Influence of Fly Ash and Densified Silica Fume As Additives on Mechanical Properties of Coir Fiber Reinforced High-Strength Concrete

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Abstract- *This paper presents the experimental investigation carried out to determine the mechanical properties of coir fibre reinforced high strength concrete of grade M50 incorporating fly ash (FA) and densified silica fume (DSF). Three different compositions of coir fiber reinforced concrete (CFRC) were made. First CFRC without additives, second CFRC made by 10% replacement of cement mass with FA, in the third composition 10% of cement mass was replaced with DSF. In each mentioned admixture, coir was added in its natural length by 0.4% of the binder volume. The mechanical properties viz., compressive strength, flexural tensile strength, density and elasticity modulus of all mixes has been determined. The investigations revealed that adding coir fibres to high strength concrete caused a slight reduction in density and compressive strength of concrete by about 1.5 and 1.2% respectively. However, it improved the flexural tensile strength and dynamic elasticity modulus by 4 and 9%. Improvement of ductility in presence of coir has been proven through direct observation and experiment. Coir fiber reinforced concrete contains FA presented the highest strength compared to other mixes with about 8% higher strength compared to control concrete. It also presented the highest quality through sonic investigation followed by CFRC without additive and CFRC incorporating 10% DSF.*

Keywords— High Strength Concrete; Coir Fiber; Densified Silica Fume; Fly Ash; Compressive Strength; Flexural Strength; Young Modulus

I. INTRODUCTION

High strength concretes (HSC) has been extensively used in construction industry in recent years since most of the rheological and mechanical characteristics of these materials are better than those of normal strength concretes (NSC). HSC contains chemical admixtures, for water reduction, and having a compressive strength between 50 and 80 MPa.

Almost all these concretes have mineral additives involve for a variety of reasons including strength improvement, reduction of permeability, higher crack resistance and durability factors. Some pozzolans such as silica fume (SF) and fly ash (FA) have a significant potential in this context.

Advantageous incorporation of SF through pozzolanic reaction and micro-filler properties in HSC has been reported by some researchers . Similarly, FA characteristic as a partial cement replacement has been investigated by different authors and it is concluded that in addition to many environmental benefits, it also improves the properties and quality of HSC. However, as strength and softness are inversely proportional, HSC is more brittle than NSC and has some poor performances in case of ductility. As a result, it is essential for this type of concrete to be reinforced. Since, steel reinforced concrete has a short lifecycle due to the corrosion of the steel and it requires to be repaired continuously , adding fibres in the composite is efficient in order to overcome these problems and improving the toughness, tensile strength and deformation characteristics of the concrete, mainly due to their excellent properties and low cost. Among different types of fibres, natural fibres are renewable, non-hazardous, economic, abundant and are a proper replacement of asbestos . Coir is a kind of natural fibre which is abundantly available in tropical areas, moreover it is tough and durable, provide excellent insulation against temperature and sound and is unaffected by moisture . The achieved results of all the researches on the effect of coir on concrete properties have presented that coir fibre improves the mechanical properties of concrete. However, the number of these studies is very few and also there are no enough standards and reliable information available about the mechanical properties of HSC incorporating pozzolans and coir fiber in a combination. GENERAL Concrete is a mixture of various materials, consist of cement, fine aggregate, coarse aggregate and water which has emerged as a dominant construction material for the infrastructural and building needs. Concrete is probably the most extensively used construction material in the world. It is only second to water as the most heavily consumed substance with about six billion tones being produced every year.

Waste material has gained attention among researchers as replacement to natural aggregate or cement in concrete making. The sense of using waste materials in concrete not only of the economic factor but the more significant aspect is to protect the environment since more solid waste are produced day by day. There are also some other benefit can expected to be gained in term of quality in concrete by using aggregate from waste products such as sustainability in construction.

Durability of concrete has been as interest in research field since the durability problem has largely affecting concrete for a long term performance. Repair work due to weakening of concrete also imposed considerable expense and economic impact due to the repair works has been a great concern. To be durable, the concrete mass must have high resistance to access of external damaging agent which would consequently lead to the breakup of the hardened mass. To have such resistance, the durability of the Concrete should be of primary design concern along with strength design criteria.

Coal is one of the world's most important sources of energy, fuelling almost 40 percent of electricity worldwide. In many countries this figure is much higher: Poland relies on coal for over 97 percent of its electricity; South Africa for 92 percent; China for 77 percent; and Australia for 76 percent. In India, nearly 61% of power is made from coal based power plants.

PHYSICAL PROPERTIS OF CONCRETE:

Workability:

Workability that property of freshly mixed concrete that determines its working characteristics, i.e. the case with which it can be mixed, placed, compacted and finished.

- Factors effecting workability:
- Method and duration of transportation
- Quantity and characteristics of cementing materials
- Concrete consistency (slump)
- Aggregate grading, shape & surface texture
- % entrained air
- Water content
- Concrete & ambient air

Compressive strength:

Compressive strength is defined as the measured maximum resistance of a concrete or mortar specimen to an axial load, usually expressed in psi (pounds per square inch) at an age of 28-days.

