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RESEARCH ARTICLE

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TERNARY EFFECTS ON CEMENT BLENDS OF CONCRETE CONTAINING NANO SILICA, METAKAOLIN AND ZEOLITE WITH FIBERS

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ABSTRACT

Fast progress of present-day concrete practice brings development of new technologies applying in concrete. An experimental investigation was carried out to evaluate the mechanical properties of concrete mixtures containing natural zeolite, nano silica and metakaolin (MK) in ternary blended system up to 30% replacement. Mixes were prepared using water to binder ratio of 0.42 wt%. Hydration characteristics of the different hardened concrete were investigated via the examination of compressive strength test, split tensile strength and flexural strength under normal curing conditions at time intervals up to28 days.

The replacement of cement 17.5% by the pozzolanic materials such as metakaolin (5%), zeolite (5%) and nano silica (2.5%) gives 52% higher compressive strength than the plain concrete. It is also observed, with the addition of zeolite (10%), metakaolin(15%) and nano silica (2.5%) that the compressive strength is decreased about 15% lower than the reference mix. This mix was taken for further investigation, and the natural fibres (coir and sisal) are added up to 1.25%. At lower content of fibre (coir fibre and sisal fibre), up to 1%, the relative increase in strength is observed about 20 to 50% higher than the plain concrete. This could be due to the potential of fibre to resist the compressive stress. The addition of fibres significantly improved many of the engineering properties of the concrete, notably compressive strength, flexural strength and tensile strength. When fibre is incorporated up to 1% in concrete, this could be prevented as cracks propagate gradually.

Keywords—Concrete; Nano Silica; Natural Zeolite; Metakaolin; Coconut coir fiber; Sisal fiber

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INTRODUCTION

Infrastructure development across the world created demands for constructing material. Concrete manufacturing involves consumption of ingredients like cement, aggregate, water, admixtures. Above all of them cement production involves high energy consumption and it is responsible for approximately 7% of world CO_2 emission. CO_2 is a major contributor to the green house effect and consequently responsible for global warming of the planet.

Therefore research on use of by-product cementing material such as fly ash, silica fume, ricehuskash, metakaolin, zeolite, nanosilica, flyash has in place of cement increasing in concrete technology. This material having good pozzolanic activity and it is produced high strength concrete. It has higher powder content than normal concrete. The additions of pozzolanic materials improve the mechanical characteristics of these concrete and contribute towards a higher durability. Pozzolans are known to increase the durability, lower the heat of hydration, and increase the resistance to sulphate attack.

Concrete made with Portland cement has certain characteristics. It is strong in compression but weak in tension and tends to be brittle. The weakness in tension can be overcome by the use of conventional steel bar reinforcement and to some extent by the inclusion of a sufficient volume of certain fibres. The use of fibers alters the behaviour of the fibre-matrix composite after it has cracked, thereby improving its toughness.

Metakaolin(MK) has become a popular partial replacement of cement in construction industry. MK is increasingly being used to produce materials with higher strength, denser microstructure, lower porosity, higher resistance to ions, and improved durability. MK has pozzolanic properties which is the reason of its positive effect on the final properties of the concrete.

Nano Silica (NS) is one of the blending materials used to improve the properties of concrete. NS concrete is stickier than normal concrete due to large surface area of NS, and also it has better permeability resistance. NS is typically a highly effective pozzolanic material. It normally consists of very fine vitreous particles approximately 1000 times smaller than the average cement particles. It has proven to be an excellent admixture for cement to improve strength and durability and decrease permeability. NS reduces the setting time and increases the compressive strength and tensile strength. NS consumes calcium hydroxide crystals & improves the interfacial zone.

Natural zeolite (NZ) is a popular type of natural pozzolan which has been widely utilized in construction. NZ are hydrated alumino-silicates that occur mainly in altered volcanic tuffs. Because of their origin, they can be associated with substantial amounts of clays, feldspars or glass. Zeolites consist of an open silica framework, for which alumina can substitute in variable proportions, whereas exchangeable alkaline and alkaline-earth metals compensate for the resulting charge deficit. Together with variable amounts of water, these cations are more or less loosely bound to framework oxygen's in the open channels. It is known that they show considerable pozzolanic activity despite their distinct crystalline structure.

