261
0.32	500	–	–	160	5.50	567	1324
	450	–	50	160	5.72	562	1313
	425	–	75	160	6.00	560	1307
	400	–	100	160	6.22	558	1301
0.34	500	–	–	170	5.00	560	1305
	450	–	50	170	5.00	555	1294
	425	–	75	170	5.00	553	1290
	400	–	100	170	5.00	551	1285
0.3	–	550	–	165	6.60	550	1283
	–	495	55	165	6.80	546	1273
	–	468	82	165	7.19	543	1267
	–	440	110	165	7.43	540	1261
0.32	–	500	–	160	6.50	567	1324
	–	450	50	160	6.76	562	1313
	–	425	75	160	7.08	560	1307
	–	400	100	160	7.36	558	1301
0.34	–	500	–	170	6.40	560	1305
	–	450	50	170	6.40	555	1294
	–	425	75	170	6.40	553	1290
	–	400	100	170	6.40	551	1285

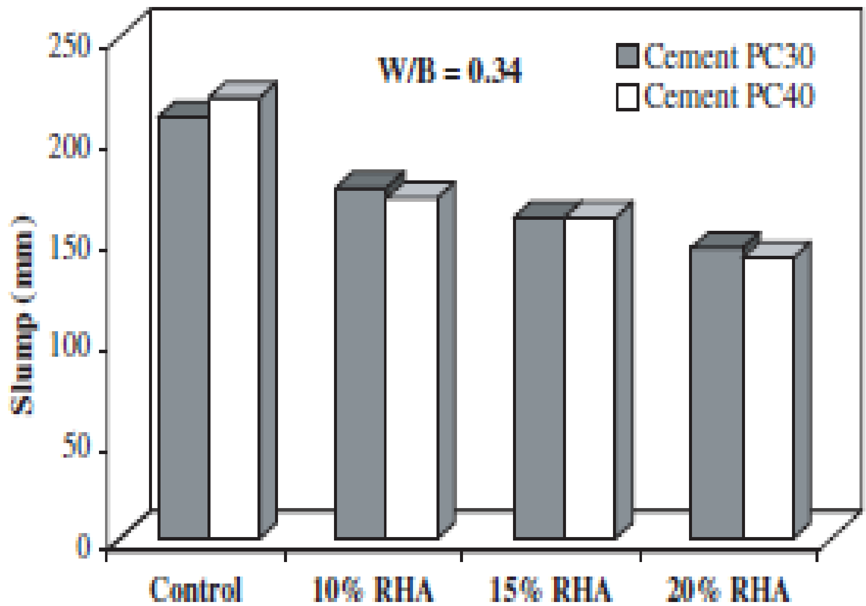


Fig.2.7 Slump variation of gap-graded concretes made with cements of different fineness at constant super plasticizer content. (Bui et al., 2004)

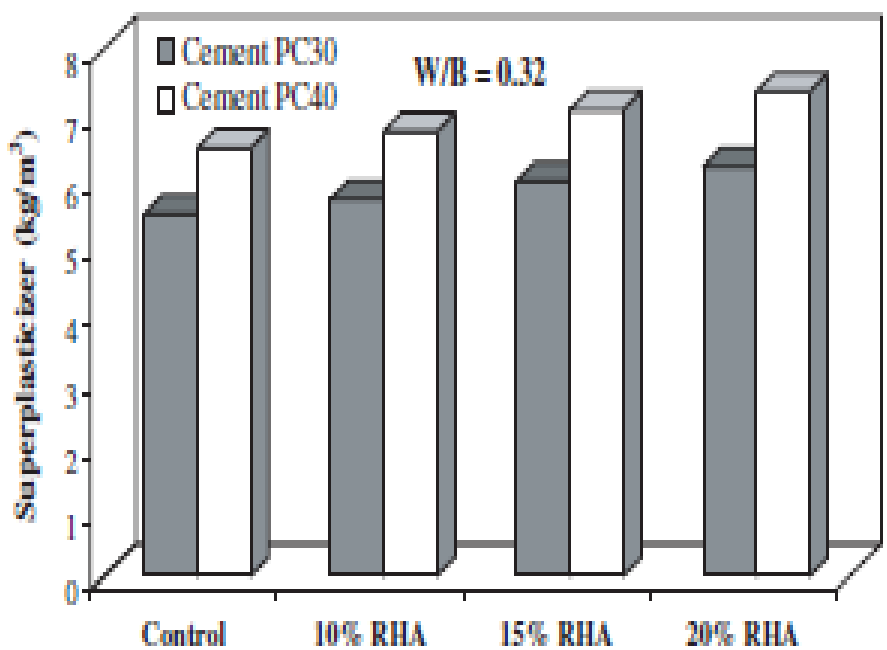


Fig.2.8 Super plasticizer requirement for a constant workability of RHA blended gap- graded concretes made with cements of different fineness. (Bui et al., 2004)

- **Slump (Fig.2.7)**

All the mixtures have high slump values and they all are stable. A reduction in slump of the blended concrete mixtures is found when a part of the PC is replaced by RHA at equal super plasticizer content.This decline in slump increases with replacement level of cement by RHA.

- **Super Plasticizer (Fig.2.8)**

The finer cement (PC40) requires a higher super plasticizer dosage for achieving equal slump.For the plain PC30 concrete, a super plasticizer dosage of 1% by mass of the cement is required to attain a slump of 210mm.In case of the finer cement (PC40), the super plasticizer dosage is increased to 1.28% for obtaining approximately the same slump.

- **Habeeb et al. (2010**) investigates the workability, fresh density and super plasticizer content of rice husk ash (RHA) produced by using a Ferro-cement furnace.

Specifications – The slump was maintained in the range of 200 – 240 mm. The water to binder ratio was kept constant as 0.53. GRINDING TIME FI-180min , F2 –270 min ,F3 - 360 min.

Table 2.9 The average particle size of OPC and RHA (Habeeb et al., 2010)

Material	OPC	RHAF0	RHAF1	RHAF2	RHAF3
Grinding time (minutes)	-	90	180	270	360
Average particle size (µm)	22.1	63.8	31.3	18.3	11.5

Table 2.10 Fresh concrete properties. (Habeeb et al., 2010

MIX	RHA CONTENT (%)	SP CONTENT (%)	SLUMP (mm)	FRESH DENSITY (kg/m^3)	BLEEDING
CM	0	0.63	230	2347	NEGLIGIBLE
05FI	5	1.12	200	2328	-
10F1	10	1.35	210	2293	-
15F1	15	1.60	220	2270	-
20F1	20	1.83	220	2253	-
05F2	5	1.20	215	2335	NEGLIGIBLE
10F2	10	1.48	220	2301	-
15F2	15	1.70	220	2284	-
20F2	20	1.90	215	2270	-
05F3	5	1.20	205	2351	-
10F3	10	1.60	230	2312	-
15F3	15	1.78	210	2305	-
20F3	20	2.00	210	2294	-

- SP content has to be increased along with the RHA fineness and content due to the high specific surface area of RHA which would increase the water demand, therefore, to maintain high workability, SP content rose up to 2% for the 20F3 mixture. **Fig.2.9**

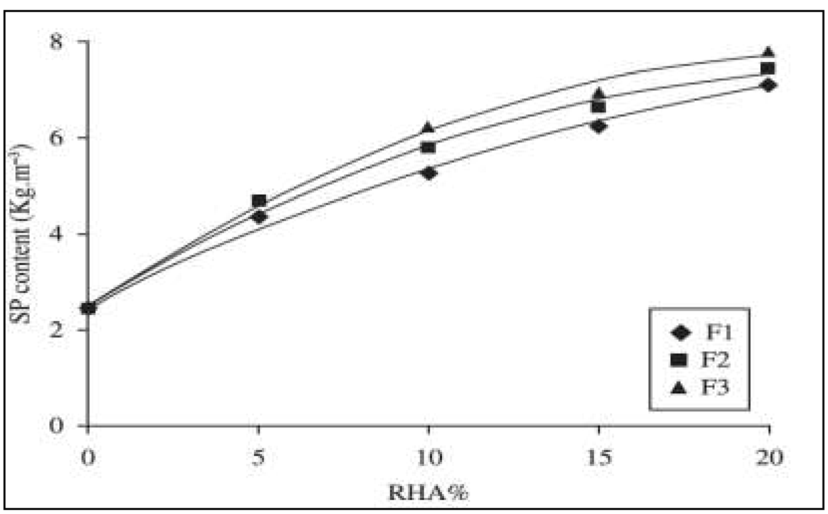


Fig.2.9 The effect of RHA percentage and APS on the SP content.
(Habeeb et al., 2010)

2.5 FLEXURAL STRENGTH

Khan et al. (2012) studied the flexural strength of RHAC.(Fig.2.11) Test was carried out on RHAC concrete beams containing 0%, 25%, 30% and 40% of RHA as a replacement of OPC All the concrete beams were cast in 1:2:4 mixture design ratio of Cement: sand: coarse aggregate, respectively.

Curves in Fig. 2.10 shows :The load taken by pure OPC concrete beams was greater than the RHAC concrete beams both at first crack development and failure.The deflection at mid span decreased with the increase of RHA content in RHAC concrete beams both at first crack development and at failure. For 25% RHAC concrete beam the mid span deflection at failure load is 32 mm as compared to 38 mm for OPC concrete beam. For 25% OPC replacement with RHA, the beam performed very well in flexure.The failure load for 25% RHAC is 51 KN which is quite close to 54 KN for OPC concrete beam.

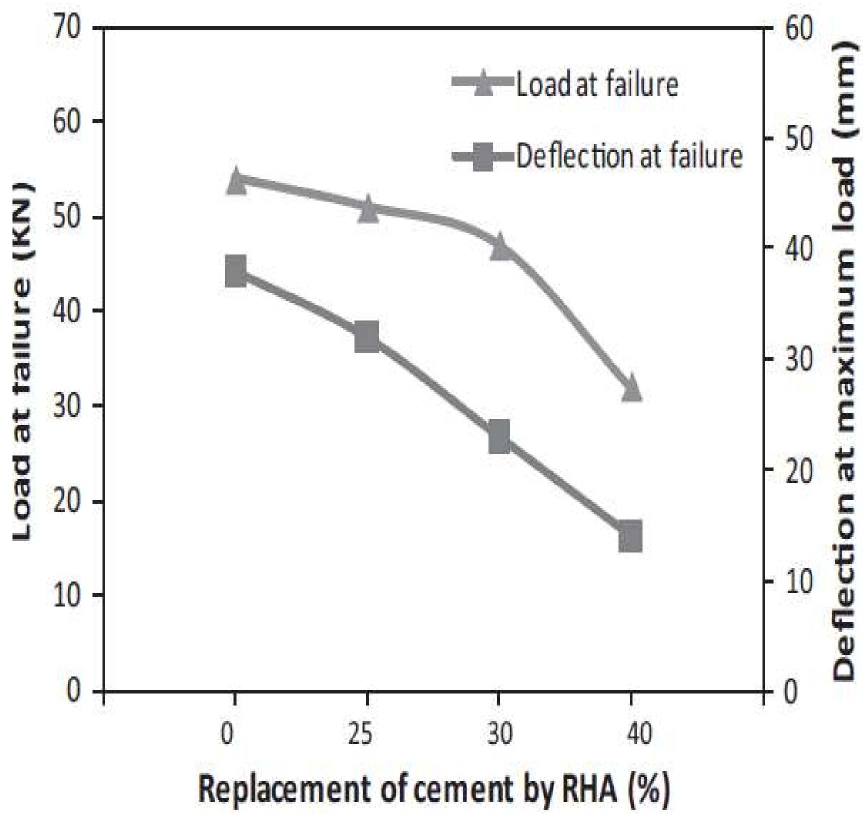


Fig.2.10 Flexural strength of RHAC containing different proportions of RHA.

2.6 STEEL FIBRE REINFORCED CONCRETE

Steel fibre reinforced concrete (SRFC) is concrete dispersed steel fibres. The most important regulation of steel fibre in concrete is to control and retard the tensile cracking of the composite material. The steel fibre reinforced concrete improves the strength characteristics like flexural strength, flexural toughness, strain capacity, split tensile strength, compressive strength and crack arrest properties which lead to use in highway and airfield pavements, overlays and bridge deck slabs.

Wang, et al. (1996), investigated the fibre reinforced concrete beams under impact loading. Impact tests were carried out on small concrete beams reinforced with different volumes of both polypropylene and steel fibres. The drop height of the instrumented drop weight impact machine was so chosen that some specimens failed completely under a single drop of the hammer, while others required two blows to bring about complete failure. It was found that, at volume fractions less than 0.5% polypropylene fibres gave only a modest increase in fracture energy. Steel fibres could bring about much greater increase in fracture energy was also modest; above 0.75% fibre pull-out was the primary mechanism with a large increase in fracture energy.

Furlan and Bento (1997), analyzed the influence of fibre on the structural performance in situations of different ratios of shear reinforcement, some aspects of the properties of fresh and hardened concrete are introduced. The main alterations resulting from the use of fibres were increased shear strength, stiffness (particularly after cracking stage) and ductility. Other parameters used in analyzing performance were the properties of the hardened concrete (compressive strength, tensile strength, and modulus of elasticity), and stresses in the stirrups, in the longitudinal reinforcement and in the concrete (at the web and compression zone).

Chunxiang and Patnaikuni (1998), studied on the properties of high-strength steel fibre-reinforced concrete beams in bending. They investigated that the flexural rigidity before yield stage and the displacement at 80% ultimate load in the descending curve are improved and crack number and length at comparable loads is reduced after the addition of steel fibres. The descending part of the load-displacement curve of the concrete beams without steel fibres is much steeper than that with steel fibres, which shows that the addition of steel fibres makes the high strength concrete beams more ductile. The research results of ten high-strength reinforced concrete beams and steel fibre-reinforced high strength concrete beams, with steel fibre content of 1% by volume. The enlarged ends of mild carbon steel fibres with three different dimensions were selected.

Nataraja et al. (1999), carried out the investigation on stress-strain curve for steel fibre reinforced concrete under compression. The complete stress-strain curve of the material in compressions is needed for the analysis and design of structures. In this experimental investigation, an attempt has been made to generate the complete stress-strain curve experimentally for steel-fibre reinforced concrete for compressive strength ranging from 30 to 50 MPa. Round crimped fibres with three volume fractions of 0.5%, 0.75% and 1.0% (39, 59, and 78 kg/m3) and for two aspect ratios of 5 and 82 are considered. The effect of fibre addition to concrete on some of the major parameters namely peak stress, strain at peak stress, the toughness of concrete and the nature of the stress-strain at peak stress, the toughness of concrete and the nature of the stress-strain curve is studied. A simple analytical model is proposed to generate both the ascending and descending portions of the stress-strain curve. There exists a good correlation between the experimental results and those calculated based on the analytical mode. Equations are also proposed to quantify the effect of fibre on compressive strength, strain at peak stress and the toughness of concrete in terms of fibre reinforcing parameter.

Elsaigh et al. (2005) carried out investigation on steel fibre reinforced concrete for road pavement applications. In this paper, they established that the use of SFRC for road pavements and compare its execution with plain concrete under traffic loading. The determining of SFRC properties on performance and design aspects of concrete roads are discussed. Results coming out from road trial sections, tested under in-service traffic, are used to validate the use of the material in roads.