Water/cement ratio:

- The single most important indicator of strength is the ratio of the water used compared to the amount of cement(w/c ratio)
- Basically, the lower this ratio is, the higher the final concrete strength will be
- This concept was developed by Duff Abrams of The Portland Cement Association in the early 1920s and is in today world wise use.

Segregation:

Segregation may be of three types

1. Coarse aggregate separating out or settling down from the rest of the matrix.
2. Paste separating away from coarse aggregate.
3. Water separating out from the rest of the material being a material of lowest specific gravity.

The conditions favorable for segregation are:

1. Badly proportioned mix where sufficient matrix is not there to bind and contain the aggregates
2. Insufficiently mixed concrete with excess water content
3. Dropping of concrete from heights as in the case of placing concrete in column concreting
4. When concrete is discharged from a badly designed mixer, or from a mixer with worn out blades
5. Conveyance of concrete by conveyor belts, wheel barrow, long distance haul by dumper, long lift by skip and hoist are the other situations promoting segregation of concrete

Bleeding:

Bleeding in concrete is sometimes referred as water gain. It is a particular form of segregation, in which some of the water from the concrete comes out to the surface of the concrete, being of the lowest specific gravity among all the ingredients of concrete.

Setting of concrete:

The hardening of concrete before its hydration is known as setting of concrete. OR The hardening of concrete before it gains strength. OR The transition process of changing of concrete from plastic state to hardened state.

Setting of concrete is based or related to the setting of cement paste. Thus cement properties greatly affect the setting time.

Factors affecting setting:

Following are the factors that affect the setting of concrete.
1. Water Cement ratio
2. Suitable Temperature
3. Cement content
4. Type of cement
5. Fineness of cement
6. Relative humidity
7. Admixtures
8. Type and amount of aggregate

Hydration of concrete:

Concrete derives its strength by the hydration of cement particles. The hydration of cement is not a momentary action but a process continuing for long time. Of course, the rate of hydration is fast to start with, but continues over a very long time at a decreasing rate In the field and in actual work, even a higher water/cement ratio is used, since the concrete is open to atmosphere, the water used in the concrete evaporates and the water available in the concrete will not be sufficient for effective hydration to take place particularly in the top layer.

Air entrainment:

Air entrainment reduces the density of concrete and consequently reduces the strength. Air entrainment is used to produce a number of effects in both the plastic and the hardened concrete. These include:

1. Resistance to freeze–thaw action in the hardened concrete.
2. Increased cohesion, reducing the tendency to bleed and segregation in the plastic concrete.
3. Compaction of low workability mixes including semi-dry concrete.

DESCRIPTION OF MARBLE POWDER

Waste marble powder is generated as a by-product during cutting of marble. The waste is approximately in the range of 20% of the total marble handled. The amount of waste marble powder generated at the study site every year is very substantial being in the range of 250-400 tones. The marble cutting plants are dumping the powder in any nearby pit or vacant spaces, near their unit although notified areas have been marked for dumping. This leads to serious environmental and dust pollution and occupation of vast area of land especially after the powder dries up (as shown in Figure 1). This also may leads to contamination of the underground water reserves (Branco et al., 2004; Vijayalakshmi et al., 2001).

Traditionally, WMP products are disposed of as soil conditioners or land fill. However, there might be reusing or recycling alternatives that should be investigated and eventually implemented. Thanks to Civil Engineering research, numerous uses of waste marble powder have been introduced, including use in tiles manufacturing, concrete mixes, subgrade fill, and modified binder (Huseyin et al., 2010; Nunes et al., 2009; Akbulut et al., 2007; and Bache H., 1981). Of our particular interest is the use of WMP in cement industry as a substitute of limestone for the production of clinker.

Environmental Problems Attributed to Waste Marble Powder

The WMP imposes serious threats to ecosystem, physical, chemical and biological components of environment. Problems encountered are:

- It adversely affects the productivity of land due to decreased porosity, water absorption, water percolation etc.
- When dried, it becomes air borne and cause severe air pollution. Introduces occupational health problems, it also affects machinery and instruments installed in industrial areas (Hwang et al., 2008).
- Affecting quality of water during rainy season, and reducing storage capacities and damaging aquatic life.
- It adversely affect social and industrial activities of people since the heaps of powder remain scattered all round the country are an eye sore and spoil aesthetics of entire region (Munoz-Montano et al., 2003).

Durability of concrete:

The durability of cement concrete is defined as it's ability to resist weathering action,chemicalattack,abrasion,or any other process of deterioration.durable concrete will retain it's original form,quality,and serviceability when exposed to it's environment.