Coconut fibers obtained from coconut husk, it is the agricultural waste products obtained in the processing of coconut oil, and are available in large quantities in the tropical regions of the world. Coconut fiber has been used to enhance concrete and mortar, and has proven to improve the toughness of the concrete.

Sisal fiber is one of the natural fibers used in commercial application, in which it is estimated in more than half of the total of all natural fibers used. The plants look like giant pineapples, and during harvest the leaves are cut as close to the ground as possible. The soft tissue is scraped from the fibers by hand or machine. The fibers are dried and brushes remove the remaining dirt, resulting in a clean fiber. Sisal produces sturdy and strong fibers.

Considerable efforts has been taken worldwide to utilize local natural waste and by-products materials as supplementary cementing materials to improve the properties of cement concrete as well as the use of these materials leads to the proper disposal of natural waste results in the less impact on environment.

Review of Literature

The influence of nanosilica particles on the mechanical properties and durability of concrete through measurement of compressive strength, tensile strength, water absorption and the depth of chloride penetration. It was observed that the compressive and tensile strength increased in presence of nano silica particles, which indicates the pozzolanic activity of nano silica. Improvement in interfacial transition zone was noted and also water absorption, capillary absorption and distribution of chloride ion test results indicate the nano silica concrete has better permeability resistance than the normal concrete. (Khanzadi et al 2010). The result of an experimental study to evaluate the strength of hardened concrete for nano silica. Replacing the nano silica by various percentage of cement from 0.25% to 2.50% for M20 and M40 concrete at 7 and 28 days of curing. The maximum strength was obtained for the replacement ratio 2% for M20 grade concrete, 1.5% for M40 grade concrete. It can be concluded that the value of efficiency factor can be considered as 6.0 to arrive economical mix design. Addition of nano particles makes concrete stickier. (C.K. Sridhar et al 2014). The performance of mortar and concrete with local metakaolin was replaced upto the 30% by mass of cement. The compressive strength of mortar was increased upto 15% replacement of metakaolin after that, the compressive strength was decreased. The flexural strength of mortar was increased up to 20% replacement of metakaolin. The addition of superplasticzers was increased to maintain the workability. The compressive strength of concrete was increased up to 10% replacement of metakaolin. The metakaolin has a very positive effect on water permeability under pressure. Mixes upto 15% replacement of metakaolin gives better resistance against permeability. (M.Si.Ahmed et al 2012). The mechanical and durable property of concrete mixtures containing natural zeolite and metakaolin, and it is compared with the normal concrete. Concrete mixtures with replacement level up to 20% with metakaolin or zeolite produced blended concrete with a similar strength compared to reference concrete. At early age the compressive strength of metakaolin is decreased but its strength was upgraded more than normal concrete. At all curing ages the compressive strength of zeolite is decreased, but it's not impressive. Water penetration and water absorption confirmed the beneficial effects of zeolite and metakaolin on the durability indexes of concrete by replacement volume up to 20%. The generous effects on the durability might be attributed to the pozzolanic reactions developed in the concrete mixtures incorporated metakaolin or zeolite as supplementary cementitious materials. (R.Madandoust et al 2013). The pozzolnic reaction between portlandite and different types of nearly pure natural zeolites was studied. Analcime, phillipsite, chabazite, erionite, mixed with portlandite and water 1:1:2 by weight and the progress of the pozzolanic reaction was quantitavely determined by thermo gravimetrical analysis by 3 to 180 days. The result shows the external surface area only influences the short term reactivity, whereas the cation content has an effect on both long and short term reactivity. Long term reactivity is mainly related to the Silica/ Alumina ratio of the zeolite. Samples with zeolite rich in silica react faster than their alumina. (G.Mertens et al 2009). Various pozzolanic cement paste based ordinary Portland cement, metakaoln , granulated blast furnance slag were studied. X-ray diffraction analysis analysis carried at various time intervals upto 90 days, it showed a decrease in the intensity of ch peaks in the presence of metakaolin and ground granulated blast furnance slag. Thermal ananlysis carried out for the mix containing 30% ground granulated blast furnance slag and metakaolin at 28 days. It confirmed the results in x-ray diffraction analysis. Electrical conductivity was measured during the early stages of hydration and compared to ordinary Portland cement. Higher slag metakaolin content have higher resistant to corrosion. (Maha R.Mohamed et al 2013).