Wegian **et al. (2011)**, studied on the influences of fly ash on behaviour of fibre reinforced concrete structures. The aim of this study was to measure the tensile and compressive strength of concrete with different steel fibre and fly ash percentage. Concrete specimens with different fibre contents like 0.5%, 1% and 1.5% by volume were tested. Fly ash contents in mixes ranged b/w 0 and 30% by weight. Sixteen concrete mixes were prepared. The result of this study confirmed that the addition of steel fibre has a negligible effect on the compressive strength of concrete but it improves the flexural strength.

***Neophytou* et al. (2011)**, studied on the proportioning of steel fibre reinforced concrete mixes for pavement construction and their impact on environment and cost. The innovative concept of the project is the use of recycled steel tyre-cord wire as concrete fibre reinforcement, which provides additional environmental benefits for tyre recycling over land filling. Within the project framework a demonstration of a steel-fibre reinforced roller-compacted concrete (SFR-RCC) pavement was constructed in a rural area in Cyprus. In order to assess the economical and environmental picture of the demonstration pavement, life cycle cost analysis (LCCA) and life cycle assessment (LCA) studies were undertaken, which also compared the under study pavement design with four conventional alternatives. The main output of the studies is that SFR-RCC is more environmentally and economically sustainable than others.

The proposed SFR-RCC pavement design is well sustainable alternative to SFRC for use in road construction industry both in economical and environmental terms. Given available design methodology, existing laying and material production equipment, SFR-RCC pavement may be the ideal new approach in road construction.

However, further work can be done towards a more environmental and economical pavement design. Most importantly, the life cycle studies showed that the steel fibre type and dosage can greatly influence the environmental (emissions and energy consumption) and economical indicators of concrete pavement layer. This is because the pavement layer depth, required to support the traffic load, is affected by the mechanical properties of SFRC which in turn are influenced by fibre type and dosage. On the other hand, recycled concrete aggregate may replace natural aggregates used in concrete mix, achieving only a small reduction in air emissions. But, it is more environmentally sustainable to recycle wastes than to extract natural resources.

Soulioti (2011), carried out investigation on effect of fibre geometry and volume fraction on the flexural behaviour of steel fibre reinforced concrete. In this paper the effect of fibre geometry and fibre volume fraction has been investigated for steel fibre reinforced concretes. Specifically the compression strength, the flexural strength and toughness were studied as a function of the above parameters and compared to unreinforced concrete. The effect of the fibre inclusion on the slump and air content properties of fresh concrete has been also evaluated.

The test results led to the conclusion that the fibres play an important role, not only in the fresh state of the concrete, but also in the mechanical properties of hardened concrete specimens. Concerning fresh concrete, the addition of steel fibres in the concrete mixture reduced the slump in the range of 65-90 mm, compared to plain concrete.
The air content increased with the raising of fibre volume fraction. Mixtures with high fibre volume fraction (1 and 1.5% by concrete volume) presented higher air content than mixtures with smaller fibre volume fraction (0.5% by concrete volume).

Plain concrete specimens failed catastrophically by a single crack, and separation into two pieces. On the contrary, the fibre-reinforced concrete specimens, even those with small fibre volume fraction (0.5%), retained post-cracking ability to carry out loads.

Vardhan et al. (2012), carried out laboratory investigation on the influence of steel fibre on concrete at a dosage of 0.8% volume of concrete. Experimental investigation was done using M20 mix and tests were carried out as per recommended procedures by relevant codes. The study parameters of this investigation included compressive strength, split tensile strength and flexural strength of conventional and fibre reinforced concrete. The results indicated that the compressive, split tensile and flexural strength of fibre reinforced concrete is increased by 32.14%, 52.38%, 12.68% respectively when compared to the conventional concrete.

Patel et al. (2012), investigated that the shear strength of Steel Fibre Reinforced Concrete (SFRC) moderate deep beams without stirrups having span to depth ratio 2.0, 2.4, 3.0, 4.0. The 12 numbers of beams were tested. 12 numbers of beams were tested to failure under two point symmetrical loading. A complete shear deformational behaviour along with load-deflection response, crack patterns and modes of failure is studied experimentally. Shear strength is evaluated using empirical equations proposed here in this work for estimation of ultimate shear strength of moderate deep beams without stirrups. Experimental results of ultimate shear strength are compared with theoretical results calculated from proposed equation proposed. The comparison shows that eh equation proposed here provides the most accurate estimates of shear strength. In addition to concrete strength, the influence of other variation such as fibre factor, span to depth ratio, longitudinal steel ratio and size effect is considered.

Khan et al. (2013)**,** performed on steel fibres to increase the load carrying capacity of concrete members. Fibres substantially reduce the brittleness of concrete and improve its engineering properties, such as tensile, flexural, impact resistance, fatigue, load bearing capacity after cracking and toughness. It shows a review of research performed on Steel Fibre reinforced concrete. The performance of the Steel Fibre Reinforced Concrete (SFRC) has shown a significant improvement in flexural strength and overall toughness compared against Conventional Reinforced Concrete.

2.7 GAP FINDINGS

The combined effect of the steel fibres and Rice husk Ash had never been studied for the compressive and flexural strength characteristics of the Pavement Quality Concrete. In this study the cement has been replaced with Rice husk Ash from 0% to 20% and steel fibres have been added as 0.5% to 1.5%.

CHAPTER-3

MATERIALS AND DESIGN METHODOLOGY

3.1 GENERAL

The present chapter deals with the presentation of results obtained from various tests conducted on material used for developing concrete. In order to achieve the objectives of present study, an experimental program was planned to investigate the effect of Rice husk Ash, steel fibre and super plasticized on compressive strength and flexure strength of concrete.

3.2 MATERIAL USED

The properties of material used for making concrete mix are determined in laboratory as per relevant code of practice. Different materials used in present study were cement, coarse aggregates, fine aggregates, and super-plasticizer, in addition to Rice husk Ash and steel fibres. The aim of studying of various properties of material is used to check the appearance with codal requirements and to enable an engineer to design a concrete mix for a particular strength. The description of various materials which were used in this study is given below:

3.2.1 Portland Cement

Although all materials that go into concrete mix are essential, cement is very often the most important because it is usually the delicate link in the chain. The function of cement is first of all to bind the sand and stone together and second to fill up the voids in between sand and stone particles to form a compact mass. It constitutes only about 20 percent of the volume of concrete mix; it is the active portion of binding medium and is the volume of concrete mix; it is the active portion of binding medium and is the only scientifically controlled ingredient of concrete. Any variation in its quantity affects the compressive strength of the concrete mix. Portland cement referred as (Ordinary Portland Cement) is the most important type of cement and is a fine powder produced by grinding Portland cement clinker. The OPC is classified into three grades, namely 33 Grade, 43 Grade, 53 Grade depending upon the strength of 28 days. It has been possible to upgrade the qualities of cement by using high quality limestone, modern equipments, maintaining better particle size distribution, finer grinding and better packing. Generally use of high grade cement offers many advantages for making stronger concrete. Although they are little than low grade cement, they offer 10-20% saving in cement consumption and also they offer many hidden benefits. One of the most important benefits is the faster rate of development of strength.

Ordinary Portland Cement (OPC) of 43 Grade (JK-Lakshmi cement) from a single lot was used throughout the course of the investigation. It was fresh and without any lumps. The physical properties of the cement as determined from various tests conforming to Indian Standards IS: 8112:1989 are listed in Table 3.1. Cement was carefully stored to prevent deterioration in its properties due to contact with the moisture.

Table 3.1 Properties of OPC 43 Grade Concrete

Sr. No.	Characteristics	Values Obtained Experimentally	Values Specified By IS 8112:1989
1	Specific Gravity	3.15	-
2	Standard Consistency, percent	28	-
3	Initial Setting Time, minutes	148	30(Min.)
4	Final Setting Time, minutes	259	600(Max.)
5	Compressive Strength 7 days 28 days	 37.4 N/mm 48.5 N/mm	 33N/mm² (minimum) 43N/mm² (minimum)

3.2.2 Aggregate

Aggregates constitute the bulk of a concrete mixture and give dimensional stability to concrete. To increase the density of resulting mix, the aggregates are frequently used on two or more sizes. The most important function of the fine aggregate is to assist in producing workability and uniformity in mixture. The fine aggregate assist the cement paste to hold the coarse aggregate particles in suspension. This action promotes plasticity in the mixture and prevents the possible segregation of paste and coarse aggregate, particularly when it is necessary to transport the concrete some distance from the mixing plant to placement. The aggregates provide about 75% of the body of the concrete and hence its influence is extremely important. They should therefore meet certain requirements if the concrete is to be workable, strong, durable and economical. The aggregates must be proper shape, clean, hard, strong and well graded.

a) Coarse Aggregates

The aggregate which is retained over IS Sieve 4.75 mm is termed as coarse aggregate. The coarse aggregates may be of following types:-

i) Crushed graves or stone obtained by crushing of gravel or hard stone.

ii) Uncrushed gravel or stone resulting from the natural disintegration of rocks.

iii) Partially crushed gravel or stone obtained as product of blending of above two types.

The normal maximum size is gradually 10-20 mm; however particle sizes up to 40 mm. Gap graded aggregates are frequently better than those continuously graded, which might expensive grader internal friction and give reduced flow. Regarding the characteristics of different types of aggregate, crushed aggregates tend to improve the strength because of interlocking of angular particles, while rounded aggregates improved the flow because of lower internal friction.

Table 3.2 Properties of coarse aggregate

Characteristics	Value
Colour	Grey
Shape	Angular
Maximum Size	20mm
Specific Gravity	2.70
Water Absorption	0.36%

Table 3.3 Sieve Analysis of Coarse Aggregate (20 mm)

Weight of Sample Taken = 3000gm					
Sr. No.	**IS-Sieve (mm)**	**Wt. Retained (gm)**	**%age retained**	**%age passing**	**Cumulative % retained**
1	80	0.00	0.00	100.00	0.00
2	40	0.00	0.00	100.00	0.00
3	20	25.00	0.83	99.17	0.83
4	10	2087.00	69.56	29.61	70.39
5	4.75	869.00	28.97	0.64	99.36
6	Pan	19.00	0.64	0.00	170.58
	Total	3000.00		Sum	170.58+500=670.58
				F.M=	6.71

The coarse aggregate used were a mixture of locally available crushed stone of . The aggregates were washed to remove dirt, dust and then dried to surface dry condition. Specific gravity and other properties of coarse aggregates are given in Table 3.2. The sieve analysis of coarse aggregate was done. Table 3.3

b) ***Fine Aggregates***

The aggregates most of which pass through 4,75 mm IS sieve are termed as fine aggregates. The fine aggregates may be of following types:

i) Natural sand, i.e. the fine aggregate resulting from natural disintegration of rocks.

ii) Crushed stone sand, i.e. the fine aggregate produced by crushing hard stone.

iii) Crushed gravel sand, i.e. the fine aggregate produced by crushing natural gravel.

According to size, the fine aggregate may be described as coarse, medium and fine sands. Depending upon the particle size distribution IS: 383-1970 has divided the fine aggregate into four grading zones (Grade I to IV). The grading zones become progressively finer from grading zone I to grading IV.

In this experimental program, fine aggregate (stone dust) were collected from Jhelum Stone Crusher, Mirthal, Pathankot and conforming to Grade Zone II. It was coarse sand light brown in colour. The sand was sieved through 4.75 mm sieve to remove particles greater than 4.75 mm size. Sieve analysis and physical properties of fine aggregate are tested as per IS: 383-1970 and results are shown in Table 3.4. Specific gravity of fine aggregates were experimentally determined as 2.62. Sieve analysis of fine aggregates was performed to get Fineness Modulus.

Table 3.4 Sieve Analysis of Fine Aggregate

Weight of sample taken = 1000 gm					
Sr. No.	**IS-Sieve (mm)**	**Wt. Retained (gm)**	**%age retained**	**%age passing**	**Cumulative % retained**
1	4.75	6.00	0.6	99.40	0.6
2	2.36	85.00	8.50	90.90	9.10
3	1.18	138.00	13.80	77.10	22.90
4	600µ	233.00	23.30	53.80	46.20
5	300µ	392.00	39.20	14.60	85.40
6	150µ	128.00	12.80	1.80	98.2
7	Pan	18.00	1.8	0.00	
	Total	1000.00		Sum	262.4
				F.M=	2.62

c) ***Rice Husk Ash***

Rice husk ash used was obtained from M/S GOLDEN FOODS PRODUCTS (Perboiled rice unit) located in Vill.Dulladi,Nabha. The Specific gravity of rice husk ash is 2.04 . Chemical oxide composition of rice husk ash were given in Table 3.5. Rice husk ash was sieved from150 micron and different proportions i.e. 10%, 15%, 20% used for further study.

Table 3.5 Chemical composition of Rice husk ash (%)

Sr. No.	Parameters	Results
1	LOI	2.54
2	SiO_2	89.34
3	$Al2O_3$	0.29
4	Fe_2O_3	0.26
5	CaO	3.93
6	MgO	0.61
7	$Na_2 O$	0.05
8	K_2O	0.19

d) ***Steel Fibre***

Mild steel fibres having 30 mm length and 0.6 mm thickness i.e. aspect ratio (I/d) 50 which are corrugated and obtained through cutting of steel wires have been used. The fibres have been cut by fibre cutting machine to an accurate size. Three different proportions of fibres i.e. 0%, 0.5%,1% and 1.5% have been used. Properties of steel fibre used are tabulated in Table 3.6.

Table 3.6 Properties of Steel Fibres

Average Thickness	0.6 mm
Length	30 mm
Density	7850 kg/m^3
Tensile Strength	8500 kg/ m^3
Shape	Crimped steel fibre

3.2.3 Super plasticizer

Super-plasticizers constitute a relatively new category and improved version of plasticizer. They are chemically different from normal plasticizers. Use of super-plasticizer permits the reduction of water to the extent up to 30 percent without reducing workability in contrast to possible reduction up to 15 percent in case of plasticizers. The mechanism of action of super-plasticizer is more or less same as in case of ordinary plasticizer. The super-plasticizer are more powerful as dispersing agents and they are high water reducers. It is use of super-plasticizer which has made it possible to use w/c as low as 0.25 or even lower and yet to make flowing concrete to obtain compressive strength of the order of 120 MPa or more. It is the use of super-plasticizer which has made it possible to use fly ash, rice husk ash, slag and particularly silica fume to make high performance concrete.

Super-plasticizers are also often used when pozzolanic ash is added to concrete to improve strength. This method of mix proportioning is especially popular when producing high-strength concrete and fibre reinforced concrete. Adding 1-2% super-plasticizer per unit weight of cement is usually sufficient. However, note that most commercially available super-plasticizers come dissolved in water, so the extra water added has to be accounted for in mix proportioning. Adding an excessive amount of super-plasticizer will result in excessive segregation of concrete and is not advisable. Some studies also show that too much super-plasticizer will result in a retarding effect.

Super-plasticizers are chemical admixtures that can be added to concrete mixtures to improve workability. Unless the mix is "straved" of water, the strength of concrete is inversely proportional to amount of water added or water-cement (w/c) ratio. In order to produce stronger concrete, less water is added which makes the concrete mixture very unworkable and difficult to mix, necessitating the use of plasticizers, water reducers, super-plasticizer or dispersants.