Significance of durability:

When designing a concrete mix or desiging a concrete structure, the exposure condition at which the concrete is supposed to withstand is to be assessed in the beginning with good judgement. in case of foundations, the soil charactistics are also required to be investigated. the environmental pollution is increasing day by day particularly in urban areas and industrial atmospheres. it is reported that in industrially developed countries over 40% of total resources of the building industries are spent on repairs and maintainence. in I ndia, the money ie., spent on repairs of building is also considerable. every government department and municipal bodies have their own “repair boards” to deal with repairs of building. it is a sad state of affairs that we do not give enough attention to durability aspects even when we carry out repairs.

Impact of w/c ratio on durability:

The volume change results in cracks and cracks are responsible for dis-integration of concrete. the permeability is the contributory factor for volume change and higher w/c ratio is the fundamental cause of higher permeability. therefore, use of higher w/c ratio-permeabilty-volume change-cracks-disintegtation-failure of concrete is a cyclic process in concrete. therefore, for a durable concrete, use of lowest possible w/c ratio is the fundamental requirement to produce dense and impermeable concrete.

Permeability effect on durability:

w/c ratio is the fundamental point for concrete durability. another important point for consideration is the permeability of concrete. in case of durability permeability of concrete has much wider and direct repercussion on durability that of w/c ratio. forexample, micro cracks at transition zone is a consideration for permeability whereas w/c ratio may not get involved directly. it may be mentioned that micro cracks in the intial stage are so small that they may not increase the permeability. but propagation of micro cracks with time due to drying shrinkage, thermal shrinkage and externally applied load will increase the permeability of the system.

Permeability effect on concrete:

Theoretically, the introduction of aggregate of low permeability into cement paste, it is expected to reduce the permeability of the system because the aggregate particles intercept the channels of flows and make it take a circuitous route. compared to neat cement paste, concrete with the same w/c ratio and degree of maturity, should give a lower co-efficient of permeability. but in practice it is seen from test data it is not the case. The introduction of aggregate, particularly larger size of aggregates increase the permeability considerably. the development of micro cracks that are produced in the transition zone. the size of micro cracks that are generated at the transition zone.

PROBLEM FORMULATION

Conventional reinforced concrete uses steel rebars to increase the strength and ductility. Nevertheless, steel reinforcement is still costly in all countries throughout the world. In order to overcome the complexity, cost-effective but safe constructional material is required. Natural fibres can be one possible material, as they are economical and locally available in many countries. In this work, fly ash (FA) and densified silica fume (DSF) are employed in coir fibre reinforced high-strength concrete.

II. LITERATURE REVIEW

Compressive Strength

The strength development of concrete is stimulated by means of porosity of hydrated paste that is controlled via the presence of bond cracks at the interface of aggregate and hydrated paste and the water/cement ratio. The strength of individual constituent material of concrete has mark on the strength of concrete mix. The investigations display that bottom ash debris are vulnerable and greater porous than natural sand debris. The demand of mixing water elevated on its use in concrete as sand substitute. The higher demand of water is responsible for multiplied extent of all pores: pores left by using water, fissures shaped by bleeding etc. The higher water cement ratio outcomes in low density of bottom ash concrete mix. Since bottom ash concrete has better bleeding, there are extra probabilities of extra bleeding water getting trapped below the aggregates. This trapped water results inside the formation of the extra variety of small pores near to the aggregate surfaces. These pores prevent the excellent bonding of cement paste with the aggregate. Therefore the transition region between the aggregate and cement paste becomes susceptible and porous which in the end consequences in discount in strength of bottom ash concrete mix. The weak microstructure acquired with the usage of bottom ash is answerable for the decrease in compressive strength.

Ghafoori and Bucholc (1996) observed that compressive strength of bottom ash concrete was lower than that of control concrete but with increased curing age compressive strength was almost same. The mean compressive strengths of bottom ash concrete were 30% and 25% lower than those of control concrete at the curing age of 3 days and 7 days respectively. This difference dropped to

17% and 7% at 28 days and 180 days curing age. When a low dosage of admixture was used, compressive strength of bottom ash concrete at all levels of cement content improved. Compressive strength of bottom ash concrete at the age of 28 days increased by nearly 20% than that of the mix produced without admixture and by 3.5% than that of control concrete. However when a high range water reducing admixture was used in combined mixture of 50% bottom ash and 50% natural sand, compressive strength surpassed those of control mixture.

Ghafoori and Bucholc (1997) found that compressive strength of combined bottom ash and sand mix was lower than that of control concrete. The average differences in compressive strength at the age of 3 days and 7 days were 12% and 14.5% respectively. When high range water reducing admixture was used in combined mixture, compressive strength surpassed those of control sample at all levels of age. At 28 days of age the compressive strength increased by 24%.