Experimental Program

Materials Used

i)CEMENT

Ordinary Portland cement type (grade 53) was used for this investigation and it is confirm to the IS 12269-1987. Chemical composition and Physical properties of cement given in the table I and II

ii)FINE AGGREGATE

Locally available sand is used as fine aggregate. The sand confirming to IS: 2386 (part I) 1963 is used as fine aggregate. Physical properties of the sand is given in the table I and II.

iii)WATER

Ordinary tap water used for mortar preparation. Water should be clean and free from organic materials and deleterious amounts of dissolved acids, alkalies, and salts.

iv)METAKAOLIN

The raw material in the manufacture of metakaolin is kaolin clay. Kaolin is a fine white, clay mineral that has been used in the manufacture of porcelain. It is the dehydyroxylation form of the clay mineral kaolinite. The temperature of dehydroxylation in the range of 530°C to 630°C. Physical and chemical properties of metakaolin is given in the table I and II.

TABLE I. PHYSICAL PROPERTIES OF CEMENT, SAND, METAKAOLIN, NANO SILICA AND ZEOLITE

Properties	*Cement*	*Sand*	*Metakaolin*	*Zeolite*	*Nano Silica*
Specific gravity	3.15	2.65	2.56	2.5	2.5
colour	gray	Brownish gray	white	White	white
Initial setting time(min)	30	-	-	-	-
Final setting time(min)	600	-	-	-	-
Physical form	powder	Sub angular	Powder	powder	powder
Fineness modulus	-	3.57	-	-	-
Size	5-45µm	Smaller than 4.75mm	7-25 µm	Less than 2µm	35±5nm

TABLE II. CHEMICAL COMPOSITION OF CEMENT, METAKAOLIN, NANO SILICA AND ZEOLITE

Constituents	*Cement (%)*	*Metakaolin (%)*	*Nano silica (%)*	*Zeolite (%)*
CaO	63.25	0.37	0.01	0.50
SiO_2	22.42	52.37	99.5	45.17
Al_2O_3	4.68	42.87	0.08	37.59
Fe_2O_3	3.68	1.12	-	0.5
Tio2	-	1.77	0.04	0.50
MgO	0.25	0.25	0.01	-
Na_2O	0.75	0.12	-	0.31
K_2O	1.74	0.20	-	6.07
Loss of ignition	0.45	0.38	0.08	-
Alkalies	-	-	0.02	-

v)ZEOLITE

Zeolite is a naturally occurring pozzolanic mineral that can be benificated through calcination. The optimum pozzolanic reactivity and specific surface area are obtained when the calcinations is done at 800°C for 8 minutes. Chemical composition and physical properties of the zeolite is given in the table I and II.

vi)NANO SILICA

Nano silica is a non–crystalline form of silicon di-oxide and silica. It is the byproduct of silicon and ferro silicon alloy production and consists of spherical particles with an average particle diameter of 150nm. Chemical composition and Physical properties of nano silica is given in the table I and II.

vii)COCONUT COIR FIBER

The coconut fibre is extracted from coconut husk were soaked in water for one month and later placed in 10 % concentration of sodium hydroxide solution for 7 days to remove the vegetation matter. Physical properties of the coir fibre are given in the table III.

vii)SISAL FIBER

Vegetable sisal fibre is brought up from Tirunelveli. The sisal fibre is washed by the tap water to remove the dust particles and it is soaked in 10 % concentration of sodium hydroxide solution to remove the vegetation matter. Physical properties of sisal fibre are given in the table III.

TABLE III. PHYSICAL PROPERTIES OF COIR AND SISAL FIBER

Physical properties	Coconut coir fibre	Sisal fibre
Density	1.15g/cm^3	1.45g/cm^3
Length	20mm	15mm
Diameter	0.25mm	0.2mm
Aspect ratio	80	75

Mix Proportions

Concrete cube produced at various replacements ratio of metakaolin (5%, 10%, 15%) nano silica (2.5%) and zeolite (5%, 10%, 12.5%) by weight of cement. The water to cement ratio in the production of concrete is taken as 0.4 wt % of cement.

Casting and Curing of the Specimen

Metal moulds, preferably steel or cast iron is used for casting of the concrete, to prevent distortion. The height of the mould and the distance between the opposite faces are of the specified size ±0.2 mm. the base plate is of such dimensions as to support the mould during filling without leakage and it is preferably attached to the mould by screws. After that the thorough mixing of concrete is essential for the production of uniform concrete.