The super-plasticizer "MasterRheobuild 1126ND" procured from **BASF India Limited Construction Chemicals Division,Plot No.37, Chandivali Farm Road, Chandivali, Andheri(East)Mumbai – 400072 India** was used in present study. The technical data provided by manufacturer is given in Table 3.7

Table 3.7 Properties of Super-plasticizer

Sr. No.	Characteristics	Value
1.	Appearance	Dark brown free flowing liquid
2.	Chloride content	< 0.2%
3.	Relative Density :	1.24 ± 0.02 at 25°C
4.	pH :	> 6

The dosage of super-plasticizer recommended is 0.6% to 2% by weight of cementitous material 2 % super-plasticizer by weight of cementitous material was selected in this study to get the medium range of workability.

3.2.4 Water

The potable water is generally considered satisfactory for mixing and curing of concrete. Accordingly potable water was used for making concrete available in Material Testing laboratory. This was free from any detrimental contaminants and was good potable quality.

3.3 MIX DESIGN OF PAVEMENT QUALITY CONCRETE (PQC)

Step 1 As per clause **602** of MORTH Specification

- Cement – 43 grade OPC as per **IS 8112** as per **602.2.2**
- Coarse aggregate – 20 mm as per **602.2.4**

  Loss angles Abrasion value not greater than 35%

  Impact value not greater than 30%
- Fine aggregate – Natural sand as per **IS 383**
- Admixture – BASF AEA (if required)

  Air entrained concrete 5% maximum (optional)

Step 2 Design Parameter:

1. Flexural strength required at 28 days = 4.5 N/mm^2 as per MORTH
2. Maximum water cement ratio = 0.40 as per clause **602.3.3.1**
3. Maximum size of coarse aggregate = 20 mm
4. Degree of quality control = Good
5. Minimum cement content = 350 kg/ m^3 as per clause **602.3.2**
6. Maximum cement content = 450 kg/m^3 as per clause **602.3.2**

Step 3 Calculation of fine aggregate content :

After determining the weight per cubic meter of cement, water, coarse aggregate and percentage of air content, the fine aggregate is calculated so as to produce one cubic meter of concrete using absolute volume method. On converting the weight per cubic meter into volume, we have ...

(a) Volume of cement = $\dfrac{\text{Weight of cement}}{\text{Specific gravity of cement X 1000}}$

(b) Volume of coarse aggregate = $\dfrac{\text{Weight of coarse aggregate}}{\text{Specific gravity of coarse aggregate X 1000}}$

(c) Volume of water = $\dfrac{\text{Weight of water}}{1000}$

(d) Volume of fine aggregate = 1 – {Volume of cement + coarse aggregate + water + Air Content}

(e) Weight of fine aggregate = volume of fine aggregate X specific gravity X 1000

Now by following the above steps for mix design, the mix proportion for different compressive strength are given by using following data:

Specific gravity of fine cement = 3.15

Specific gravity of fine aggregate = 2.71

Specific gravity of coarse aggregate, 20 mm = 2.70

Slump value = 50 to 70

The proportions for PQC mixtures are tabulated in Table 3.9

Table 3.8 Mix Design Concrete (M-40)

Max. Size of aggregate, (mm)	Mix proportions (C:FA:CA)	W/C Ratio	Materials for 1 m^3 in kg				
			Water	Cement	F.A	C.A (20mm)	SP
20	1:2.52:3.22	0.40	140	350	882.68	1127.57	7
The estimated values of steel fibre contents are = 40 kg/m^3 (0.5%) ,80 kg/m^3 (1%) and 120 kg/m^3 (1.5%)							

Step 4 Estimation of fibre content:

The fibre content is taking as 0.5 percent by volume. Therefore

$$0.5\% \text{ by volume} = \frac{0.005 \text{ X Unit Weight of fibre}}{0.995 \text{ X Unit weight of concrete}} \text{ X } 100$$

= % by weight

We have, Unit weight of fibre = 7860 kg/m^3

Unit Weight of concrete = 2300 kg/m^3

$$0.5\% \text{ by volume} = \frac{0.005 \text{ X } 7860}{0.995 \text{ X } 2399} \text{ X } 100 = 1.7173\% \text{ by weight}$$

$$0.5\% \text{ fibre by volume} = \frac{\% \text{ by weight}}{100} \text{ X unit weight of concrete in } kg/m^3$$

$$0.5\% \text{ fibre by volume} = \frac{1.7173 \text{ X } 2300}{100}$$

= 39.4979 kg/m^3 Or 40 kg/m^3 (approx.)

Fibre content = 40 kg/m^3

Table 3.9 Quantity of material in (kg/m^3) for different mixes and varying w/c ratio

Mix ID	W/C	Water (Kg)	Super plasticizer (Kg)	Cement (Kg)	F.A. (Kg)	C.A. (20mm) (Kg)	SF (Kg)	RHA (Kg)
RHA-0%/SF-0%	0.4	140	7	350	882.68	1127.57	0	0
RHA-10%/SF-0%	0.4	140	6.3	315	882.68	1127.57	0	35
RHA-15%/SF-0%	0.4	140	5.355	267.75	882.68	1127.57	0	82.25
RHA-20%/SF-0%	0.4	140	4.284	214.2	882.68	1127.57	0	135.8
RHA10%/SF-0.5%	0.4	140	6.3	315	882.68	1127.57	40	35
RHA-15%/SF-0.5%	0.4	140	5.355	267.75	882.68	1127.57	80	82.25
RHA-20%/SF-0.5%	0.4	140	4.284	214.2	882.68	1127.57	120	135.8
RHA-10%/SF-1.0%	0.4	140	6.3	315	882.68	1127.57	40	35
RHA-15%/SF-1.0%	0.4	140	5.355	267.75	882.68	1127.57	80	82.25
RHA-20%/SF-1.0%	0.4	140	4.284	214.2	882.68	1127.57	120	135.8
RHA-10%/SF-1.5%	0.4	140	6.3	315	882.68	1127.57	40	35
RHA-15%/SF-1.5%	0.4	140	5.355	267.75	882.68	1127.57	80	82.25
RHA-20%/SF-1.5%	0.4	140	4.284	214.2	882.68	1127.57	120	135.8

3.4 CASTING AND CURING OF TEST SPECIMENS IN LABORATORY

The mass of cement, each size of aggregate, and water for each were governed by weight and the concrete were mixed in a laboratory mixer. When the mixing drum is accused by a power loader, all the mixing water should be put into the drum before the solid material. Subsequently, half the coarse aggregates are loaded in the mixer. If admixture is used, it is diluted with some water and spread at the last in the mix when the total elements are loaded in the mixer. The duration of mixing should not be less than 2 minutes after all the materials are in the drum, and had to continue till the resulting concrete of all the appearance. The entire operation as laid down was carefully followed for preparation of all the concrete mixes. Each batch of concrete was cured for consistency immediately after mixing by the slump test as described in IS: 1199:1959. The mould for test specimen conforming to IS: 10086-1982 were used for casting of cubes and beams, as per laid down specifications for mould to be used in tests of cement and concrete. Compression test specimens were cubical sized with dimensions for 15x15x15 cm and for flexural test beams specimens should be of size 15x15x70 cm.

Table vibration was used for compaction of concrete in the mould. The test specimens were stored in a place, free from vibration in moist air of at least 90% relative humidity, and at a temperature of 27°± 2° Celsius for 24 hours. After this period, the specimen were marked and removed from the mould and then stored in clean water until the time of test. The test samples were cured in the curing tank which is available in laboratory. At the time of rest the test samples were tested immediately on removal from water, when they were still in the wet condition. The samples were tested after a curing period of 7 day and 28 day for compressive strength and 7 day and 28 day for flexural strength.

CHAPTER-4
RESULTS AND DISCUSSION

4.1 GENERAL

This chapter deals with the presentation of results obtained from various tested conducted on material used for developing concrete. In order to achieve the objectives of present study, an experimental program was planned to investigate the effect of Rice husk Ash and steel fibre on flexural strength, compressive strength of concrete at 7 & 28 days respectively so as to assess its feasibility on highway pavement. The experimental program consists of casting, curing and testing of controlled and Rice husk Ash concrete specimen at different ages. The details of material and experimental procedure adopted for various tests are shown in Figure 4.1 to 4.5.

The experimental program including the following:

i) Testing of properties of materials used for making concrete.

ii) Design of mixes for high strength concrete and high strength steel fibre reinforced concrete by making trials.

iii) Casting and curing of specimens.

iv) Tests to determine the flexural strength and compressive strength of high strength steel fibre reinforced concrete. ‘

4.2 COMPRESSIVE STRENGTH

4.2.1 General

In most structural applications, concrete is employed primarily to resist compressive stresses. When a plain concrete member is subjected to compression, the failure of the member takes place, in its vertical plane along the diagonal. The vertical crack occurs due to lateral tensile strains. A flow in the concrete, which is in the form of micro crack along the vertical axis of the member will take place on the application of axial compression load and propagate further due to the lateral tensile strains. If the concrete contains steel fibres, the crack propagation gets effectively arrested by the fibres oriented at the right angle to the axis of loading. The lateral tensile strain is resisted by the fibres and hence the compressive strength of the member is increased.

4.2.2 Test Procedure and Results

Test specimens of size 150 X 150 X 150 mm were prepared for testing the compressive strength of high strength steel fibre reinforced concrete. The mix for various percentage of steel fibre and replacement of Rice husk Ash with fine aggregate was done.

Table 4.1 Compressive Strength Test Results

Cube Strength (MPa)		
Type of concrete (M-40)	**7 days**	**28 days**
RHA-0%/SF-0%	27.02	48.26
RHA-10%/SF-0%	26.07	46.81
RHA-15%/SF-0%	23.07	41.43
RHA-20%/SF-0%	20.43	36.68
RHA-10%/SF-0.5%	26.80	48.11
RHA-15%/SF-0.5%	23.71	42.58
RHA-20%/SF-0.5%	20.99	37.69
RHA-10%/SF-1.0%	27.55	49.45
RHA-15%/SF-1.0%	24.37	43.75
RHA-20%/SF-1.0%	21.57	38.73
RHA-10%/SF-1.5%	28.31	50.82
RHA-15%/SF-1.5%	25.05	44.97
RHA-20%/SF-1.5%	22.17	39.80

In this study, the mix was done by manually. The cement and fine aggregate were first mixed dry to uniform colour and then coarse aggregate was added and mixed with the mixture of cement and fine aggregates. Water was then added and the whole mass mixed. In case of HS SFRC the fibres were added just before adding water and mixed dry thoroughly. Same in the case of Rice husk Ash , Rice husk Ash was replaced with fine aggregate with different percentage and added before adding water. The interior surface of the moulds and the base plate were highly oiled before concrete was placed. After this the specimens were removed from the moulds and placed in clean fresh water at a temperature of 27 + 2 C for 28 days curing. For testing in compression, no cushioning material was placed between the specimen and the plates of the machine. The load was applied axially without shock till the specimen was crushed. Test results of compressive strength test at the age of 7 and 28 days are given in the Table 4.1. The cube strength results of concrete mix are also shown graphically.

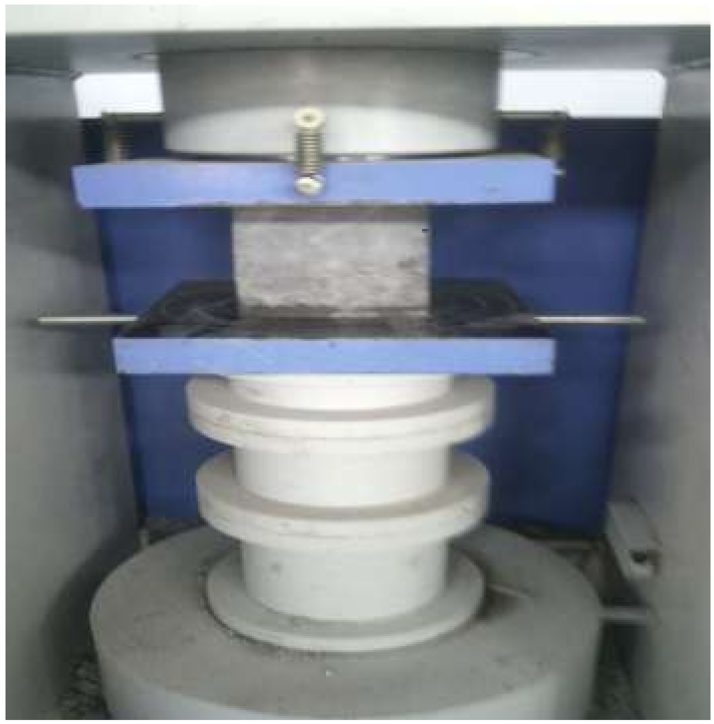


Fig. 4.1 Test for Compressive Strength of Concrete

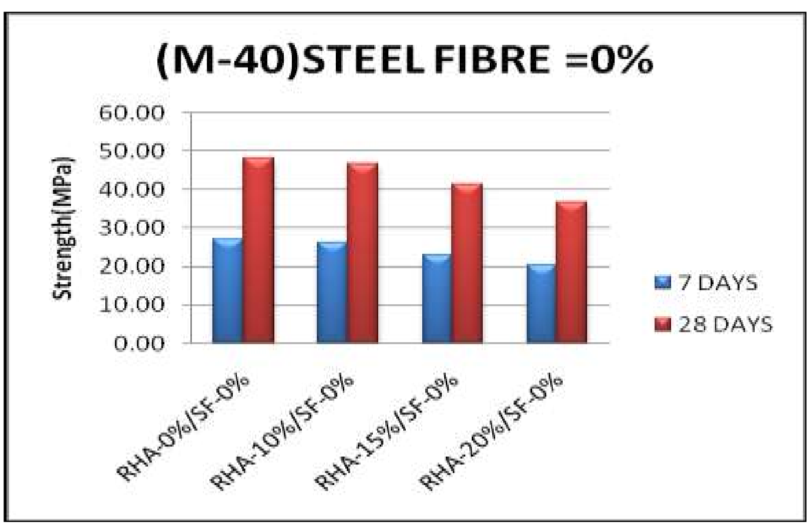


Fig. 4.2 Variation of compressive strength of concrete for 0% S.F and different percentage of RHA

