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Hardened Properties of the Concrete Containing Polypropylene Fiber and Rice Husk Ash Powder

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ABSTRACT

It is determined that studies confirmed polypropylene fiber Reinforced Concrete mixes provide development of high overall performance and high power concretes. This study was conducted to investigate the strength and acid resistance properties of Rice Husk Ash (RHA) concrete reinforced with polypropylene fibres (PP). The properties evaluated include compressive strength, splitting tensile strength and Flexural strength test, an experimental program was planned. Ordinary Portland Cement (OPC) was partially replaced with RHA up to 10% constant for all mixes and addition of PP fiber different percentage as 0.50%, 75%, 1%, 1.5% and 2% by weight of binder. The use of RHA in concrete mixes was found to increase the compressive strength at later ages and higher amount of PP Fiber with decreases compressive strength. The splitting tensile strength was found to increase percentage PP fiber with decreasing concrete strength. Finally it is observed that increasing mechanical properties of concrete upto used 1% PP fiber for all mixes after that increasing more percentage of PP fiber with decreasing all properties of concrete. The addition of small amount of polypropylene improved the mechanical properties of concrete.

Keywords- polypropylene fiber, concretes, compressive strength, splitting tensile,

1. Introduction

The capability of durable structure to resist weathering action, chemical attack, abrasion and other degradation processes during its service life with the minimal maintenance is equally important as the capacity of a structure to resist the loads applied on it. Although concrete offers many advantages regarding mechanical characteristics and economic aspects of the construction, the brittle behavior of the material remains a larger handicap for the seismic and other applications where flexible behaviour is essentially required. Recently, however the development of polypropylene fiber-reinforced concrete (PFRC) has provided a technical basis for improving these deficiencies. This paper presents an overview of the effect of polypropylene (PP) fibers on various properties of concrete in fresh and hardened state such as compressive strength, tensile strength, flexural strength, workability, bond strength, fracture properties, creep strain, impact and chloride penetration. The role of fibers in crack prevention has also been discussed.

VARIATION OF PROPERTIES OF CONCRETE WITH RICE HUSK

The incorporation of rice husk ash in concrete converts it into an eco-friendly supplementary cementations material. The following properties of the concrete are altered with the addition of rice husk:

- The heat of hydration is reduced. This itself help in drying shrinkage and facilitate durability of the concrete mix.
- The reduction in the permeability of concrete structure. This will help in penetration of chloride ions, thus avoiding the disintegration of the concrete structure.
- There is a higher increase in the chloride and sulfate attack resistance

The rice husk ashes in the concrete react with the calcium hydroxide to bring more hydration products. The consumption of calcium hydroxide will enable lesser reactivity of chemicals from the external environment.

APPLICATIONS OF RICE HUSK ASH

The rice husk ash is a green supplementary material that has applications in small to large scale. It can be used for waterproofing. It is also used as the admixture to make the concrete resistant against chemical penetration.

The main applications of rice husk ash in the construction are:

- High-performance Concrete
- Insulator
- Green concrete
- Bathroom floors
- Industrial factory floorings
- Concreting the foundation
- Swimming pools
- Waterproofing and rehabilitation

WHAT IS POLYPROPYLENE?

The raw material of polypropylene is derived from monomeric C3H6 which is purely hydrocarbon. Due to regular structure, it is known as isotactic polypropylene. Chemical inertness makes the fibers resistant to most chemicals.

FOLLOWING ARE THE DIFFERENT TYPES OF FIBRES

Following are the different type of fibres generally used in the construction industries.

1. Steel Fibre Reinforced Concrete.
2. Polypropylene Fibre Reinforced (PFR) cement mortar &concrete
3. Glass-Fibre Reinforced Concrete
4. Asbestos Fibres
5. Carbon Fibres
6. Organic Fibres

Fibres impart energy absorption, toughness and impact resistance properties to fibre reinforced concrete material and these characteristics in turn improve the fracture and fatigue properties of fibre reinforced concrete research in Polypropylene Fibre reinforced concrete resulted in the development of an alkali resistance fibres high dispersion that improved long term durability.