Hand mixing is used for mixing of the materials. Spread out the measured quantity of coarse aggregate and fine aggregate in alternative layers. Then the binding materials is pour on the top of it, and mix them dry by shovel, until the uniformity of colour is achieved. After that the water is sprinkled over the mixture and is continued till such time a good uniform, homogeneous concrete is obtained.

TABLE IV. **MIX PROPORTION OF CEMENT WITHOUT FIBER**

s.no	*Mix proportions of cement without fiber*			
	Cement (%)	*Zeolite (%)*	*Metakaolin (%)*	*Nano silica (%)*
1	100	-	-	-
2	87.5	5	5	2.5
3	82.5	5	10	2.5
4	77.5	5	15	2.5
5	82.5	10	5	2.5
6	77.5	10	10	2.5
7	72.5	10	15	2.5
8	80	12.5	5	2.5
9	75	12.5	10	2.5
10	70	12.5	15	2.5

The concrete is filled into the mould in layers approximately 5cm deep. Each layer is compacted by hand or vibrating machine. After the top layer has been compacted the surface of the concrete is brought to the finished level with the top of the mould. The standard tamping bar is used and the strokes of the bar are distributed in a uniform manner over the cross section of the mould.

The test specimen is stored in place free from vibration, in moist air of at least 90% relative humidity and at a temperature of 27+2°C for 24 hours+1/2 hours from the time of addition of water to the dry ingredients. After this period the specimen are marked and removed from the mould and unless required for test within 24 hours, immediately submerged in clean fresh water and kept there until taken out just prior to test. Cubical specimens (100 × 100 × 100 mm) were prepared to test the compressive strength of concrete.

Slump test

Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work.

Fig 1 slump test

Testing of Hardened Concrete

Compressive strength

Flexural strength

Split tensile test.

Compressive strength test

Specimens stored in water shall be tested immediately on removal from the water. Surface water shall be wiped off the specimen and any projecting find removed specimen when received dry shall be kept for 24 hours they are taken for testing.

Placing the specimen in the testing machine the bearing surface of the testing machine shall be wiped clean and any loose sand or other material removed from the surface of the specimen, which are to be in contact with the compression plates. The specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast. The axis of the specimen shall be carefully aligned with the centre of thrust of the spherically seated plate. No packing shall be used between the faces of the test specimen and the steel platen of the testing machine.

The spherically seated block is brought to bear on the specimen the movable portion shall be rotated gently by hand so that uniform seating may be obtained. The load is applied without shock and increase continuously at a rate of approximately 140 kg/cm2/min. until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted. Fig 2 shows the compressive strength test setup.

Fig 2 compressive strength test set-up

The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross sectional area.

After 28 days of curing the specimen was tested for compressive strength. From the above mix which one given the higher strength was taken and the natural fibre such as sisal fibre and coir fibre up to 1.25% is added to determine the compressive strength, split tensile strength and flexural strength of the concrete. The mixing was thorough to ensure that fibres were evenly distributed within the concrete matrix. Mix Proportion of Cement with Fibre is given the table v

TABLE V. **MIX PROPORTIONS OF CEMENT WITH FIBER**

s.no	Mix proportions of cement with fiber					
	Cement (%)	Metakaolin (%))	Zeolite (%)	Nano silica (%)	Coir fiber (%)	Sisal Fiber (%)
1	77.5	15	10	2.5	0.5	0.5
2	77.5	15	10	2.5	0.25	0.75
3	77.5	15	10	2.5	0.75	0.25
4	77.5	15	10	2.5	1.25	0.25
5	77.5	15	10	2.5	0.25	1.25

Flexural strength test

The beam of (500×100×100mm) sizes was casted. For each mixes 3 specimens were casted and the average of the mixes is taken for the calculation. The mould should be of metal and the metal should be sufficient thickness to prevent spreading or warping. The mould should be constructed with the longer dimension horizontal and in such a manner as to facilitate the removal of the moulded specimen without damage. The bearing surfaces of the supporting and loading rollers are wiped clean, and any loose sand or other metal removed from the surfaces of the specimen where they are to make contact with the roller.