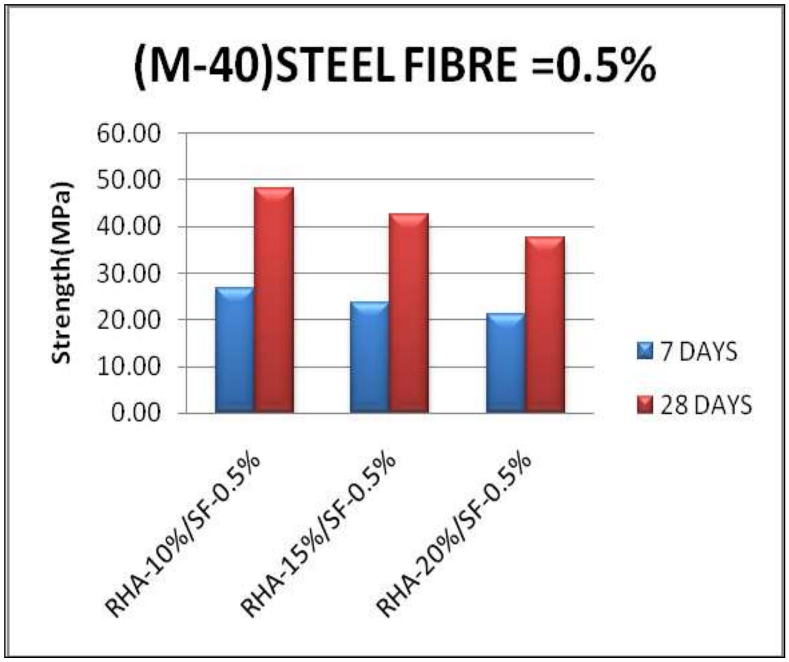


Fig. 4.3 Variation of compressive strength of concrete for 0.5% S.F and different percentage of RHA

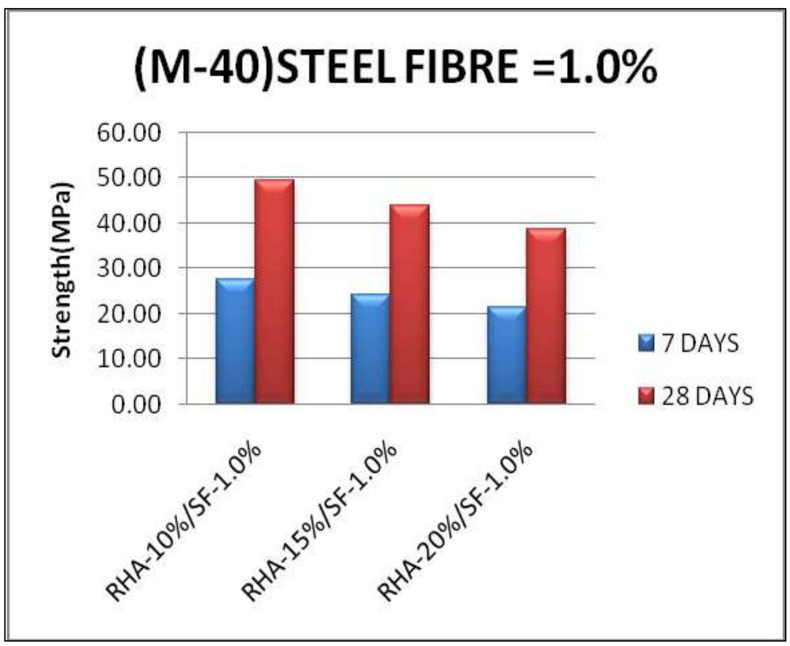


Fig. 4.4 Variation of compressive strength of concrete for 1% S.F and different percentage of RHA

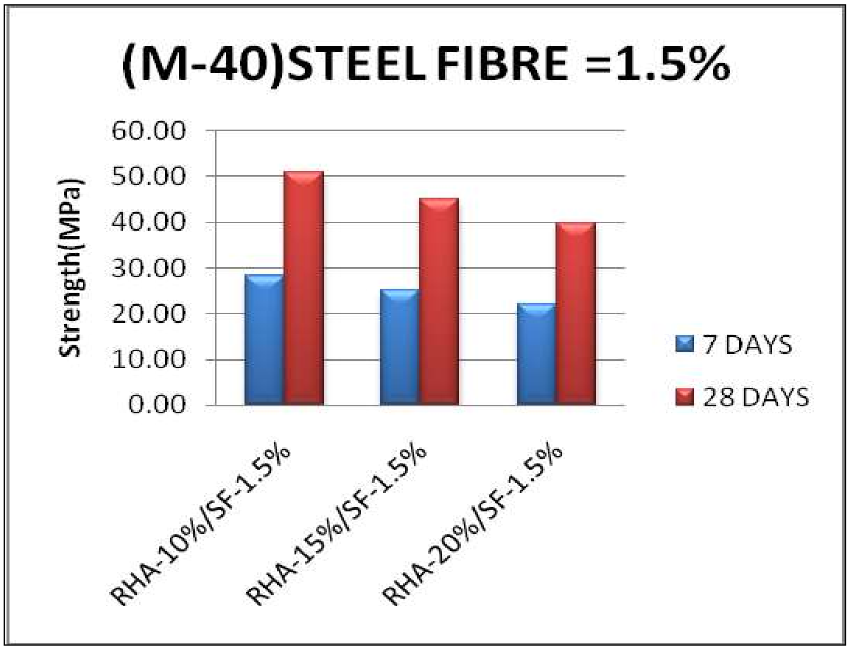


Fig. 4.5 Variation of compressive strength of concrete for 1.5% S.F and different percentage of RHA

Table 4.2 Percentage Variation of Compressive strength at 7days

Compressive strength		
Sample ID	**Percentage decrease in Compressive strength**	**Percentage increase in Compressive strength**
RHA-10%/SF-0%	-3.50	
RHA-15%/SF-0%	-14.60	
RHA-20%/SF-0%	-24.40	
RHA-10%/SF-0.5%	-0.82	
RHA-15%/SF-0.5%	-12.24	
RHA-20%/SF-0.5%	-22.32	
RHA-10%/SF-1.0%		1.95
RHA-15%/SF-1.0%	-9.80	
RHA-20%/SF-1.0%	-20.17	
RHA-10%/SF-1.5%		4.79
RHA-15%/SF-1.5%	-7.30	
RHA-20%/SF-1.5%	-17.97	

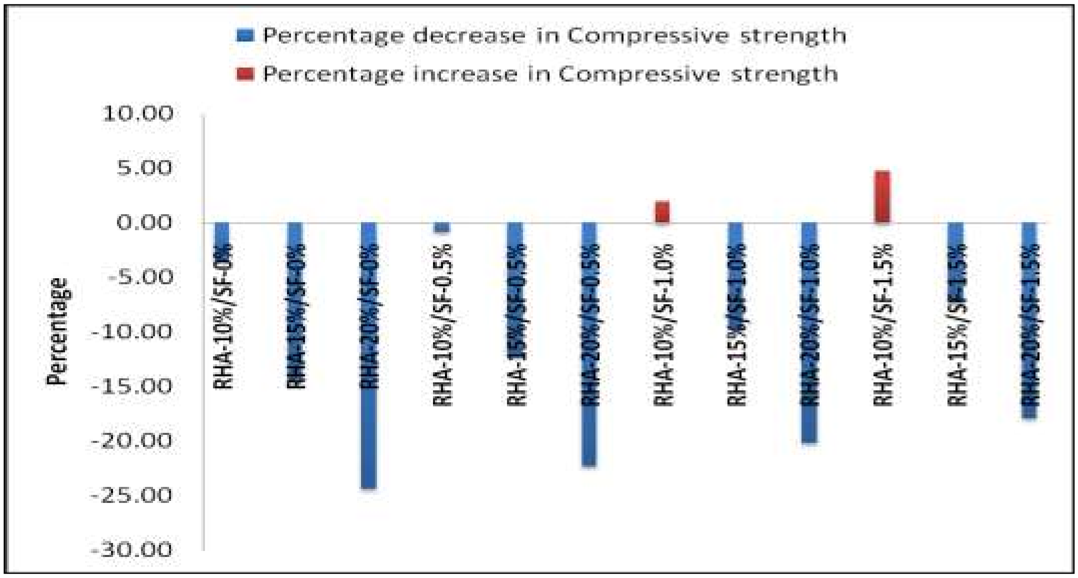


Fig. 4.6 Percentage variation of compressive strength at 7days

Table 4.3 Percentage Variation of Compressive strength at 28days

Percentage Variation of Compressive strength at 28 days		
Compressive strength		
Sample ID	**Percentage decrease in Compressive strength**	**Percentage increase in Compressive strength**
RHA-10%/SF-0%	-3.00	
RHA-15%/SF-0%	-14.14	
RHA-20%/SF-0%	-23.99	
RHA-10%/SF-0.5%	-0.31	
RHA-15%/SF-0.5%	-11.77	
RHA-20%/SF-0.5%	-21.90	
RHA-10%/SF-1.0%		2.46
RHA-15%/SF-1.0%	-9.33	
RHA-20%/SF-1.0%	-19.75	
RHA-10%/SF-1.5%		5.32
RHA-15%/SF-1.5%	-6.82	
RHA-20%/SF-1.5%	-17.53	

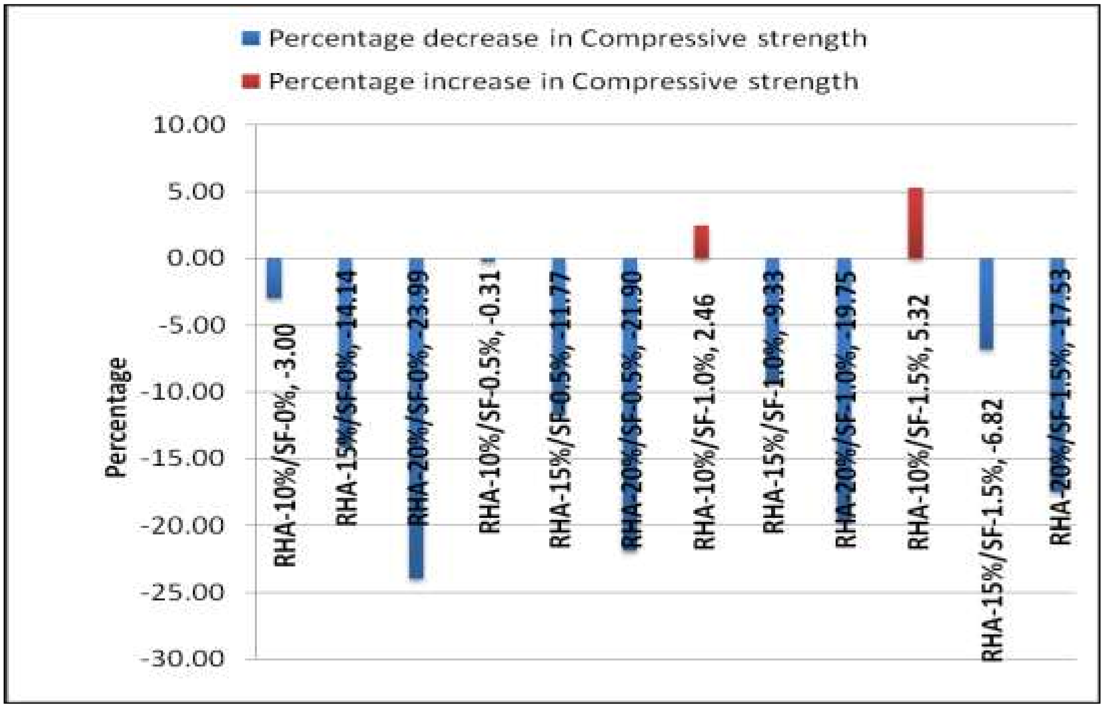


Fig. 4.7 Percentage variation of compressive strength at 28days

4.2.3 Discussion of Results for compressive strength

From the Table 4.2, 4.3 and Figures 4.6, 4.7, shows the variation of compressive strength at different ages, It is observed here that with the increase in percentage of Rice husk Ash (replacing cement) there is marginal decrease in the compressive strength (up to 20% replacement) of the concrete mixes. The maximum strength was obtained at 10% Rice husk Ash in all the replacement mixes and was not more than control mix. The compressive strength decreases with the increases in percentage of rice husk ash (RHA).For 10% replacement, the reduction is very less when compare to 15%, and 20% replacement.

On the other hand, when steel fibre is added in concrete mix there is widely increase in compressive strength as compared to nominal mix(M-40). Maximum compressive strength of pavement quality concrete incorporating Rice husk Ash and steel fibres both is achieved for 10% Rice husk Ash and 1.5% steel fibres. However if the Rice husk Ash content is increased to 20% even with 1.5 steel fibre, the strength increases but less as in 10% & 15% Rice husk Ash and 1.5% steel fibre as well as nominal mix(M-40).

4.2.4 Effect of steel fibre on compressive strength

From the Table 4.1 and Figures 4.2 to 4.6, showing the variation of compressive strength, it is observed that with the increase in percentage of steel fibre the strength increases. This happens because when steel fibres are added to concrete, the propagation of cracks was restrained due to the bonding of fibres into the concrete (ductile failure). Also it is observed that one of the most desirable benefits of adding fibres to concrete is to increase its energy absorbing capability or saying more precisely ductility. Referring to above graph, it is observed that for addition of 1.5% steel fibre and replacement of cement with 10% Rice husk Ash , the compressive strength increases the most when compared to nominal mix.

4.3 FLEXURAL STRENGTH

4.3.1 General

The most common concrete structure subjected to flexure is a highway or airway pavement and strength of concrete for pavements is commonly evaluated by means of bending tests. When concrete is subjected to bending, then tensile and compressive stresses and in many cases direct shear stresses are developed.

When fibre reinforced concrete and composite beams are loaded in pure bending, then the tensile strains develop. The load at first crack would increase with respect to high strength concrete due to crack arresting mechanism of the closely spaced fibres. After the concrete matrix cracks, the fibres continue to take higher load which is provided. Thus the ultimate flexural strength is increased.

4.3.2 Test Procedure and Results

Test specimens of beam size 150 mm X 150 mm 700 mm were prepared for testing the flexural strength of high strength steel reinforced concrete and replacement of Rice husk Ash with cement with different percentage.

The beam moulds containing the test specimens were placed in moist air for at least 90% relative humidity and a temperature of 27+2 C for 24 hours + ½ hour from the time of addition of water to the dry ingredients. After this the specimens were removed from the moulds and placed in clean fresh water at a temperature of 27 degree + 2 degree C for 28 days curing. After 28 days of curing the specimens were tested in flexure on a Universal Testing Machine. Loads were applied at the one third points at a constant rate of 30 kg/ minute. The distance between the centres of two rollers was kept 20 cm.

If the fracture occurred within the central one-third of the beam, the flexural strength was calculated on the basis of ordinary elastic theory using the following equations:

$F_b = \frac{PL}{BD^2}$, when ‘a’ is greater than 20cm for 15cm specimen.

$F_b = \frac{3Pa}{BD^2}$, when ‘a’ is less than 20cm but greater than 17cm for 15cm specimen.

Table 4.4 Flexural Strength Test Results

Flexural Strength (MPa)		
Type of concrete (M-40)	**7 days**	**28 days**
RHA-0%/SF-0%	4.26	5.35
RHA-10%/SF-0%	3.83	4.86
RHA-15%/SF-0%	2.80	4.32
RHA-20%/SF-0%	2.52	3.80
RHA-10%/SF-0.5%	4.02	5.08
RHA-15%/SF-0.5%	2.94	4.41
RHA-20%/SF-0.5%	2.65	3.99
RHA-10%/SF-1.0%	4.22	5.29
RHA-15%/SF-1.0%	3.09	4.52
RHA-20%/SF-1.0%	2.78	4.19
RHA-10%/SF-1.5%	4.43	5.44
RHA-15%/SF-1.5%	3.25	4.63
RHA-20%/SF-1.5%	2.92	4.30

Where,

Fb = Flexural Strength of the specimen in N/mm2

B = Width of the specimen (= 150 mm)

D = Depth of the specimen (= 150 mm)

L = Span of the specimen (=700 mm)

P = Maximum load in Newton (N) applied to the specimen

The point load condition have been used for test procedure in which the two points loading is at 20 cm distance from each other and a point load on the top .Two specimen for each mix were tested. Test results of flexural test at the age of 28 days curing are given in Table 4.4. The flexural strength results of concrete mix are also shown graphically.