Jaturapitakkulet al. (2003) studied the potential of using bottom ash from the Mae Moh power plant in Thailand as pozzolonic material. He found bottom ash which was used in concrete due to its pozzolonic reaction, improved its quality by grinding until the particle size retained on sieve 325 was less than 5% by weight. Bottom ashes before and after being ground were investigated and compared for their physical and chemical characteristics. The bottom ashes were used to replace Portland cement in mortar and concrete mixtures. He found that the particle of bottom ash was large, porous and a regular shapes. The grinding process reduced the particle size as well as porosity of bottom ash. Compressive strengths of mortar containing 20 to 30% of bottom ash as cement replacement were much less than that of cement mortar at all edges, but use of ground bottom ash produce higher compressive strength than the cement mortar after 60 days. He used bottom ash at 20% replacement of cement to make concrete, the concrete with higher cement content produce higher percentage of compressive strength. He concluded that ground bottom ash could be used Bottom ash as a good pozzolonic material.

Aramraks (2006) demonstrated that the compressive strength of 50% and 100% replacement bottom ash concrete was found to be approximately 20–40% lower than that of natural sand mixtures.

Andrade et al. (2007) observed that concrete mixes prepared with addition of bottom ash as equivalent volume replacement, correcting bottom ash quantities according to the moisture content showed very significant loss in compressive strength. However in case of concrete mix prepared with the addition of bottom ash as non-equivalent volume replacement, without correcting bottom ash quantities according to the moisture content the compressive strength of bottom ash concrete was similar to that of reference concrete.

Shi-Cong and Chi-Sun (2009) demonstrated that at a fixed W/C, the compressive strength decreased with the increase in the FBA content at all the ages. However when concrete was designed with a fixed slump range, bottom ash concrete showed higher compressive strength than that of the control at all the ages. The improvement in compressive strength could be attributed to the decrease in free W/C due to the fact that for a given slump, the high water absorption properties of FBA lead to reduction in demand of free water to produce the target slump value.

Yakhlaf and Safiuddin (2013) reported the Properties of freshly mixed carbon fibre reinforced self-consolidating Concrete; he examined the effects of discrete pitch-based carbon fibres on the fresh properties of self-consolidating concrete. Different carbon fibre reinforced self-consolidating concrete mixtures were produced incorporating 0%, 0.25%, 0.5%, 0.75% and 1% carbon fibres by concrete volume with two water-to-binder ratios (0.35 and 0.40). The characteristic properties of SCC are determined. The hardened concretes were tested by a Scanning Electron Microscope to observe the distribution of fibres. Carbon fibres were well-distributed and they slightly decreased the unit weight of concrete

Vikrant and Kavita (2013) studied the strength of normal concrete using metallic and synthetic fibers, in metallic fibers, steel fibers of hook end with 50, 60 aspect ratio and crimped round (copper coated) of 52.85 aspect ratio containing 0% and 0.5% volume fraction were used without adding admixtures. In synthetic fibers category, fibrillated polypropylene fibersof15 mm, 20 mm and 24 mm cut length at 0.4% by weight of cement were used without adding admixtures.The positive effect of steel fibers with different aspect ratios and fibrillated polypropylene fibers with different cut length in compression and splitting strengths.

Corinaldesi and Moriconi (2011) studied the characterization of self-compacting concretes prepared with different fibers and mineral additions, he prepared self-compacting concrete mixesby using three different types of fibersmade of steel, poly-vinyl-alcohol (PVA) and high toughness poly-propylene (PPHT) and two different types of mineral addition (limestone powder and powder from recycled concrete).Excellent performances were generally obtained, particularly for the self-compacting concretes prepared with steel fibers and powderfrom recycled concrete.

III. MATERIAL PROPORTION AND MIX DESIGN

MATERIAL

Test Program

The test program is planned to investigate the properties of the materials and its behavior. The test program involves

- Determination of essential properties of constituent materials principally cement, sand, coarse aggregates according to important Indian standard details.
- Determination of the essential parameters required in outline like compressive strength, split tensile strength.

Materials

- Cement, Fine aggregates, Coarse aggregates, water, Coal Bottom Ash and Super plasticizer are utilized as a part of throwing the cubes and cylinders of the specimen and the properties of these materials are said underneath,

Cement

- Ordinary Portland cement of 53 grade of Ultra Tech cement was utilized for the investigation. This cement is the most broadly utilized one as a part of the development business in India.
- The physical properties of cement as got from different tests are as given. All the tests were completed as per methodology set down in IS: 12269-1987.
- The estimations of the physical properties of cement which are normal consistency test, fineness of cement test, compressive strength, specifictest, setting test are given underneath in Table..

Table: Physical Properties of Cement

Sr. no.	Characteristics	Value obtained experimentally	Value specified by IS :12269-1987
1.	Normal consistency (%)	32	26 to 33
2.	Fineness of cement (%)	8.32	10
3.	Setting time (minutes) 1 initial 2 final	40 Minutes 360 Minutes	30 Minutes 600 Minutes
4.	Specific gravity	3.15	3.15
5.	Compressive strength (N/mm^2) 1. 3 days 2. 7 days 3. 28 days	34 N/mm^2 45 N/mm^2 59 N/mm^2	27 N/mm^2 37 N/mm^2 53 N/mm^2

Fine Aggregate

The Fine aggregate conforming to Zone-2 according to IS 383 was used. The fine aggregate used was obtained from a nearby river source. The sand obtained was sieved as per IS sieves (i.e. 2.36, 1.18, 0.6, 0.3, and 0.15mm).