Flexural strength is often measured on flexural testing machine. Two points loading is applied on the centre of the beam .The specimen is then placed in the machine in such a manner that the load is applied to the uppermost surface as cast in the mould. The axis of the specimen is carefully aligned with the axis of the loading device. No packing is used between the bearing surface of the specimen and the rollers. The load is applied without sock and increasing continuously. The load is increased until the specimen fails, and the maximum load is applied to the specimen during the test is recorded. Fig 3 shows the flexural strength test setup of the concrete beam.

The flexural strength $F_b = Pl/(bd^2)$

Fig 3 Flexural strength test set-up

Split tensile strength test

Cylindrical test specimens have a length equal to twice the diameter. There are 15cm in diameter and 30 cm long were casted. For each mixes 3 specimens were casted and the average of the mixes is taken for the calculation. Draw diametrical lines on two ends of the specimen so that they are in the same axis plane. The diameter of specimen to the nearest 0.2 mm by averaging the diameters of the specimen lying in the plane of remarked lines measured near the ends and the middle of the specimen. The length of specimen also shall be taken be nearest 0.2 mm by averaging the two lengths measured in the plane containing pre marked lines.

Place the specimen on the testing machine and align it so that the lines marked on the end of the specimen are vertical and centred over the plate. The assembly is positioned to ensure that lines marked on the end of specimen are vertical and the

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projection of the plane passing through these two lines interest the centre of the platen. Apply the load without shock and increase it continuously at the rate to produce a split tensile strength of approximately 1.4 to 7.5 N/mm2/min, until no greater load can be sustained. Record the maximum load applied to specimen. Fig 4 shows the split tensile strength test setup of the cylinder.

The split tensile strength T = 2P/ (πld)

Fig 4 Split tensile strength test set-up

Results and Discussion

The results of workability, mechanical strength properties such as compressive strength, split tensile strength, flexural strength have discussed.

Workability properties

The property of concrete which determine the amount of useful internal work necessary to produce full compaction is known as workability. The workability of fresh concrete is measured by means of slump con test.

As the pozolanic materials content is increased, the concrete may appear to become sticky due to their higher powder contentis shown in table VI

TABLE VI. SLUMP VALUE OF THE CONCRETE MIXES WITHOUT FIBRE

Slump value for the Concrete mixes without fibre (mm)									
Control mix	M1	M2	M3	M4	M5	M6	M7	M8	M9
26	24	26	27	28	27	26	25	26	24

There are two parameters that strongly influence the degree of damage to concrete workability caused by fibres. These are fibre volume fraction and aspect ratio. Generally increasing volume fraction and/or increasing aspect ratio of fibres results in further reduction of fresh concrete workability. Table 5.2 shows the slump value of concrete mixes with fibre.

TABLE VII. SLUMP VALUE OF THE CONCRETE MIXES WITH FIBRE

Slump value for the Concrete mixes with fibre (mm)					
Control mix	CS-1	CS-2	CS-3	CS-4	CS-5
26	28	27	26	26	27

TABLE VIII. COMPRESSIVE STRENGHT OF MIXES WITHOUT FIBRE

S.no	Compressive strength of concrete mixes without fiber				
	Cement (%)	Zeolite (%)	Meta kaolin (%)	Nano silica (%)	Compressive strength (N/mm^2)
Control mix	100	-	-	-	31.56
Mix 1	87.5	5	5	2.5	39.36
Mix 2	82.5	5	10	2.5	48.22
Mix 3	77.5	5	15	2.5	36.5
Mix 4	82.5	10	5	2.5	32.46
Mix 5	77.5	10	10	2.5	33.39
Mix 6	72.5	10	15	2.5	23.73
Mix 7	80	12.5	5	2.5	24.00
Mix 8	75	12.5	10	2.5	25.777
Mix 9	70	12.5	15	2.5	29.53

COMPRESSIVE STRENGTH

Totally 30 cubes specimen of size 100×100×100 mm with 10 mixes were casted and tested. Results for compressive strength based on the average values of three test data for all mixtures are presented in the table IX.