Fig. 4.8 Test for Flexural Strength of Concrete

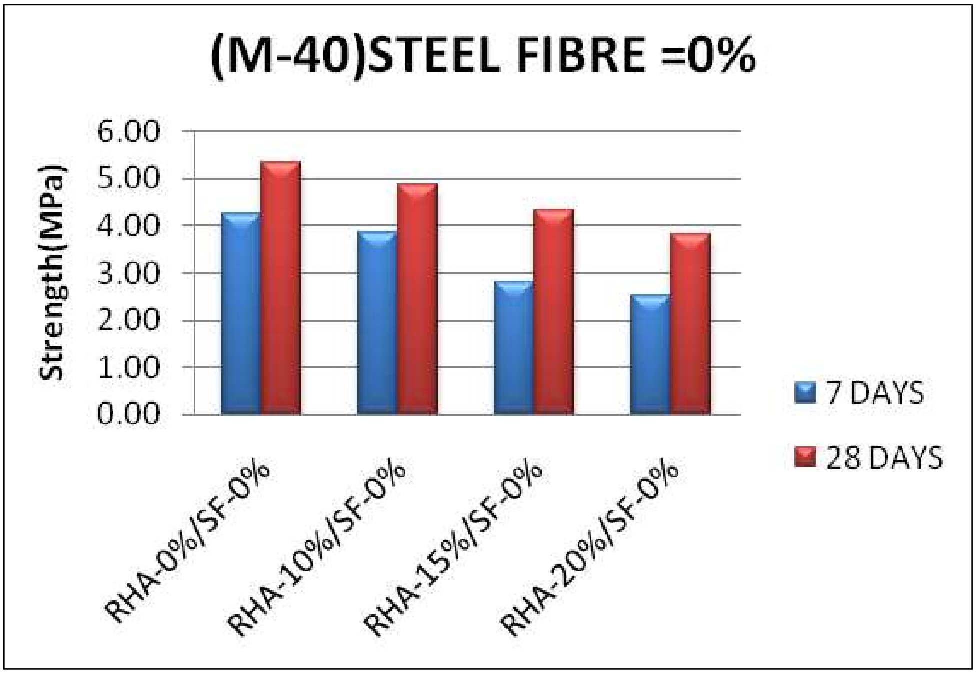


Fig. 4.9 Variation of Flexure strength of concrete for 0% S.F and different percentage of RHA

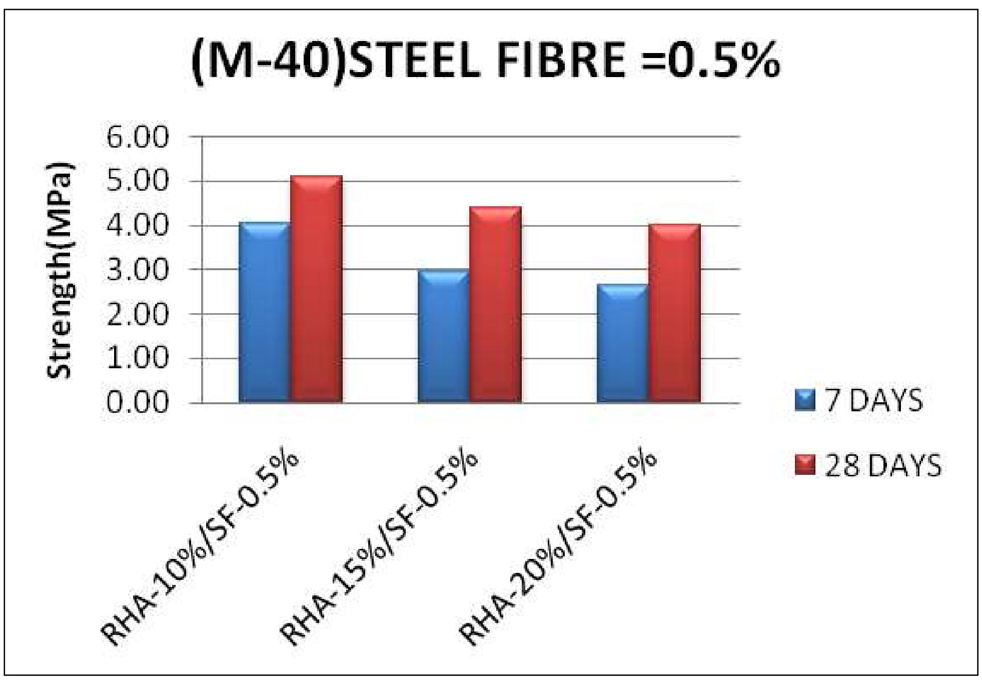


Fig. 4.10 Variation of Flexure strength of concrete for 0.5% S.F and different percentage of RHA

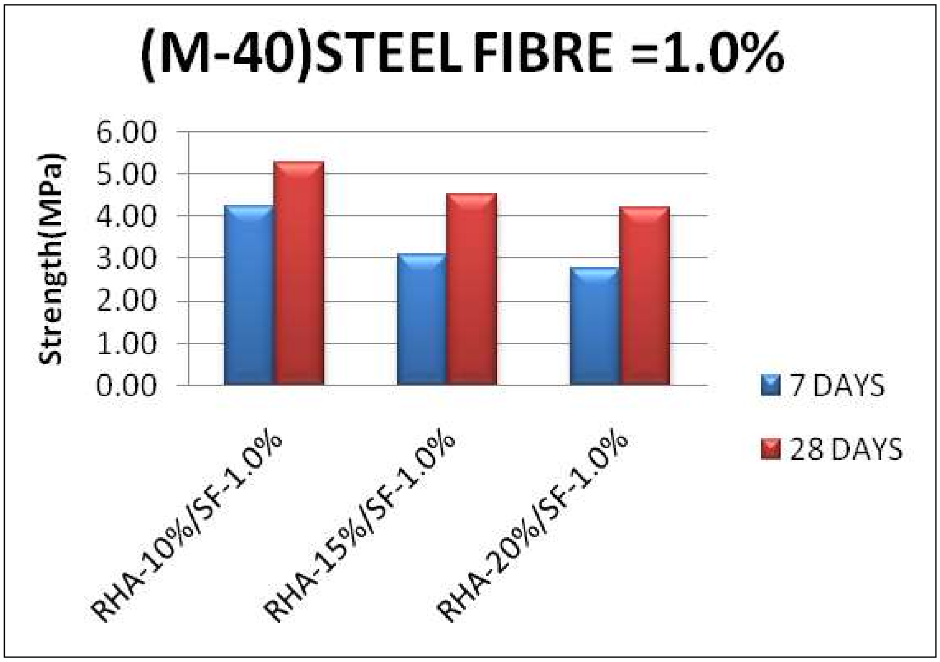


Fig. 4.11 Variation of Flexure strength of concrete for 1% S.F and different percentage of RHA

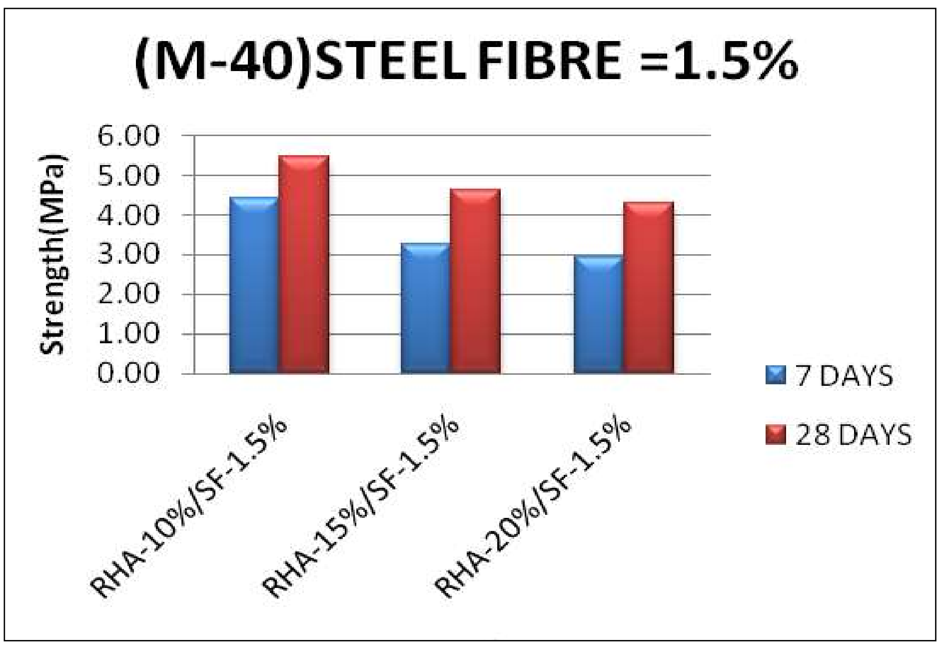


Fig. 4.12 Variation of Flexure strength of concrete for 1.5% S.F and different percentage of RHA

Table 4.5 Percentage Variation of Flexure strength at 7 days

Percentage Variation of Flexural strength at 7 days		
Flexural strength		
Sample ID	Percentage decrease in Flexural strength	Percentage increase in Flexural strength
RHA-10%/SF-0%	-10.09	
RHA-15%/SF-0%	-34.16	
RHA-20%/SF-0%	-40.75	
RHA-10%/SF-0.5%	-5.60	
RHA-15%/SF-0.5%	-30.87	
RHA-20%/SF-0.5%	-37.78	
RHA-10%/SF-1.0%	-0.88	
RHA-15%/SF-1.0%	-27.41	
RHA-20%/SF-1.0%	-34.67	
RHA-10%/SF-1.5%		4.08
RHA-15%/SF-1.5%	-23.79	
RHA-20%/SF-1.5%	-31.41	

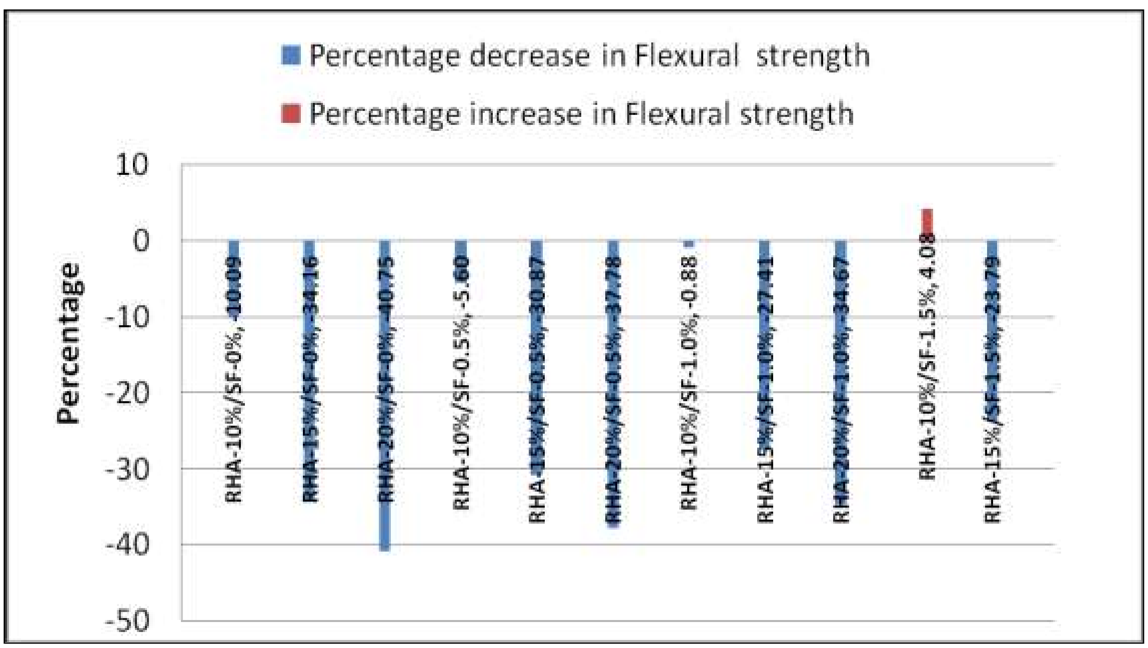


Fig. 4.13 Percentage variation of Flexure strength at 7 days

Table 4.6 Percentage Variation of Flexure strength at 28days

Flexural strength		
Sample ID	**Percentage decrease in Flexural strength**	**Percentage increase in Flexural strength**
RHA-10%/SF-0%	-9.01	
RHA-15%/SF-0%	-19.20	
RHA-20%/SF-0%	-28.87	
RHA-10%/SF-0.5%	-4.92	
RHA-15%/SF-0.5%	-17.58	
RHA-20%/SF-0.5%	-25.31	
RHA-10%/SF-1.0%	-1.11	
RHA-15%/SF-1.0%	-15.51	
RHA-20%/SF-1.0%	-21.58	
RHA-10%/SF-1.5%		1.86
RHA-15%/SF-1.5%	-13.41	
RHA-20%/SF-1.5%	-19.63	

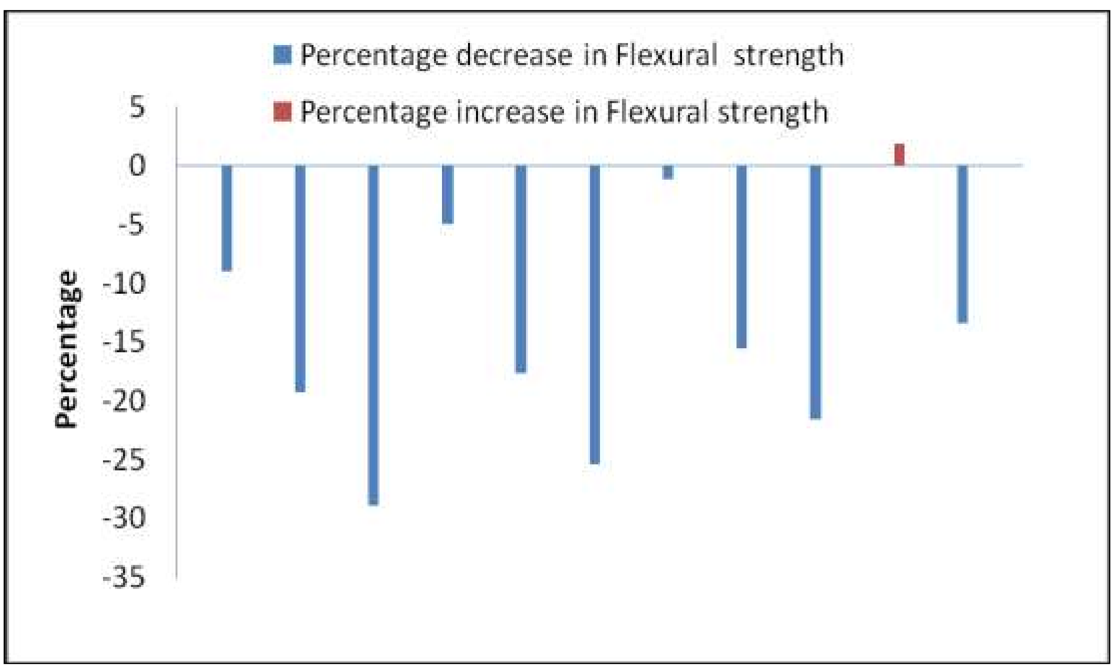


Fig. 4.14 Percentage variation of Flexure strength at 28days

4.3.3 Discussion of Results for flexure strength

From the Table 4.5,4.6 and figures 4.13,4.14 shows the variation of flexure strength at 28 days. It is observed here that with the increase percentage of Rice husk Ash (replacing cement) the flexure strength increase and is not more than the control mix (MF40). The maximum flexure strength is attained at 10% Rice husk Ash (replacing cement) which is less than the control mix (MF40). Further increase in Rice husk Ash (upto 20%) the increase is not significant. On the other hand, when the steel fibre is added in the concrete mix, there is significant increase in flexure strength as compared to controlled mix. Maximum flexure strength of pavement quality concrete incorporating Rice husk Ash and steel fibre both is achieved for 10% Rice husk Ash and 1.5% steel fibres. However, if the Rice husk Ash content is increased to 15%,20% even with 1.5% steel fibre, the strength increases but less as in 10% Rice husk Ash and 1.5% steel fibre as well as nominal mix(M-40).