Fig. sand

Coarse Aggregate:

Crushed granite was used as Coarse aggregate. The coarse aggregate was obtained from a local crushing unit having 20mm nominal size. 20mm well graded aggregate according to IS 383 is used in this investigation. The coarse aggregate procured from quarry was sieved through the sieves of sizes 20mm, 16mm, 12.5mm, 10mm and 4.75mm respectively. The material retained on each sieve was filled in bags and stacked separately.

Fig. Aggregates

Water

Fresh and clean consumable water is utilized for casting the specimens a role as a part of the present examination. The water which is utilized is predominantly free from organic matter, sediment, oil, sugar, chloride and acidic material according to Indian standard.

Super Plasticizer

Generally in order to increase the workability the water content is to be increased provided a corresponding quantity of cement is also added to keep the water cement ratio constant, so that the strength remains the same as cement, being in fine state of division will have a tenancy to flocculate in wet concrete. This flocculation's entraps certain amount of water used in the mix and there by all the water is not freely available to fluidity the mix. In the other way to avoid the use of excess quantity of water and cement, super plasticizer is used to fluidity the mix and improve the workability of concrete. Glenium 51 is required to improve the workability.

Preparation of Test Specimens

Mix Proportion

The mix proportions of bottom ash concrete and control concrete are given in table. The control concrete mixture was composed according to IS: 10262-2009. Natural sand was supplemented with coal bottom ash by various percentages in concrete (i.e., 0%, 10%, 20%, 30%, 40%, 50%).Fixed quantities of cement and coarse aggregates (30% 10 mm and 70% 20mm of the total 1356 kg/m3 were utilized respectively in the manufacturing of all the concrete samples. The fixed water cement ratio of 0.43 was applied in all the concrete mixtures.

Table. Mix Design

Percentage Replacement (%)	Fine aggregate (%)	Coal Bottom Ash (%)
0	100	0
10	90	10
20	80	20
30	70	30
40	60	40
50	50	50

Mix Ratio used for the thesis is 0.43:1:1:2 (W/C: C: S: A) which is of M25 grade.

Mixing:

The amount of water in the mixture played an important role on the behavior of fresh concrete. When the mixing time was long, mixtures with high water content bleed and segregate. This phenomenon was usually followed by low compressive strength of hardened concrete.

The effects of water content on the mixture and the mixing time were critical parameters which decide the concrete strength. From the preliminary work, it was observed that the mixing period of concrete should be within five to seven minutes and while mixing the following steps should be followed

- First Mix all dry materials with the shovel.
- Add water to the mixture at the end of dry mixing, and continue the wet

Fig. Mixing of concrete

Slump Test

Slump is an estimation of concrete's workability. For mixing the concrete a half pack blend was used. To begin with coarse aggregates of 20 mm, 10 mm were set in the mixture then sand and cement were combined in dry state then water was included and mixed until the homogeneous blend were achieved.

Principle

The slump test result is a measure of the conduct of a compacted modified cone of concrete under the activity of gravity. It quantifies the consistency or the wetness of cement.

Apparatus

1. Slump cone,
2. Scale for measurement,
3. Tamping rod (steel)

Procedure of Concrete Slump Test

1. The mould for the slump test is a frustum of a cone, 300 mm in height. The base is 200 mm in distance across and it has a littler opening at the highest point of 100 mm (4 in).
2. The base is put on a smooth surface and the holder is loaded with concrete in three layers, whose workability is to be tried.

Each layer is temped 25 times with a standard 16 mm (5/8 in) measurement steel pole, adjusted toward the en

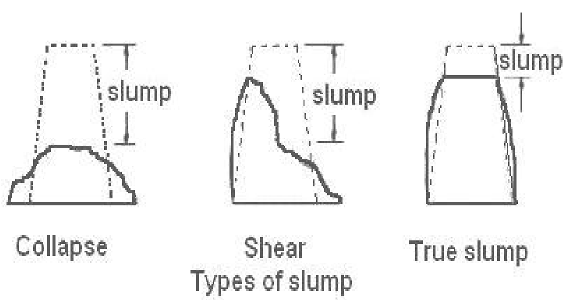

Fig.Various Slumps

Shear Slump

Collapse SlumpIn a breakdown slump the concrete falls totally. A breakdown slump will for the most part imply that the blend is excessively wet or that it is a high workability blend, for which slump test is not suitable.

In a shear slump the top portion of the concrete shears off and slips sideways.

True Slump

In a true slump the concrete simply subsides, keeping more or less to shape

1. This is the only slump which is utilized as a part of different tests.
2. Mixes of stiff consistence have a Zero slump, so that in the somewhat dry range no variety can be recognized between blends of various workability
3.