Polypropylene Fibre Reinforced Concrete (PPFRC) is composed of concrete, reinforced with glass fibres to produce a thin, lightweight, yet strong material. Though concrete has been used throughout the ages, PPFRC is still a relatively new invention. High compressive and flexural strengths, ability to reproduce fine surface details, low maintenance requirements, low coefficients of thermal expansion, high fire resistance, and environmentally friendly made PPFRC the ideal choice for civil engineers. The strength of PPFRC is determined by Polypropylene content, fiber size, fibre compaction, distribution and orientation.

ADVANTAGES OF POLYPROPYLENE FIBRES

- It increases the tensile strength of the concrete.
- It reduces the air voids and water voids the inherent porosity of gel.
- It increases the durability of the concrete.
- Fibres such as graphite and glass have excellent resistance to creep, while the same is not true for most resins. Therefore, the orientation and volume of fibres have a significant influence on the creep performance of rebars/tendons. Reinforced concrete itself is a composite material, where the reinforcement acts as the strengthening fibre and the concrete as the matrix. It is therefore imperative that the behaviour under thermal stresses for the two materials be similar so that the differential deformations of concrete and the reinforcement are minimized.
- It has been recognized that the addition of small, closely spaced and uniformly dispersed fibres to concrete would act as crack arrester and would substantially improve its static and dynamic properties.

1.2 Literature survey

Toutanji (1999) studied mechanical properties of expansive-cement concrete containing silica fume and polypropylene fibers. Properties studied include those of the fresh mix properties, length change, rapid chloride permeability, compressive strength, flexural behaviour, and bond of hardened concrete.

Silica fume content used was 5 and 10% and fiber volume fraction was 0.10, 0.30, and 0.50%. Results showed that the use of 5% silica fume combined with 0.30% fiber volume fraction results in optimum mixture design for repair applications from the standpoints of workability, bond, strength, length change and permeability.

Griffiths (2000) carried out the study to investigate the mechanical properties of glass fibre reinforced polyester polymer concrete. It was found that the modulus of rupture of polymer concrete containing 20% polyester resin and about 79% fine silica aggregate is about 20 MPa. The addition of about 1.5% chopped glass fibres (by weight) to the material increases the modulus of rupture by about 20% and the fracture toughness by about 55%. Glass fibres improve the strength of the material by increasing the force required for deformation and improve the toughness by increasing the energy required for crack propagation.

Hassan and Cabrera (2000) carried out study on the influence of two mineral admixtures, silica fume (SF) and fly ash (FA), on the properties of super plasticized high-performance concrete. Evaluation was made by comparing the porosity, compressive strength, oxygen permeability, oxygen diffusion and chloride micron. It was observed that SF contributed to both short and long-term properties of concrete, FA required a relatively long time to get its beneficial effect. For the SF and FA concrete mixes, 10 and 30 by weight of OPC were replaced by SF and FA. A high super plasticizer dosage was used. The water—binder ratios was 0.32, 0.32 and 0.29 for the OPC, SF, and FA respectively. Concrete cubes (100 mm) and slabs

(400×250×40mm3) were cast out of each mix. Minimum strength values of 80mpa 28 days and 90MPa 1 year were achieved for different mixes regardless of the binder type. It was found that SF enhances the early ages as well as long-term properties of concrete. It reduces the permeability by 71 and 87 1 and 365 days compared to OPC concrete. FA concrete has relatively poorer characteristics early ages, and achieves similar strength in the long term.

Seddik et.al (2000) performed a study on the development of high performance concrete using silica fume (SF), relatively high water-binder ratios. Compressive strength and dynamic modulus of elasticity were determined the ages of 28 and 91 days in accordance to ASTM C39 and BS 1881: part 209, initial surface absorption (ISA) was determined the age of 28days in accordance to BS 1881: part 5. It was observed that the highest compressive strength, modulus of elasticity and the lowest ISA were exhibited by the water-cured specimens compared to dry air curing 28 and 91 days. It was observed that concrete containing silica fume (about 10 by weight) can increase the compressive strength by 16 and elastic modulus by 5. Water-binder ratio of 0.45 gives more compressive strength (around 20), more dynamic modulus of elasticity (1.3) than water-binder ratio of 0.50.

Kanstad et.al (2000) performed a study to address the effect of silica fume on the early age crack sensitivity of HPC. Tests were performed on concrete containing silica fume ranging from 0 to 15%, with a w/c ratio of 0.40. Tests carried on realistic temperatures, tensile strength, modulus of elasticity, and autogenously shrinkage. All tests were conducted under isothermal conditions. Data were collected for 7 days for autogenously shrinkage. It was observed that an increase in silica fume content raises the tensile strength and modulus of elasticity but also causes more auto genous shrinkage. Despite the higher drying shrinkage, increasing the curing time could reduce this.