4.3.4 Effect of steel fibre on flexure strength

From the Table 4.4 and Figures 4.9 to 4.12, showing the variation of flexure strength, it is observed here that with the increase percentage of steel fibre the flexure strength follows a pattern similar to that of compressive strength. This happens because when the steel fibres are added to the concrete, the propagation of cracks was restrained due to the bonding of fibres into the concrete (ductile failure). The maximum strength was obtained at 10% Rice husk Ash in all the replacement mixes and was not more than control mix. The flexure strength decreases with the increases in percentage of rice husk ash (RHA).For 10% replacement, the reduction is very less when compare to 15%, and 20% replacement.

On the other hand, when steel fibre is added in concrete mix there is widely increase in flexure strength as compared to nominal mix(M-40). Maximum flexure strength of pavement quality concrete incorporating Rice husk Ash and steel fibres both is achieved for 10% Rice husk Ash and 1.5% steel fibres. However if the Rice husk Ash content is increased to 20% even with 1.5 steel fibre, the strength increases but less as in 10% & 15% Rice husk Ash and 1.5% steel fibre as well as nominal mix(M-40).

CHAPTER-5

DESIGN AND ANALYSIS OF PAVEMENTQUALITY CONCRETE

5.1 DESIGN OF PAVEMENT QUALITY CONCRETE (PQC) FOR INDIAN HIGHWAYS

5.1.1 Introduction

Guidelines for the design of rigid pavements for highways were first approved by the Cement Concrete Road Surfacing Committee in March 1973 and published subsequently in the IRC:58-2002 editions. In view of the recent upward revision of the legal limit on the maximum laden axle loads of commercial vehicle from 8160 kg to 10200 kg, appropriate modifications have become necessary in some sections of the Guidelines of IRC: 58-1988, which resulted in the publication of IRC:58-2002, "Guidelines for the Design of Plain Jointed Rigid Pavements for Highways". The early approach to the Design of Rigid Pavement was based on Westergaard's analysis. Recent advance in knowledge have led to vast changes in the design methodology.

5.1.2 Factor Governing Design

a) ***Factor Governing Design***

It considered single and tandem axle loads, their repletion, tyre pressure and lateral placement characteristics of commercial vehicles.

b) ***Wheel Load***

The legal axle load limits in India have been fixed as 10.2, 19 and 24 tonnes for single axles, tandem axles and tridem axles respectively, a large number of axles operating on National Highways carry much higher loads than the legal limits. Data on axle load distribution of the commercial vehicles is required to compute the number of repetitions of single and tandem axles of different weights expected during the design period. For most of the commercial highways vehicles, the tyre pressure ranges from 0.7 to 1.0 MPa but it is found that stresses in concrete pavements having thickness of 20 cm or more are not affected significantly by the variation of tyre pressure in the range mentioned earlier. A tyre pressure of 8.0 Mpa may be adopted for design.

For computation of stresses in the pavements, the magnitude of axle loads should be multiplied by Load Safety Factor (LSF). For important roads, like, Expressways, National Highways and other roads where there will be uninterrupted traffic flow and high volume of truck traffic, the value of LSF is taken as 1.2. For roads of lesser importance having lower proportion of truck traffic, LSF may be taken as 1.1. For residential and other streets that carry small number of commercial traffic, the LSF may be taken as 1.0.

c) ***Design Period***

Normally, cement concrete pavements have a life span of 30 years and should be designed for this period. When the traffic intensity cannot be predicted accurately for a long period of time, and for low volume roads, a design period of twenty years may be considered. However, the design engineer should use his judgment about the design life taking into consideration the factors, like, traffic volume, the traffic growth rate, the capacity of the road.

d) ***Design Traffic***

Assessment of average traffic should normally be based on 7 X 24 hours count made in accordance with IRC: 9 "Traffic Census on Non-Urban Roads". The actual value of growth rate 'r' of heavy commercial vehicles should be determined. However, if actual data is not available, an average annual growth rate of 7.5 percent may be adopted.

The cumulative number of repetitions of axles during the design period may be adopted from the following formula :

$$C = \frac{365 X A\{(1+r)^n - 1\}}{r}$$

Where

C = Cumulative number of axles during the design period.

A = Initial number of axles per day in the year when the road is operational.

R = Annual rate of growth of commercial traffic (expressed in decimals).

N = Design period in years.

In most of design problems, it is expected that the weights and number of trucks travelling in each direction are fairly equal. This may not be true for roads, like Haul roads in mine areas where many of the trucks haul full loads in one direction and return empty in the other direction. In such cases, suitable adjustment should be made.

e) *Temperature Differential*

Temperature differential between the top and the bottom of concrete pavements causes the concrete slab to wrap, giving rise to stresses. The temperature differential is a function of solar radiation received by the pavement surface at the location, losses due to wind velocity and thermal diffusivity of concrete and is thus location, losses due to wind velocity and thermal diffusivity of concrete and is thus affected by geographical features of the pavement location. As far as possible, values of actually anticipated temperature differentials at the location of the pavement should be adopted for pavement design.

5.2 CHARACTERISTICS OF SUBGRADE AND SUB BASE

5.2.1 Strength

The strength of sub grade is expressed in terms of modulus of sub grade reaction K. Which is defined as pressure per unit deflection of the foundation as determined by plate bearing tests. As the limiting design deflection for cement concrete pavements is taken as 1.25 mm, the k-value is determined from the pressure sustained at this deflection. As k-value is carried out by test plate diameter, the standard test is to be carried out with a 75 cm diameter plate. IS:9214-1974, “Method of Determination of Modulus of Sub grade Reaction of Soil in the field” may be referred. A frequency of one test per km per lane is recommended for assessment of k-value, unless the foundation changes with respect of sub grade soil, type of sub-base or the nature of formation i.e. cut or fill when additional tests may be conducted. An approximate idea of k-value of a homogenous soil sub grade may be obtained from its soaked CBR value using Table 5.1. It is advisable to have a filter layer above the sub grade for drainage of water to prevent (i) excessive softening of sub grade and (ii) erosion of the sub grade particularly under adverse moisture condition.

The approximate increases in k-values of sub grade due to different thickness of sub-bases made up to untreated granular, cement treated granular and dry lean concrete (DLC) layers may be taken from Table 5.2. 7-day unconfined compressive strength of cement treated granular soil should be a minimum of 2.1 Mpa. Dry Lean Concrete should have a minimum compressive strength of 7 Mpa at 7 days.

Table 5.1 Approximate K-value corresponding to CBR values for Homogenous Soil Sub grade.

Soaked CBR value %	2	3	4	5	7	10	15	20	50	100
k-value (kg/cm2/cm)	2.1	2.8	3.5	4.2	4.8	5.5	6.2	6.9	14.0	22.2

Table 5.2 K-Values with Dry Lean Concrete Sub-Base

k-value of sub grade kg/ cm2/ cm	2.1	2.8	4.2	4.8	5.5	6.2
Effective k over 100 mm DLC, kg/ cm2/ cm	5.6	9.7	16.6	20.8	27.8	38.9
Effective k over 150 mm DLC, kg/ cm2/ cm	9.7	13.8	20.8	27.7	41.7	---

The maximum value of effective k will be 38.9 kg/ cm2/ cm for 100 mm of DLC and 41.7 kg/ cm2/ cm for 150 mm of DLC.

5.2.2 Separation layer between sub-base and pavement

Foundation layer below concrete slabs should be smooth to reduce the inter layer friction. A separation membrane of minimum thickness of 125 micron polythene is recommended to reduce the friction between concrete slabs and dry lean concrete slab-base (DLC).

5.3 CHARACTERISTICS OF CONCRETE

5.3.1 Design Strength

The concrete pavements fail due to bending stresses, it is necessary that their design is based on the flexural strength of concrete. The relationship b/w the flexural strength and compressive strength may be worked out. The mix should be so designed that the minimum structural strength requirement in the field is met at the desired level. Thus, S1 = Characteristics flexural strength at 28 days.

S = Target average flexural strength at 28 days.

Za = Tolerance factor for the desired confidence level, known as the standard normal variate.

σ = Expected standard deviation of field test samples; if it is not known, it may be initially.

Assumed as per IS; 456-2000

Then the target average flexural strength is given as:

$S = S1 + Za\,\sigma$

For pavement construction, the concrete mix should preferably be designed and controlled on the basis of flexural strength. Flexural strength should be determined by modulus of rupture tests under third point loading. The preferred size of the beam should be 15 cm X 15 cm X 70 cm when the size of the aggregate is more than 19 mm. When the maximum size of aggregate is less than 19 mm, 10 cm X 10 cm X 50cm beams may be used. IS: 516 should referred for the test procedure.

5.3.2 Fatigue behaviour of cement concrete

Due to repeated application of flexural stresses by the traffic loads, progressive fatigue damage takes place in the cement concrete slab in the form of gradual development of micro-cracks especially when the applied stress in terms of flexural strength of concrete is high. The ratio b/w the flexural stress due to the load and the flexural strength of the concrete is known as stress ratio (SR). If the stress ratio is less than 0.45, the concrete is expected to sustain infinite number of repetitions. As the stress ratio increases, the number of load repetitions required to cause cracking decreases. The relation b/w fatigue life (N) and stress ratio is given as:

N = unlimited for SR < 0.45

$$N = \left\{\frac{4.2577}{SR-0.4325}\right\}^{3.268} \qquad \text{When } 0.45 \le SR \le 0.55$$

$$\log_{10} N = \frac{0.9716-SR}{0.0828} \quad \text{for } SR > 0.55$$

The values of fatigue life for different values of stress ratio are given in Table 5.3.

5.4 DESIGN OF SLAB THICKNESS

Step by step procedure of Design of Slab Thickness Pavement as per IRC 58-2002.

Step1. As per IRC 58-2002, Axle load (AL) in Single Axle and Tandem Axle (Tonnes) is given .

Step2. From the given data, cumulative repetition in 20 yrs. Can be calculated from the formula which is given below:

$$C = \frac{365XA\{(1+r)^{n}-1\}}{r}$$

Where,

C = Cumulative number of axles during the design period.

A = Initial number of axles per day in the year when the road is operational.

R = Annual rate of growth of commercial traffic (expressed in decimals).

N = Design period in years.

Step3. After calculating cumulative repetition, Design traffic can be calculated by 25% of cumulative repetition.

Step4. The Single and tandem Axle load is multiplied with a factor of 1.2 respectively.

Step5. Stress (kg/cm2) is calculated from the given graphs as mentioned in IRC 58:2002 (Graphs between Slab thickness and flexure strength).

Step6. Stress Ratio is calculated from $\frac{\text{Stress}}{\text{Flexure Strength}}$

Step7. Expected Repetition is calculated from the Design Traffic which is multiplied with a percentage of respective Axle loads.

Step8. Allowable Repetition is calculated from the Table which is mentioned in IRC 58:2002 which is also shown below in Table 5.3.

Step9. Fatigue life consumed is calculated which is the ratio of fatigue life (N) and expected repetition (n). The design is unsafe if the cumulative fatigue life consumed is greater than 1.0.

The slab design process as per IRC 58-2002 for the pavement quality concrete tested in the laboratory is presented in Table 5.6. The Table 5.4 and 5.5 contains the input traffic data in terms of the expected repetitions for the single and tandem axles, for which the slab thickness have been calculated.

Table 5.6 to 5.14 presents the design of slab thickness by calculating the fatigue life consumed for the given axle load traffic (Table 5.5) and flexure strength of PQC achieved in the laboratory. Subsequent the following table presents the design for flexure strengths achieved by varying the percentages of rice husk ash and steel fibres in the concrete mix.

Table 5.3 Stress Ratio and Allowable Repetitions in Cement Concrete

Stress Ratio	Allowable Repetitions	Stress Ratio	Allowable Repetitions
0.45	6.279 X 10	0.66	5.83 X 10
0.46	1.4335 X 10	0.67	4.41 X 10
0.47	5.2 X 10	0.68	3.34 X 10
0.48	2.4 X 10	0.69	2531
0.49	1.287 X 10	0.70	1970
0.50	7.62 X 10	0.71	1451
0.51	4.85 X 10	0.72	1099
0.52	3.26 X 10	0.73	832
0.53	2.29 X 10	0.74	630
0.54	1.66 X 10	0.75	477
0.55	1.24 X 10	0.76	361
0.56	9.41 X 10	0.77	274
0.57	7.12 X 10	0.78	207
0.58	5.4 X 10	0.79	157
0.59	4.08 X 10	0.80	119
0.60	3.09 X 10	0.81	90
0.61	2.34 X 10	0.82	68
0.62	1.77 X 10	0.83	52
0.63	1.34 X 10	0.84	39
0.64	1.02 X 10	0.85	30
0.65	7.7 X 10		

Table 5.4 Design of Rigid Pavement as Per IRC: 58-2002

Design Life	N	30 years
Design Wheel Load	P	7000 kg
Present Traffic Intensity	Tb	3000 CVPD
28 days Compressive Strength of Concrete	fck	508.2 kg/cm^2
Flexure Strength of concrete	Fck	54.40 kg/cm^2
Modulus of Elasticity of Concrete	E	300000 kg/ cm^2
Poission's Ratio of concrete		0.15
Coefficient of Thermal Expansion of Concrete	A	10.0 x 10 per^0c
Subgrade CBR	%	7.000
K value of Subgrade	Ksg	4.800 kg/cm^3
Subbase Type		3
Thickness of Dry Lean Concrete > = 10 cm		15 cm
K Value of Subbase	Ksb	27.700 kg/cm^3
Zone of Project Corridor for Temperature		1 No.
Concrete Slab Thickness	H	24.00 cm
Temp. Difference b/w Top And Bottom Layer	Dt	13.748 C
Spacing of Contraction Joints	L	4.5 m
Length of Slab (Lane Width)	W	3.5 m
Tyre Pressure	P	8 kg/ cm2
c/c Distance Between two tyres	S	31 cm
Load Safety Factor For Fatigue analysis	LSF	1.2
Annual Traffic Growth Rate	r	7.5%