Fig. Slump Test

Moulds and Equipment:

Cube

Cube of size 150mm×150mm×150mm or 100mmx100mmx100mm can be used..

Fig.: Cube Mould

Cylinder

Cylindrical mould of diameter 150 mm and height 300 mm were utilized.

Fig.: Cylindrical Mould

Casting:

The standards moulds were fitted such that there are no gaps between the plates of the moulds. If there are small gaps they were filled with plaster of Paris. The moulds then oiled and kept ready for casting. The wet mix is poured into the moulds in three layers with each layer being given 25 blows with a tamping rod. At the end of casting the top surface was made plane using trowel and a hacksaw blade to ensure a top uniform surface.

Fig. Casting

Curing

After the completion of casting all the specimens were kept to maintain the ambient conditions viz. temperature of 27±2 C and 90% relative humidity for 24hours. The specimens were removed from the mould and submerged in clean fresh water until just prior to testing. The temperature of water in which the cubes and cylinders were submerged was maintained at 27± 2 C. The specimens were cured for 28 days.

Fig. Specimens Kept for Curing

Testing:

At the end of the required number of days of curing the specimens were taken out from the curing tank, allowed to dry properly and kept ready for testing.

MATERIAL PROPORTION AND MIX DESIGN

Type I ordinary Portland cement, produced by CIMA which is packed under the brand name "Blue Lion Cement" was used. The fine aggregates were locally sourced quartzitic natural river sand in uncrushed form with the fineness modulus of 3.26, specific gravity of 2.83 and a maximum aggregate size of 5 mm and the coarse aggregate was crushed gravel passed through 10 mm sieve.

The DSF used was a product of SCANCEM materials in Singapore with the specific gravity of 2.28, a median particle size of 28.21 μm and specific surface area of 0.2170 m²/g. This product complies with ASTM C1240-03a and AS3582.3 1994. Class F fly ash is designated in ASTM C 618 and originates from burning harder, older anthracite and bituminous coal. The medium particle size of used fly ash in this research was 26.68 micrometer with the specific gravity of 2.25. The chemical compositions of CEM1, SF and FA are presented in Table 1.

Table 1. Chemical compositions of Portland cement, FA and DSF.

% by total mass			
Chemical compound	Portland cement	Fly ash	Densified silica fume
Mgo	1.50	2.21	4.60
Al2O3	3.60	26.43	0.27
SiO2	16.00	46.25	84.00
SO3	3.10	1.85	0.44
K2O	0.34	3.07	2.70
CaO	72.00	7.61	0.66
Fe2O3	2.90	10.71	0.54
Na2O	n/d	1.11	4.20

Natural coir fiber without cutting to specific length has been added to all admixtures. The measured average length of the added coir fiber in mixes was 10cm. Type F super plasticizer of suffocated melamine formaldehyde condensates category was used by 0.2% of binding weights to keep a constant level of workability and to produce the designated slump of 30mm. The potable water from local water supply network was used as the mixing water. Table 2 shows the mixture proportions of concrete mixes. Control concrete (control) mix containing only Portland cement type I as cementations materials and without coir fiber reinforcement was manufactured. Coir fiber reinforced concrete (CFRC) was also made by ordinary Portland cement CEM1 to specifically present the effect of coir on HSC, in two other mixes coir fiber reinforced high strength concrete made by 10% replacement of cement mass with FA, and DSF respectively.

Preparation of Samples

The dry constituents were mixed together properly then superplasticizer, water and finally fibres were added to the mix. The concrete samples made by casting fresh concrete into the moulds in three layers and each layer was compacted using a vibrating table for 15 second. 24 hours after casting samples were demoulded and specific code of each admixture was written on the surface of each sample.

Then, samples were immersed in normal potable water continuously until the date of testing. Density, compressive and flexural tensile strength tests of concretes were carried out at the ages of 7 and 28 days and elasticity modulus test and sonic investigation were conducted at 28days.

Table 2. Mixture proportions.

Symbol	Mix proportion (kg/m³)				
	Cement	Sand	Gravel	DSF	FA
Control	495	689.0	1033	-	-
CFRC*	495	689.0	1033	-	-
CFR DSFC*	445.5	689.0	1033	49.5	-
CFR FAC*	445.5	689.0	1033	-	49.5

**Coir was added by 0.4% of the binder volume.*

Test Set-up

Each sample was weighted before testing and samples density was recorded in units of grams per cubic centimetre (g/cm3). Having this information was necessary to find the density of the concrete in different ages in order to determine how compact one substance is compared to another. The balances used, determined the mass of samples to an accuracy of 0.1% suggested by British Standard. Cubes with 100x100x100 mm³ dimensions were experimented for compression in ages of 7 and 28 days. For each day, three specimens were tested in order to find an accurate average. The specimens were loaded at a rate of 150 kN/min. Flexural strength test performed on prisms of height (h) 100 mm, width (w) 100 mm and length L (l) 500 mm dimensions, according to BS EN 12390-5:2009, using the Universal Testing Machine. The average of two values was taken to define flexural strength of that particular type of specimen.