Zain et.al (2000) investigated the development of high performance concrete (HPC) using silica fume (SF) at relatively high water-binder ratios. For this purpose, waterbinder ratios of 0.45 and 0.50 were considered. Test specimens were air and water cured and exposed to a medium temperature of 20 to 50 degree centigrade. The compressive strength, modulus of elasticity and initial surface absorption (ISA) of hardened concrete were determined in the laboratory. It was observed that concrete under water curing offers the best results. The highest level of compressive strength and modulus of elasticity and lowest level of ISA were produced by SF concrete under curing and at a temperature of 35 degree centigrade. It was found that, under controlled curing conditions, it is possible to produce HPC at relatively high waterbinder ratios. Silica fume concrete produced the highest level of compressive strength and dynamic modulus of elasticity and lowest level of ISA under water curing. It was observed that incorporation of silica fume in concrete significantly increases the compressive strength and the dynamic modulus of elasticity and decreased the ISA compared to control. Curing conditions significantly influenced the compressive strength and dynamic modulus of elasticity. SF concrete subjected to dry air at 35 degree centigrade after 14 days initial water curing produced the highest compressive strength and dynamic modulus of elasticity when continuously cured under water at 20 degree centigrade.

Sorousshian (2001) carried out a study on the relative effectiveness of different types of steel fibre in concrete. It was found that the inclusion of fibres decreases the workability of fresh concrete and this effect is more pronounced for fibres with higher aspect ratios. The effects of fibre type on fresh mix workability, as represented both subjectively and by the inverted slump and cone time, seem to be insignificant. Crimped fibres result in slightly higher slump values when compared with straight and hooked fibres.

Khan and lynsdale (2001) performed a study on the development of high-performance concrete and form part of an investigation into the optimization of a blended cementations system for the development of high-performance concrete. PFA 0, 20, 30 and 40 (by weight) was incorporated as partial cement replacement. These binds 0, 5, 10 and 15 SF replacement levels with water-binder (w/b) of 0.27. Concrete 100 mm cubes were cast for compressive strength and carbonation measurements. Cylinders of 100 mm diameter, 200 mm long and 50 mm diameter 100 mm were cast for the determination of splitting tensile strength and oxygen permeability. It was observed that the incorporation of SF content increased the early strength for all mixes. SF inclusion, by up to 10 replacement level, significantly reduced oxygen for all levels of PFA replacements. The incorporation of 8-12 SF yielded the optimum strength and permeability values.

Kayali et al. (2002) carried out a study on the Sintered fly ash aggregates were used in the lightweight concrete; the fines were partially replaced by fly ash. The effects on compressive strength, indirect tensile strength, modulus of rupture, modulus of elasticity, stress–strain relationship and compression toughness are reported in this study. It was observed that Compared to plain sintered fly ash lightweight aggregate concrete, polypropylene fiber addition at 0.56% by volume of the concrete, caused a 90% increase in the indirect tensile strength and a 20% increase in the modulus of rupture. Polypropylene fibre addition did not significantly affect the other mechanical properties that were investigated. Steel fibres at 1.7% by volume of the concrete caused an increase in the indirect tensile strength by about 118% and an increase in the modulus of rupture by about 80%. Steel fibre reinforcement also caused a small decrease in the modulus of elasticity and changed the shape of the stress–strain relationship to become more curvilinear. A large increase in the compression toughness was recorded in this study. This indicated a significant gain in ductility when steel fibre reinforcement is used.

Song et al. (2004) studied the mechanical properties of high-strength steel fiberreinforced concrete. The properties included compressive and splitting tensile strengths, modulus of rupture, and toughness index. The steel fibres were added at the volume fractions of 0.5%, 1.0%, 1.5%, and 2.0%. It was observed that the compressive strength of the fibre-reinforced concrete reached a maximum at 1.5% volume fraction, being a 15.3% improvement over the HSC. The splitting tensile strength and modulus of rupture of the fibre-reinforced concrete improved with increasing the volume fraction, achieving 98.3% and 126.6% improvements, respectively, at 2.0% volume fraction. The toughness index of the fibre-reinforced concrete improved with increasing the fraction. The indexes I5, I10, and I30 registered values of 6.5, 11.8, and 20.6, respectively, at 2.0% fraction. Strength models were established to predict the compressive and splitting tensile strengths and modulus of rupture of the fiber-reinforced concrete.