Table 5.5 Axle Load Spectrum

Single Axle Load		Tandem Axle Load	
Load in Tones	**Expected Repetitions**	**Load in Tones**	**Expected Repetitions**
27-29	0.00		
25-27	0.00		
23-25	0.00	42-46	0.0
21-23	0.00	38-42	0.0
19-21	0.6	34-38	0.3
17-19	1.5	30-34	0.3
15-17	4.8	26-30	0.6
13-15	10.8	22-26	1.8
11-13	22	18-22	1.5
09-11	23.3	14-18	0.5
< 09	30	< 14	2.0
Total	70.14	Total	7.0

Cumulative Repetitions in 30 Years = 113222346 CVPD

Design Traffic = 28305586 CVPD

Radius of Relative Stiffness (I) = 59.54 cm

Table 5.6 Slab Design for Mix (RHA-10%/SF-1.5%)

Flexural Strength =54.4 Kg/cm^2					**Slab Thickness= 24.00 cm**	
Axle load (AL) ,Tonnes	**AL * 1.2**	**Stress Kg/cm^2 (from chart)**	**Stress ratio**	**Expected repetition**	**Fatigue life, N**	**Fatigue life consumed**
1	**2**	**3**	**4**	**5**	**6**	**7**
Single Axle						
20	24	28	0.5147059	169833.5	400167.1	0.424406
18	21.6	26.5	0.4871324	424583.8	1521100	0.279129
16	19.2	24.95	0.4586397	1358668	16920197	0
14	16.8	22.5	0.4136029	3057003	unlimited	0
12	14.4	20	0.3676471	6227229	unlimited	0
Tandem Axle						
36	43.2	19.75	0.3630515	84916.76	unlimited	0
32	38.4	18.5	0.3400735	169833.5	unlimited	0
Cumulative fatigue damage / Life consumed						0.703536
Check for fatigue life =						safe

Table 5.7 Slab Design for Mix (RHA-0%/SF-0%)

Flexural Strength =53.5 Kg/cm^2					**Slab Thickness= 24.00 cm**	
Axle load (AL) ,Tonnes	**AL * 1.2**	**Stress Kg/cm^2 (from chart)**	**Stress ratio**	**Expected repetition**	**Fatigue life, N**	**Fatigue life consumed**
1	**2**	**3**	**4**	**5**	**6**	**7**
Single Axle						
20	24	28	0.5233645	169833.5	288477.5	0.588724
18	21.6	26.5	0.4953271	424583.8	963384.3	0.440721
16	19.2	24.95	0.4663551	1358668	7266593	0
14	16.8	22.5	0.4205607	3057003	unlimited	0
12	14.4	20	0.3738318	6227229	unlimited	0
Tandem Axle						
36	43.2	19.75	0.3691589	84916.76	unlimited	0
32	38.4	18.5	0.3457944	169833.5	unlimited	0
Cumulative fatigue damage / Life consumed						1.029445
Check for fatigue life =						Unsafe

Table 5.8 Slab Design for Mix (RHA-0%/SF-0%)

Flexural Strength =53.5 Kg/cm^2					**Slab Thickness= 24.50 cm**	
Axle load (AL) , Tonnes	**AL * 1.2**	**Stress Kg/cm^2 (from chart)**	**Stress ratio**	**Expected repetition**	**Fatigue life, N**	**Fatigue life consumed**
1	**2**	**3**	**4**	**5**	**6**	**7**
Single Axle						
20	24	27.8	0.51962617	169833.52	330931.7351	0.513198
18	21.6	26.3	0.49158879	424583.8	1177241.466	0.3606599
16	19.2	24.6	0.45981308	1358668.1	14658330.27	0
14	16.8	22.1	0.41308411	3057003.3	unlimited	0
12	14.4	19.8	0.37009346	6227229	unlimited	0
Tandem Axle						
36	43.2	19.54	0.36523364	84916.759	unlimited	0
32	38.4	18.23	0.34074766	169833.52	unlimited	0
Cumulative fatigue damage / Life consumed						0.8738579
Check for fatigue life =						safe

Table 5.9 Slab Design for Mix (RHA-10%/SF-1.5%)

Flexural Strength =54.4 Kg/cm^2					**Slab Thickness= 23.50 cm**	
Axle load (AL) ,Tonnes	**AL * 1.2**	**Stress Kg/cm^2 (from chart)**	**Stress ratio**	**Expected repetition**	**Fatigue life, N**	**Fatigue life consumed**
1	**2**	**3**	**4**	**5**	**6**	**7**
Single Axle						
20	24	29	0.53308824	169833.5	206928.3	0.820736
18	21.6	28	0.51470588	424583.8	400167.1	1.061016
16	19.2	26	0.47794118	1358668	2777147	0
14	16.8	23.4	0.43014706	3057003	unlimited	0
12	14.4	21.5	0.39522059	6227229	unlimited	0
Tandem Axle						
36	43.2	21	0.38602941	84916.76	unlimited	0
32	38.4	19.5	0.35845588	169833.5	unlimited	0
Cumulative fatigue damage / Life consumed						1.881752
Check for fatigue life =						Unsafe

Table 5.10 Slab Design for Mix (RHA-15%/SF-1.5%)

Flexural Strength =46.3 Kg/cm^2					Slab Thickness= 27.50 cm	
Axle load (AL) ,Tonnes	**AL * 1.2**	**Stress Kg/cm^2 (from chart)**	**Stress ratio**	**Expected repetition**	**Fatigue life N**	**Fatigue life consumed**
1	**2**	**3**	**4**	**5**	**6**	**7**
Single Axle						
20	24	24.2	0.522678186	169833.5	295714.4	0.574316
18	21.6	22.7	0.490280778	424583.8	1266590	0.335218
16	19.2	21	0.453563715	1358668	34263507	0
14	16.8	18.5	0.399568035	3057003	unlimited	0
12	14.4	17	0.367170626	6227229	unlimited	0
Tandem Axle						
36	43.2	17	0.367170626	84916.76	unlimited	0
32	38.4	15.85	0.342332613	169833.5	unlimited	0
Cumulative fatigue damage / Life consumed						0.909534
Check for fatigue life =						Safe

Table 5.11 Slab Design for Mix (RHA-15%/SF-1.0%)

Flexural Strength =45.2 Kg/cm^2						**Slab Thickness= 27.75 cm**
Axle load (AL) ,Tonnes	**AL * 1.2**	**Stress Kg/cm^2 (from chart)**	**Stress ratio**	**Expected repetition**	**Fatigue life, N**	**Fatigue life consumed**
1	**2**	**3**	**4**	**5**	**6**	**7**
Single Axle						
20	24	23.5	0.519912	169833.519	327414.508	0.518711
18	21.6	22.2	0.49115	424583.797	1206239.38	0.35199
16	19.2	21	0.464602	1358668.15	8645843.88	0
14	16.8	18.5	0.409292	3057003.34	unlimited	0
12	14.4	17	0.376106	6227229.02	unlimited	0
Tandem Axle						
36	43.2	17	0.376106	84916.7593	unlimited	0
32	38.4	15.75	0.348451	169833.519	unlimited	0
Cumulative fatigue damage / Life consumed						0.870701
Check for fatigue life =						Safe

Table 5.12 Slab Design for Mix (RHA-10%/SF-0%)

Flexural Strength =48.6 Kg/cm²						Slab Thickness= 26.50 cm
Axle load (AL) ,Tonnes	**AL * 1.2**	**Stress Kg/cm² (from chart)**	**Stress ratio**	**Expected repetition**	**Fatigue life, N**	**Fatigue life consumed**
1	**2**	**3**	**4**	**5**	**6**	**7**
Single Axle						
20	24	25.1	0.5164609	169833.52	373473.8	0.45474
18	21.6	24	0.4938272	424583.8	1042544	0.407257
16	19.2	22.5	0.462963	1358668.1	10260694	0.132415
14	16.8	20	0.4115226	3057003.3	Unlimited	0
12	14.4	18	0.3703704	6227229	Unlimited	0
Tandem Axle						
36	43.2	18	0.3703704	84916.759	Unlimited	0
32	38.4	16.75	0.3446502	169833.52	Unlimited	0
Cumulative fatigue damage / Life consumed						0.994412
Check for fatigue life =						Safe

Table 5.13 Slab Design for Mix (RHA-10%/SF-1.0%)

Flexural Strength =52.9 Kg/cm^2						**Slab Thickness= 25.50 cm**
Axle load (AL) ,Tonnes	**AL * 1.2**	**Stress Kg/cm^2 (from chart)**	**Stress ratio**	**Expected repetition**	**Fatigue life, N**	**Fatigue life consumed**
1	**2**	**3**	**4**	**5**	**6**	**7**
Single Axle						
20	24	27	0.510397	169833.5	477149.8	0.355933
18	21.6	25	0.47259	424583.8	4182439	0.101516
16	19.2	23	0.434783	1358668	unlimited	0
14	16.8	21.5	0.406427	3057003	unlimited	0
12	14.4	18.5	0.349716	6227229	unlimited	0
Tandem Axle						
36	43.2	18.5	0.349716	84916.76	unlimited	0
32	38.4	17	0.321361	169833.5	unlimited	0
Cumulative fatigue damage / Life consumed						0.457449
Check for fatigue life =						Safe

Table 5.14 Slab Design for Mix (RHA-10%/SF-0.5%)

Flexural Strength =50.8 Kg/cm^2					**Slab Thickness= 26.00 cm**	
Axle load (AL) ,Tonnes	**AL * 1.2**	**Stress Kg/cm^2 (from chart)**	**Stress ratio**	**Expected repetition**	**Fatigue life, N**	**Fatigue life consumed**
1	**2**	**3**	**4**	**5**	**6**	**7**
Single Axle						
20	24	26	0.511811	169833.5	449906.3	0.377486
18	21.6	24.5	0.482283	424583.8	2060962	0.206012
16	19.2	22.75	0.447835	1358668	Unlimited	0
14	16.8	20.5	0.403543	3057003	Unlimited	0
12	14.4	18.25	0.359252	6227229	Unlimited	0
Tandem Axle						
36	43.2	18.25	0.359252	84916.76	Unlimited	0
32	38.4	17.25	0.339567	169833.5	Unlimited	0
Cumulative fatigue damage / Life consumed						0.583499
Check for fatigue life =						Safe

Table 5.15 Concrete Slab Thickness

Concrete Slab Thickness					
Mix ID	**Slab thickness (cm)**	**Increase in Slab thickness (cm)**	**Decrease in Slab thickness (cm)**	**Percentage Increase in Slab thickness**	**Percentage decrease in Slab thickness**
RHA-0%/SF-0%	24.50	0		0	
RHA-10%/SF-0%	26.50	2.0		8.16	
RHA-10%/SF-.5%	26.00	1.5		6.12	
RHA-10%/SF-1.0%	25.50	1.0		4.08	
RHA-15%/SF-1.0%	27.75	3.3		13.27	
RHA-10%/SF-1.5%	24.00		-0.50		-2.04
RHA-15%/SF-1.5%	27.50	3.0		12.24	

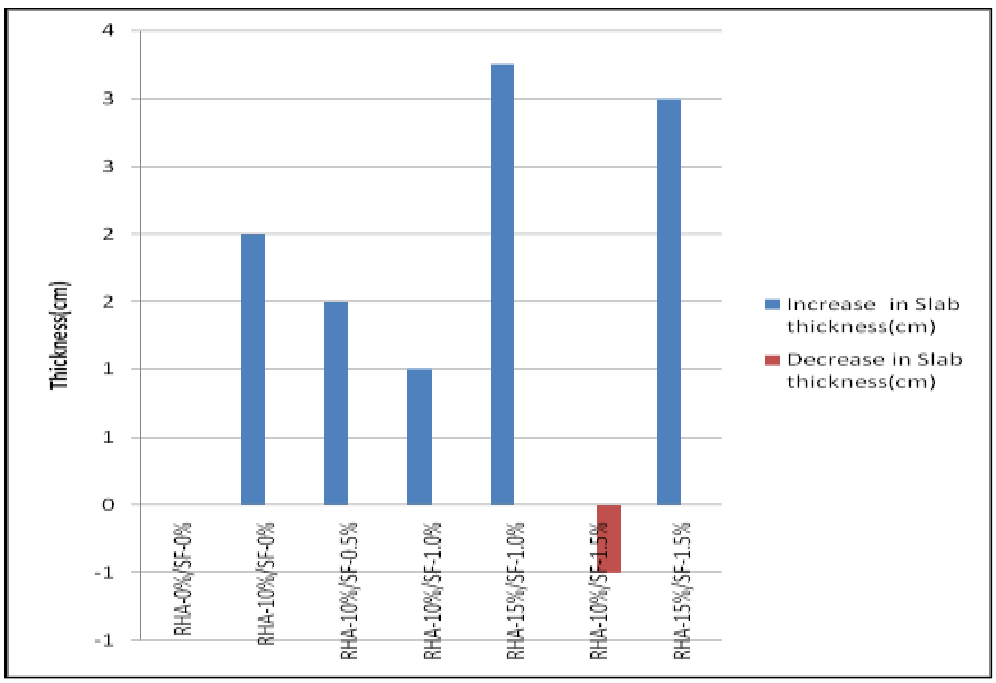


Fig. 5.1 Variation in Concrete Slab Thickness

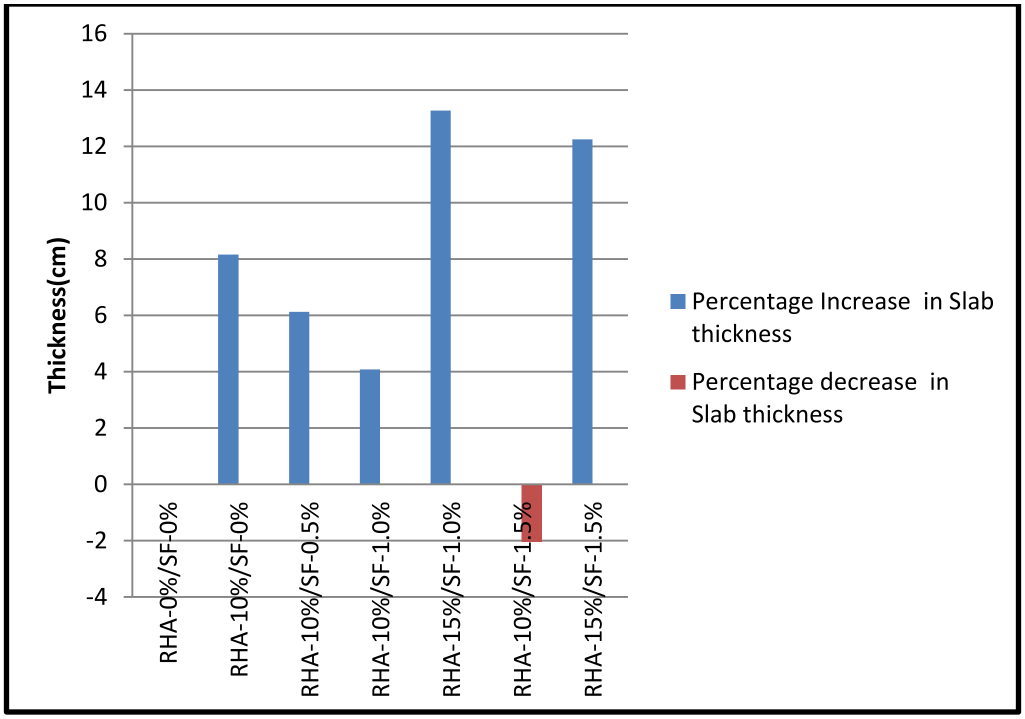


Fig. 5.2 Percentage variation Concrete Slab Thickness

Table 5.16 Saving in Cubic Meter of PQC (1000mX8.5mXSlabThickness)