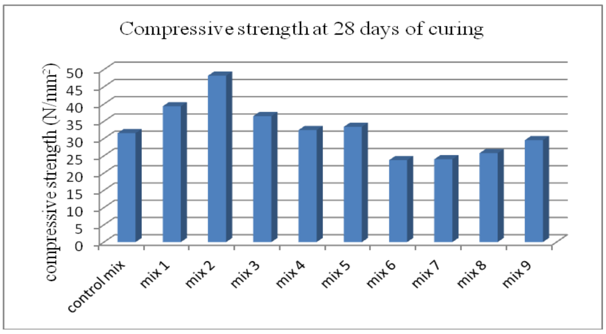

Fig 5 Compressive Strength of Concrete for Cubes

Based on the experimental results the compressive strength of concrete is affected by several factors viz. type, quality and proportion of replacing materials. The main contribution to strength development of concrete takes place about 28 days of curing. The replacement of cement 17.5 % by the pozzolanic materials such as metakaolin (5 %), zeolite (5 %) and nano silica (2.5 %) gives the higher compressive strength compare to the plain concrete.

From this Figure 5.1it is observed that, for all the mixes, the compressive strength of concrete is increased up to 25% higher than the reference mix. It is also observed, with the addition of zeolite (12.5%), metakaolin(5%, 10% and 15%) and nano silica (2.5%) that the compressive strength is decreased about 15% lower than the reference mix, but nearly equal to the control mix of concrete.

It is due to their higher powder content in concrete. The addition of pozzolanic material such as zeolite (10%, metakaolin (15%) and nano silica (2.5%) gives the strength 24% lower, compared to the reference mixes. The mix is taken for further investigation and the fibre is added about 1.5% to improve the properties of concrete such as compressive strength, split tensile strength and flexural strength is shown in table 5.4.

TABLE IX. **STRENGTH PROPERTIES OF MIXES WITH FIBRE**

S.No	Mechanical properties of concrete mixes with fibre Compressive strength (N/mm^2)	Flexural strength (N/mm^2)	Split tensile strength (N/mm^2)	Deflection (mm)
Control mix	23.73	6	2.67	0.013
Sisal fibre-0.5 Coir fibre-0.5 (CS-1)	35.8	6.2	2.92	0.013
Sisal fibre-0.75 Coir fibre-0.25 (CS-2)	33.7	6.4	2.98	0.014
Sisal fibre-0.25 Coir fibre-1 (CS-3)	26.15	5.8	2.56	0.012
Sisal fibre-1 Coir fibre-0.25 (CS-4)	25.09	5.6	2.37	0.012
Sisal fibre-0.25 Coir fibre-0.75 (CS-5)	35.3	6.72	2.86	0.015

Results of the compressive strength test for all the concrete mixes containing different ratio of fibres are presented in Table 5.4. The test results showed that the fibre had influence on the compressive strength development of concrete. At lower content of fibre (coir fibre and sisal fibre), up to 1%, the relative increase in strength is observed about 40 to 50% higher than the plain concrete.

This could be due to the potential of fibre to resist the compressive stress. The addition of coir fibre and sisal fibre up to 1.25 % give the lower compressive strength, but it is 5 to 10% higher than the reference mix. Higher fibre content in concrete might have caused voids resulting in decreased compressive strength. At 28 days curing, compressive strength of concrete mixes containing different ratio of fibre is shown in the Figure 6

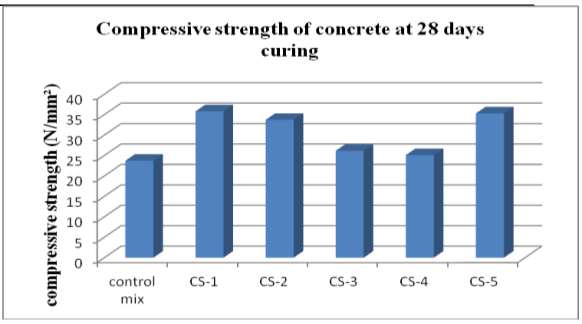

Fig 6 Compressive Strength of Concrete for Cubes

FLEXURAL STRENGTH

Flexural strength (modulus of rupture) is one of the principal factors in concrete pavement design as it measures the resistance of the concrete to flexural force. Results of the flexural strength test for all the concrete mixes containing different ratio of fibres are presented in Table IX

When concrete beams are subjected to flexural loading, there is tendency for flexural stress to develop which has the potential to initial cracks when the concrete carrying capacity is exceeded. The absence of crack is of considerable importance in maintaining the continuity of a concrete structure and in many cases in the prevention of corrosion of reinforcement.