The dynamic elasticity modulus of concrete was determined non-destructively using resonance tests as prescribed in ASTM C215 and C-666. Two prisms with 100x100x500 mm³ dimensions were tested from each composite at the age of 28days. This testing method was carried out using an E-Meter MK II™ based upon the determination of the fundamental resonant frequency of vibration of a specimen generated by an impact and sensed by an accelerometer. The frequency spectrum was computed and displayed by the meter.

Sonic investigations were carried out in direct method by employing the Portable Ultrasonic Nondestructive Digital Indicating Tester (PUNDIT) to estimate amount of cavities, cracks and defects in CFRCs. The pulse velocity in a concrete depends on its density and its elastic properties which in turn are related to the quality and the compressive strength of the concrete.

Table 3. Test results and characteristics of hardened concrete

No	Mix Reference	Compressive strength (Mpa)		Flexural strength (Mpa)		Density (kN/m³)		28-Day dynamic modulus of elasticity (Gpa)	28-Day ultrasonic pulse velocity (km/s)
		7 Day	28 Day	7 Day	28 Day	7 Day	28 Day		
1	Control	47.3	52.5	5.2	5.8	24.7	25.1	40.8	-
2	CFRC	46.9	51.7	5.7	6.3	24.3	24.8	42.6	43.8
3	CFR DSFC	44.1	50.5	5.5	6.2	23.4	24.1	41.1	42.9
4	CFR FAC	48.3	56.6	5.3	7.1	23.9	24.3	44.4	44.2

IV. RESULTS AND DISCUSSION

The experimental results of all conducted tests on the four composites are presented in Table 3 and are Analyzed in following sections

Compressive Strength:

The cube specimens were tested on compression testing machine of capacity 2000 KN. The bearing surface of the machine was wiped off clean and any loose other sand or other material removed from the surface of the specimen. Loading faces are made parallel. The specimen was placed in the machine in such a manner that the load was applied to opposite sides of the cubes. The axis of the specimen was carefully aligned at the center of the loading frame. The load applied was increased continuously at a constant rate until the resistance of the specimen to the increasing load breaks down and no longer can be sustained. The maximum load applied on the specimen was recorded.

Fig: Compressive Strength Testing Machine

COMPRESSIVE STRENGTH= (ULTIMATE LOAD) / (AREA OF CROSS-SECTION)

Figure 1 shows the compressive strength of different mixes at the age of 7-day and 28-day. Considering the results shown in Figure 1, for all series, the compressive strength increased with ages. Incorporation of coir fibers in concrete caused a minor reduction in its compressive strength capability. However, a significant improvement in the strength of coir fiber reinforced concrete with 10% cement replacement with FA could be observed. Compressive strength of coir fiber reinforced concrete incorporating DSF was slightly lower compared to that of coir fiber reinforced concrete without additive.

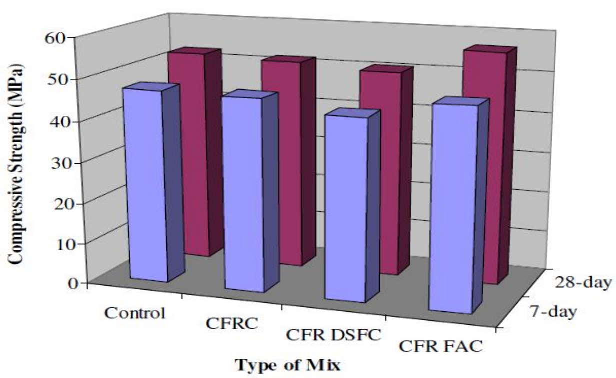

Figure 1. Compressive strength of different mixes at 7-day and 28-day

a. Coir Fibre Reinforced Concrete (CFRC)

Compressive strength of CFRC was 1.5% lower compared to that of control concrete at the age of 28 days. Coir fibres reduced compressive strength of concrete by increasing voids content due to lower efficiency in concrete compaction. Existence of the polar groups in coir caused inefficient bonding between coir and the hydrophobic matrix, since a dry coir fiber uptakes large amount of moisture content and reduced wettability in concrete mixture.

b. Coir Fibre Reinforced Fly Ash Concrete(CFR FAC)

Compressive strength of CFR FAC was about 8% higher compared to control concrete. As mentioned earlier, addition of coir increased voids content in concrete leading to reduction of compressive strength. FA used in this research consists of particles with 2.2 kg/m³ relative density which is a more efficient void-filler than Portland cement with relative density of 3.15 kg/m³. Spherical shape of FA particles also, allowed them to flow freely in mixtures and fill the forms more completely during vibration.

c. Coir Fibre Reinforced Densified Silica Fume Concrete (CFR DSFC)

Compressive strength of CFR DSFC at the age of 28 days was about 3.8% and 2.3% lower compared to control concrete and CFRC respectively. Normally, a fresh un-densified SF has particle in the size range of about 0.03-0.3 μm. However, in densification process of SF progressive entanglement of clusters of SF particles occurs during tumbling action, which results in formation of dense agglomerates so that the median particle size of DSF used in this research was 28.21 μm which is much coarser than cement particles with median particle size of 3.19 μm. Such alteration in particle size of SF has adverse effects on its micro filler action in concrete and rate of secondary hydration between SF particles with portlandite produced from primary hydration of cement.