Mix ID	Cu.m of PQC (1000mX8.5mX Slab Thickness)	Saving in Cu.m of PQC	Percentage Saving
RHA-0%/SF-0%	2082.50	0.00	0
RHA-10%/SF-0%	2252.50	-170.00	-8.16
RHA-10%/SF-0.5%	2210.00	-127.50	-6.12
RHA-10%/SF-1.0%	2167.50	-85.00	-4.08
RHA-15%/SF-1.0%	2358.75	-276.25	-13.27
RHA-10%/SF-1.5%	2040.00	42.50	2.04
RHA-15%/SF-1.5%	2337.50	-255.00	-12.24

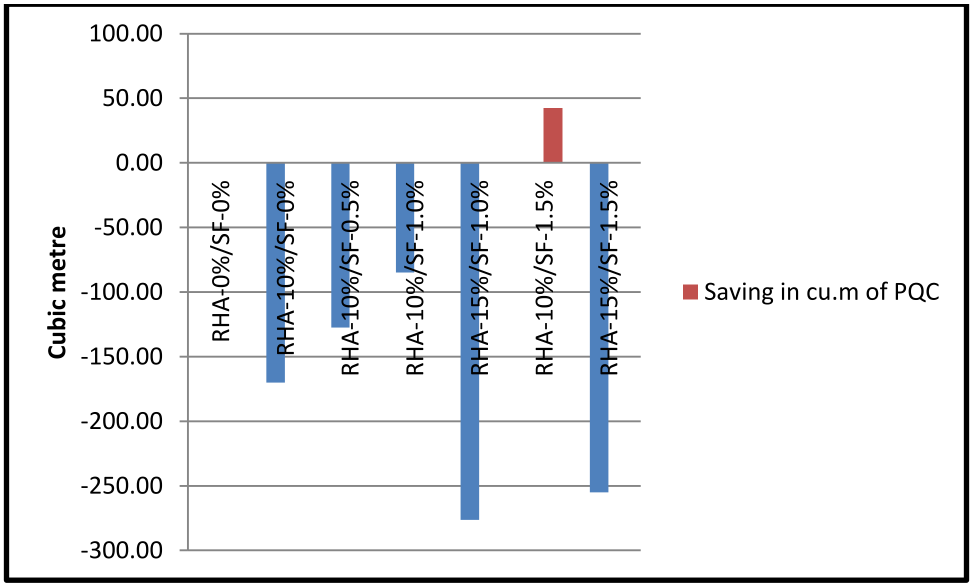


Fig. 5.3 Saving in cubic meter of PQC

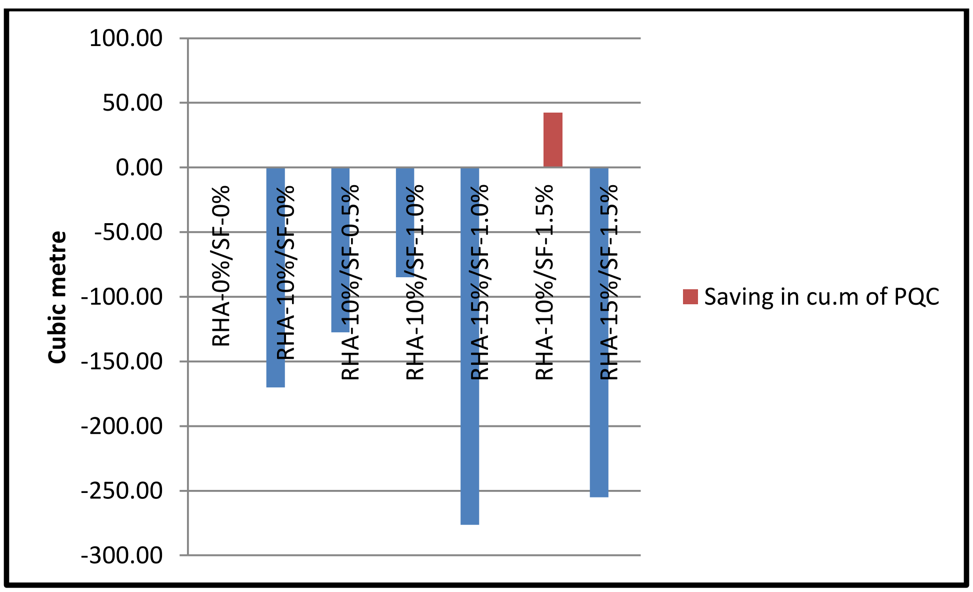


Fig. 5.4 Percentage saving in cost

Table 5.16 and fig.5.3, 5.4 show savings in cu.m of PQC and percentage savings in cu.m of PQC is found on replacing 10% Rice Husk Ash and 1.5 steel fibre. It is found that on replacing of Rice Husk Ash & addition of steel fibre shows significant results.

CHAPTER-6
CONCLUSION AND RECOMMENDATIONS FOR FURTHER STUDY

6.1 GENERAL

The present study was undertaken to investigate the compressive strength and flexure strength of concrete with different level of replacement of cement with Rice husk Ash and addition of steel fibres in the concrete mix. Cement was partially replaced by Rice husk Ash at four different levels of replacement i.e. 0%, 10%, 15% and 20% and steel fibre is added in concrete mix at different percentages i.e. 0%, 0.5% ,1% and 1.5%. Tests were performed after 7 days and 28 days of curing of concrete. 6 samples of reference mix i.e. with 0% Rice Husk Ash ,0% steel fibre,18 samples with (10%,15% & 20%)Rice Husk Ash ,0% steel fibre and 54 samples with (10%,15% & 20%) Rice Husk Ash & (0.5% ,1% and 1.5%.) steel fibre prepared for determining compressive strength and flexure strength of concrete with water-cement ratio as 0.40 for 4.5 N/mm2 (Target Mean Flexure Strength). Super plasticizer was used in all the mixes at 2% level by weight of cementious material.

6.2 CONCLUSION

From the experimental results, the following conclusion can be drawn:

Strength Characteristics

- Concrete mix with 10 percent Rice husk Ash as replacement of cement and 1.5% addition of steel fibre is the optimum level and it has been observed to show a significant increase in compressive strength at 7days and 28 days when compared with nominal mix.
- The flexure strength also tends to increase with the increase percentage of steel fibre, a trend similar to increase in compressive strength.
- On increasing the percentage replacement of cement with Rice husk Ash beyond 10%, there is significantly decrease in compressive and flexure strength value.
- Maximum strength (compressive and flexure strength) of pavement quality concrete incorporating Rice husk Ash and steel fibres, both, is achieved for 10% Rice husk

Ash and 1.5% steel fibres. However, if the Rice husk Ash content is increased to 15%, 20% , even with 1.5% steel fibre, the strength increases but less than as in 10% Rice husk Ash and 1.5% steel fibre as well as Control mix (M-40) .

6.3. SAVING IN DESIGN OF SLAB THICKNESS AND COST IN PQC

According to the results of the study, compiled for various mixes incorporating Rice Husk ,Rice husk Ash + Steel fibre and Control mix(M-40), there is slightly decrease in thickness of slab with the mix (Rice Husk Ash 10%+ Steel Fibre 1.5%) in comparison with control mix (M-40). The first three mixes (10% Rice husk Ash + 0% Steel fibre ,10% Rice husk Ash + 0.5% steel fibre and 10% Rice husk Ash + 1% steel fibre) shows slightly an increase in slab thickness i.e 2.0 cm,1.5 cm & 1.0cm respectively. The decrease in thickness of slab only is 0.50 cm with the mix (10% Rice husk Ash +1.5% steel fibre) & in rest of the mixes slab thickness increases significantly. From all the mixed, maximum of 42.50 cubic meter of PQC is saved on replacing 10% Rice husk Ash and adding 1.5% steel fibre ,also maximum percentage saving in cost is 2.04 is achieved. As in first three mixes there is slightly percentage decrease in cost saving that can achieved by further improvement in PQC.While design the cost of steel fibre should be considered.

6.4 SCOPE FOR FUTURE WORK

- In the present study experimental program was devised to study the strength characteristics of mixes containing Rice husk Ash and Steel fibre. The work can be extended to study the durability characteristics as well.
- The performance of the pavement quality concrete slabs containing Rice Husk Ash and steel fibre can be evaluated by constructing the trial stretches. The behaviour of these Pavement Quality Concrete (PQC) slabs can be analyzed under repetitive loading for the fatigue life consumed.
- Future work should be carried out by increasing the quality and percentage of RHA replacement as well as varying SP and w/b ratios.

THANKS

REFRENCES

Achilleos, Constantia, et al. “Proportioning of steel fibre reinforced concrete mixes for pavement construction and their impact on environment and cost.” Sustainability 3.7 (2011): 965-983.

Chunxiang, Qian, and IndubhushanPatnaikuni. “Properties of high-strength steel fibre-reinforced concrete beams in bending.” Cement and Concrete Composites 21.1 (1999): 73-81.

Elsaigh, WA, Kearsley, EP and Robberts, JM. “Steel Fibre Reinforced Concrete For Road Pavement Application”. Paper Presented to the 24 th Annual Southern African Transport Conference (2005), South Africa.

G.Murali, C.M. VivekVardhan, P.Sruthee, P.Charmily. “Influence of Steel Fibre on Concrete.” International Journal of Engineering Research and Applications (IJERA) ISSN:2248-9622 (2012), Vol.2, Issue 3, pp.075-078.

IRC: 58-2002, “Guideline for Design of Rigid Pavements for Highways.” The Indian Road Congress, New Delhi, 2002.

IS: 10262-1982 (Reaffirmed 2004): Recommended guidelines for concrete mix design, Bureau of Indian Standard, New Delhi-2004.

IS: 1199-1959 (Reaffirmed 1999): Methods of Sampling and Analysis of Concrete, Bureau of Indian Standard, New Delhi-1999.

IS: 2386 (Part I, III)- 1963: Methods of Test for Aggregates for Concrete, Bureau of Indian Standard, New Delhi-1963.

IS: 383-1970: Specification for Coarse and Fine Aggregates from Natural Sources for Concrete, Bureau of Indian Standard, New Delhi-1970.

IS: 4031 (Part 4, 5&6)-1988: Methods of Physical Tests for Hydraulic Cement, Bureau of Indian Standard, New Delhi-1988.

IS: 456-2000: Code of practice- plain and reinforced concrete, Bureau of Indian Standard, New Delhi-2000.

IS: 516-1959 (Reaffirmed 2004): Methods of tests of strength of concrete, Bureau of India Standard, New Delhi-2004.

IS: 8112-1989 (Reaffirmed 2005): Specification for 43 Grade Ordinary Portland Cement, Bureau of Indian Standard, New Delhi-2005.

IS: 9103-1999 (Reaffirmed 2004): Concrete Admixtures-Specifications, Bureau of Indian Standard, New Delhi-2004.

Naik TR, Kraus RN Chun YM, Ramme WB, Singh SS. Properties of field manufactured cast-concrete products utilizing recycled materials. J mater Civil Eng 2003;15(4): 400-7.

Naik, Tarun R. "Foundry industry by-products utilization. "University of Wisconsin-Milwaukee, Department of Civil Engineering and Mechanics, Center for By-Products Utilization, Report No. CBU-1989-01 (1989).

Nataraja, .C., N. Dhang, and A.P. Gupta. "Stress-strain curves for steel-fibre reinforced concrete under compression." Cement and Concrete Composites 21.5 (1999): 383-390.

Patel, Mr VR, Bhavin R. Mojidra, and I. I. Pandya. "Ultimate Shear Strength of Fibrous Moderate Deep Beams without Stirrups." International Journal of Engineering 1.1 (2012): 16-21.

Rashid, Mohammad Abdur, and Mohammad Abul Mansur. "Considerations in producing high strength concrete." Journal of Civil Engineering (IEB) 37.1 (2009): 53-63.

Soulioti, D. V., et al. "Effects of Fibre Geometry and Volume Fraction on the Flexural Behaviour of Steel-Fibre Reinforced Concrete." Strain 47.21 (2011): e535-e541.

Sydney Furlan Jr. and Joao Bento de Hanai. "Shear Behaviour of Fibre reinforced Beams". Cement and Concrete Composites 19 (1992) 359-366.

Wang, Nianzhi, Sidney Mindess, and Keith Ko. "Fibre reinforced concrete beams under impact loading." Cement and concrete research 26.3 (1996): 363-376.

Wegian, Falah M., A. Alanki, and A. Alotaibi. "Influence of Fly Ash on Behaviour of Fibres Reinforced Concrete Structures." Journal of Applied Sciences 11.17 (2011): 3185-3191.

Uduweriya, R. B.Y. B., Subash, C., Sulfy, M. M. A., and Silva, S.D. (2010) "Investigation of Compressive Strength of Concrete Containing Rice-Husk-Ash", International Conference on Sustainable Built Environment (ICSBE-2010) Kandy, pp. 13-14

Givi, A.N., Rashid, S.A., Aziz, F.N.A. and Salleh, M.A.M. (2010) "Assessment of the effects of rice husk ash particle size on strength, water permeability and workability of binary blended concrete", Construction and Building Materials 24 (2010) pp. 2145–2150.

Bui, D.D., Hu, J. and Stroeven, P. (2005) "Particle Size Effect On The Strength Of Rice Husk Ash Blended Gap-Graded Portland Cement Concrete", Cement & Concrete Composites 27 (2005), pp 357–366.

Khani, M.M., Ramezanianpour, A.A. and Ahmadibeni, Gh. (2009) "The Effect of Rice Husk Ash on Mechanical Properties and Durability of Sustainable Concretes", International Journal of Civil Engineering. Vol. 7, No. 2, June 2009.

Habeeb, G.A. and Mahmud, H.B. (2010) "Study on Properties of Rice Husk Ash and Its Use as Cement Replacement Material", Materials Research 13 (2010) pp. 185-190.

Khan, R., Jabbar, A., Ahmad, I., Khan, W., Khan, A.N. and Mirza, J. (2011) "Reduction in environmental problems using rice-husk ash in concrete." Construction and Building Materials 30, pp. 360–365.

Nagrale, S.D., Hajare, H. and Modak, P.R. (2012) "Utilization of Rice Husk Ash", International Journal of Engineering Research and Applications (IJERA). Vol. 2, Issue 4, pp. 001-005.

Zhang, M.H., Lastra, R. and Malhotra, V.M.(1996) “Rice-Husk Ash Paste And Concrete: Some Aspects Of Hydration And The Microstructure Of The Interfacial Zone Between The Aggregate And Paste”, Cement and Concrete Research, Vol. 26, No. 6, pp. 963-977.