Poon et al. (2004) studied the compressive behaviour of fiber reinforced high-performance concrete subjected to elevated temperature. Combination of steel (hooked) and polypropylene (19 mm length) fibers with different volume fractions were added into the mix. Those authors concluded that PP fibers slightly increased the specific toughness and compressive strength of the concrete for unheated specimens, however, they resulted in a quicker loss of the compressive strength and toughness after exposure to the elevated temperatures. They also stated that the combined use of PP fiber and steel fiber showed little benefits compared with the use of steel fibers only.

Huang et al. (2006) studied the morphology and dynamic contact angels of PP fibers treated with plasma. The treatment was performed with oxygen and argon at a pressure of 15 Pa. The authors concluded that the plasma treatment can considerably reduce the contact angle and significantly improve the wettability of PP fibers. They also found that the surface roughness is the main reason for reducing the receding contact angle, while the advancing contact angle is more related to the surface properties of the fibers.

Zeilml et al. (2006) added 1.5 kg/m3 PP fiber, 18 μm diameter and 6 mm length, to the concrete mixture. They performed permeability test on specimens with no heat treatment and after pre-heating to the temperature ranging from 80 to 600 ºC to evaluate the influence of PP fiber in spalling behaviour of in-situ concrete. They concluded that at pre-heating temperatures lower than 140 ºC, the permeability of concrete was three to four times larger than that of plain concrete with decreasing differences for increasing temperatures. For temperature between 140 and 200 ºC, the difference between the permeability of concrete with and without PP fibers increased. Hence, in the case of the tested in-situ concrete, the effect of melting of PP fiber had equal impact as the difference in the low temperature permeability.

Banthia and Gupta (2006) investigated the influence of PP fiber geometry on plastic shrinkage cracking in concrete. Four types of PP fibers, three monofilament and one fibrillated fiber type, with different volume fractions were added into separate concrete overlay mixtures. They concluded that PP fibers are highly effective in controlling plastic shrinkage cracking in concrete. The addition of fibers reduced the total crack area, maximum crack width and the number of cracks. They also stated that the effectiveness of fiber reinforcement increases when fiber volume fraction increases.

Aly et al. (2008) evaluated the effect of PP fibers on shrinkage and cracking of concretes. They employed a commercial PP fiber in the form collated fibrillated fiber bundles of 19 mm length with different volume fractions fibers ranging from 0.05 to 0.5 % in the mixtures. They concluded that increasing dosages of PP fiber in concrete caused small but consistent increases of the overall total shrinkage strain of concrete. The increases in shrinkage are notable in concretes without any curing (exposed at 1-day). In concretes with 7-days moist curing, the shrinkage differences are not significant. The authors also concluded that concrete mixtures that incorporated PP fiber are more permeable and hence more vulnerable to drying, as evidenced by more moisture lost during the period of drying than the companion mixtures without fibers.

Hsie et al. (2008) investigated the mechanical properties of PP hybrid fiber-reinforced concrete. The combination of coarse monofilament PP fibers and staple PP fiber with different volume fractions were evaluated. They concluded that the performance of hybrid FRC was better than that of single FRC. Comparing with the strength of plain concrete, the compressive strength of PP hybrid FRC, splitting tensile strength, and modulus of rupture, increased by 17.31 %, 13.35 % and 24.60 %, respectively.

Ganeshan et.al (2008) carried out a study on the effect of steel fibres on the strength and behaviour of fibre reinforced SCC structural elements subjected to flexure. The variables in this study were aspect ratio (15, 25 and 35) and percentage of volume fraction (0, 0.25, 0.5 and 0.75) of fibres. It was found that the first crack load and the post cracking behaviour were found to have improved due to the addition of fibres. A marginal improvement in the ultimate strength was observed. The addition of fibres had enhanced the ductility significantly. The optimum volume fraction of fibres was found to be 0.5 percent.

Methodology and flow chart

Splitting Tensile Test

This test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine (Fig.3.2) and load is applied until failure of the cylinder, along the vertical diameter.