From this Figure 6 the addition of sisal fibre 0.25%, 0.75%, 0.5% and coir fibre 0.75%, 0.25%, 0.5% gives the flexural strength 6.72, 6.4, 6.2 N/mm² respectively. The addition of fibres up to 1% improves the flexural strength of concrete 3 to 15% higher than the reference concrete. The addition of sisal fibre 1%, 0.25% and coir fibre 0.25%, 1% gives the flexural strength 5.6 and 5.8 N/mm² respectively. It is observed that the strength is 3.3 and 6.5% lower than the reference mix. The flexural strength of concrete beam is decreased when the addition of fibre is increased.

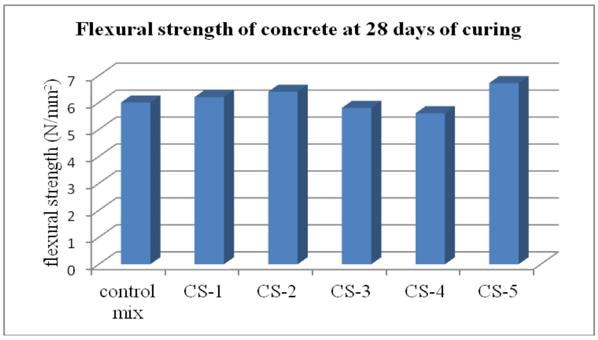

Fig 7 Flexural strength of concrete for beams.

SPLIT TENSILE STRENGTH

Split tensile strength which is a indirect measure of tensile strength of concrete. Fibre is a tough material that could provide needed resistance to limit propagation of cracks when optimum volume fraction is used. When the maximum reached failure will occur whether or not the stress is increased for normal concrete. But, when fibre is incorporated in concrete, this could be prevented as cracks propagate gradually is shown in the figure 8.

Fig 8 Crack Pattern of Cylinder

From the test results presented in table IX, it is noticed that the splitting tensile strength of plain concrete, improved by the addition of coir and sisal fibre. From the Figure 8 it is clearly observed that, there is no much variation in enhancement of tensile strength. The addition of coir fibre (0.25%, 0.5%, and 0.75%) and sisal fibre (0.75%, 0.5%, 0.25%) gives the tensile strength 2.98, 2.92, 2.86 N/mm² respectively.

The tensile strength is 11%, 9% 7% higher than the reference concrete. The addition of coir fibre 1%, 0.25% and sisal fibre (0.25%, 1%) gives the tensile strength 2.37, 2.5 N/mm² respectively. The figure 8 indicated that the strength is increased up to 1.0% by volume of fibre then decreased as fibre volume fraction increased, but still higher than plain concrete.

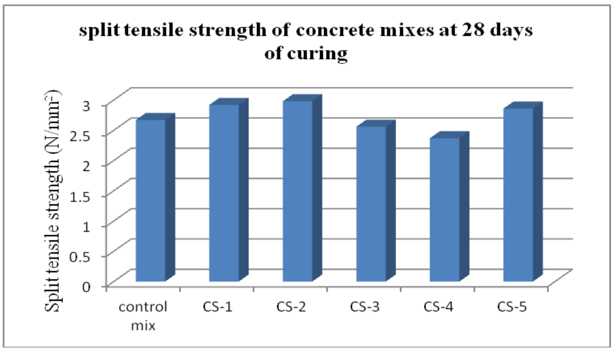

Fig 8 Split Tensile Strength of concrete for Cylinder

Conclusions

The findings of experimental investigations on the strength characteristics of concrete enhanced with coconut fibres and sisal fibres are reported. The following conclusions can be derived.

At lower content of fibre (coir fibre and sisal fibre), up to 1%, the relative increase in strength is observed about 40 to 50% higher than the plain concrete. This could be due to the potential of fibre to resist the compressive stress. Higher fibre content in concrete might have caused voids resulting in decreased compressive strength.

From this investigation the addition of fibres (sisal fibre and coir fibre) up to 1% improves the strength properties of concrete. It becomes evident that cement based matrices reinforced with sisal and coir fibres are on the horizon, thus bringing new trends in composite materials. But to make this a reality, some conditions may have to be met.

The addition of fibres significantly improved many of the engineering properties of the concrete, notably compressive strength, flexural strength and tensile strength. The ability to resist cracking and spalling were also enhanced.

However, the addition of fibres adversely affected the tensile strength as expected, due to difficulties in compaction which consequently led to increase of voids. Making concrete structure stronger in compression and tension, and it is more economical.

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