The test was conducted on cylinders of size 100mmdia and of 300 mm length. Specimens were taken out from curing tank at the age of 28, days of water curing. Surface water was then allowed to drip down. Specimens were then tested on 200 tones capacity Compression Testing Machine (CTM). And test as per IS: 516 and 1199. Different types of specimens prepared were shown in Fig.3.4.

The split tensile strength was determined by using the following formula.

Split tensile Strength (MPa) = 2P / ΠDL

P = Splitting Load in KN

D= diameter of cylinder sample

L = length of cylinder sample

Fig. 3.3 Splitting tensile test

Flexural strength Tests

All the beam specimens were tested on a Universal testing machine of 2000 kN capacity The technical data of UTM machine are shown in Table 3.14. The testing procedure of all the beam specimens was same. First the beams were cured for a period of 28 days then its surface is cleaned with the help of sand paper. After this the specimens were given a white wash and identification number. The white wash was given to enable the detection of cracks during testing at various stages of loading. Two point transverse loading was used to testing the beam specimens. Two-point loading is conveniently provided by the arrangement shown in Fig. Flexural strength test Flexural strength is calculated using the equation: F= PL/ (bd2) Where, F= Flexural strength of concrete (in MPa). P= Failure load (in N). L= Effective span of the beam (400mm).

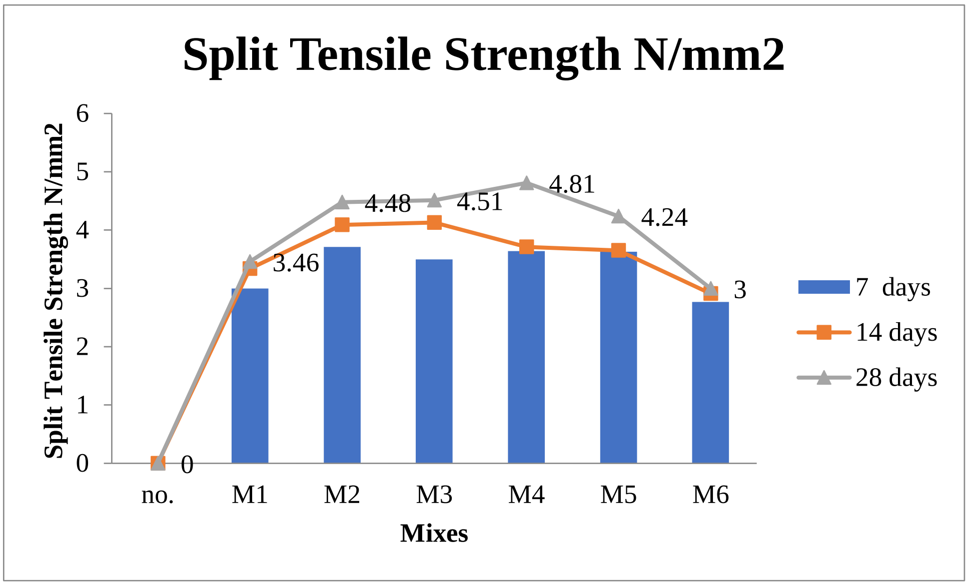
RESULTS AND DISCUSSION

Split Tensile Strength Test Results

The results of the splitting tensile strength tests conducted on concrete specimens of different mixes cured at different ages are presented and discussed in this section. The splitting tensile strength test was conducted at curing ages of 7, 14, and 28 days. The splitting tensile strength test results of all the mixes at different curing ages are shown in Table 4.3.Variation of splitting tensile strength of all the mixes cured at 7,14, and 28 days is also shown in Fig.

Table 1. Splitting tensile strength (MPa) results of all mixes at different curing ages.

Mix no.	Description	7 days	14 days	28 days
1	90%OPC+10%RHA+0%PP	3.00	3.34	3.46
2	90%OPC+10%RHA+0.5%PP	3.71	4.09	4.48
3	90%OPC+10%RHA+0.75%PP	3.50	4.13	4.61
4	90%OPC+10%RHA+1%PP	3.64	3.71	4.81
5	90%OPC+10%RHA+1.5%PP	3.63	3.65	4.24
6	90%OPC+10%RHA+2%PP	2.77	2.91	3.00



Graph 1 Variation of split tensile strength of concrete with age

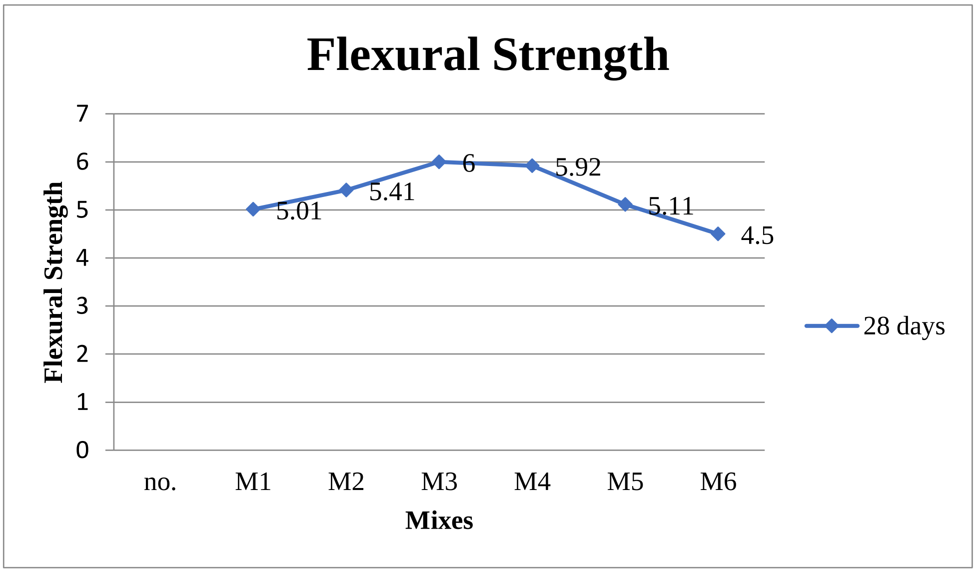
Results shows that mix 4 has 28 days split tensile strength when mix adopted as90%OPC+10%RHA+1%PP as compared to normal mix.

Flexural strength Tests Results

The results of the flexural strength tests conducted on concrete specimens of different mixes cured at different ages are presented and discussed in this section. Flexural strength test was conducted at curing ages of 28 days. The flexural strength test results of all the mixes at different curing ages are shown in Table 4.4.Variation of splitting tensile strength of all the mixes cured at 28 days is also shown in Fig.

Table 2. Flexural strength (MPa) results of all mixes at different curing ages.

Mix no.	Description	28 days
1	90%OPC+10%RHA+0%PP	5.01
2	90%OPC+10%RHA+0.5%PP	5.41
3	90%OPC+10%RHA+0.75%PP	6.00
4	90%OPC+10%RHA+1%PP	5.92
5	90%OPC+10%RHA+1.5%PP	5.11
6	90%OPC+10%RHA+2%PP	4.50



Graph 2. Variation of Flexural strength of concrete with age

Results show that mix 4 has 28 days flexural strength more compared to control concrete.

DISCUSSION ON RESULTS

Slump : Results shows that as the addition of fibres to concrete mix increases, the workability of concrete mix has found to decrease as compared to control mix.

Compressive Strength Test Results show that mix M2 has 28 days compressive strength more in compare to control concrete when 90%OPC+10%RHA+0.5%PP used.

Split Tensile Strength Test Results shows that mix 4 has 28 days split tensile strength when mix adopted as90%OPC+10%RHA+1%PP as compared to normal mix.

Flexural strength Tests Results show that mix 4 has 28 days as flexural strength when mix adopted as 90%OPC+10%RHA+1%PP as compared to control concrete.

CONCLUSION AND SCOPE FOR FURTHER STUDY

Based on the scope of work carried out in this investigation, following conclusions are drawn.

a. It was observed that flexural strength of concrete increasing with optimum addition percentage of PP fiber as 1%.

b. The effect of RHA in concrete to fill the presence void in mix due to increasing all mechanical properties of RHA concrete.

- Study can be for light weight and high performance concrete.
- Study can be carried out to evaluate the shear performance of beam specimens made with natural fiber and rice husk ash.
- More investigations and laboratory test should be done on the strength characteristics of natural fiber and rice husk ash. It is recommended that testing can be done on concrete slabs, beams and walls.
- Study can be carried out to investigate the behavior of concrete specimens with different replacement of cement with rice husk ash.
- Study can be carried out on high strength and durability concrete with natural fiber and rice husk ash.

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