Flexural tensile strength

Figure 2 demonstrates the flexural strength of different mixes at the age of 7-day and 28-day. Comparing to control concrete, the flexural tensile strength of CFRC, CFR DSFC, CFR FAC improved by about 9%, 7%, and 23% respectively.

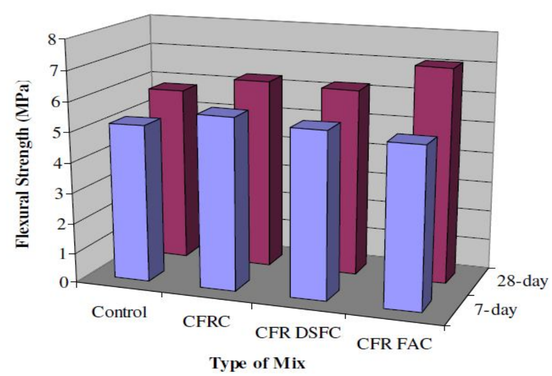

Figure 2. Flexural strength of different mixes at 7-day and 28-day

Modulus of Elasticity

Figure 3 illustrates the modulus of elasticity of different mixes at the age of 28-day. Comparing to the PHSC, the dynamic elasticity modulus of CFRC, CFR DSFC and CFR FAC improved by about 4%, 1%, and 9% respectively. Among the factors affecting modulus of elasticity of concrete, moisture condition plays an important role.

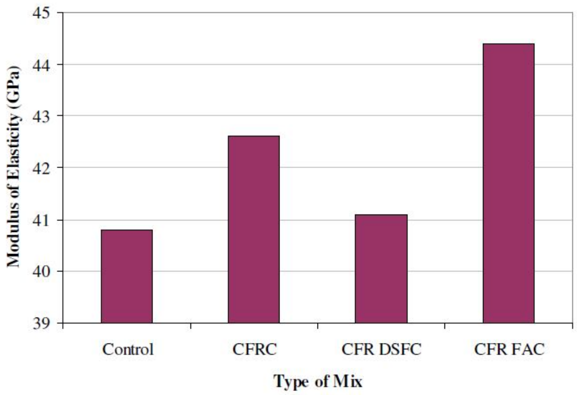

Figure 3. Flexural strength of different mixes at 7-day and 28-day

DENSITY

Density measurements of 7, 14 and 28 days of four admixtures are presented in Table 4.7 which are achieved by weighting cubes and prisms before compression and flexural testing. For all series it was observed that, density of concrete was slightly increased over the age. Densities of the four admixtures are in the range of 2400-2600 kg/m³ which are above the considered range for conventional concrete.

There was a slight reduction in the density of CFR FAC and CFR DSFC compared to CFRC because FA and DSF have a lower specific gravity compared to cement. Specific gravity of FA and DSF are2.25 and 2.2 respectively, which are somewhat lighter than Portland cement with a specific gravity of3.15. Thus, adding this pozzolans to a concrete mixture will not density the concrete. Contribution of coir fiber also decreased concrete density by about 1.2% since presence of voids in concrete reduces the density and strength

Ductility

When plain concrete cubes were subjected to compressive strength, small initial cracks formed on the surface of samples. Cracks progress fast and extend followed by crashing and blasting to failure. Failure occurs suddenly once the ultimate compressive load was achieved. However, when CFRC samples were subjected to the compressive loads specimen seems still unbroken even when ultimate loading and failure occurred. Figure 4 shows the test specimens after compression test.

(a) PHSC Sample (b) CFRC Sample

Figure 4. Samples shape after failure

Ultrasonic pulse velocity (UPV)

Among all specimens, CFR FAC obtained the highest UPV at 28 days. It was higher than UPV of the CFRC about 1% and the lowest UPV was attained by CFR DSFC that was lower than that of CFR HSC about 2%. It signified that the FA series specimens might have more compacted microstructures than DSF series specimens. Concrete with less porosity has higher strength and higher UPV since the presence of void on the path will increase the path length as it goes around the void. UPV of CFRC, CFR DSFC and CFR FAC were between 4.2 and 4.5 km/s. Therefore, according to IS: 13311 Part 1, they were classified as sound concrete with desirable quality.

V. CONCLUSIONS

When coir fiber is added to concrete and part of the Portland cement is replaced by fly ash or densified silica fume, each of these additives acts in a different but co-operative way, depends upon their chemical or physical characteristic. Incorporation of natural coir fibers causes about 1-2% reduction in ultimate compressive strength of high strength concrete, this may be due to lowering the quality of compaction in presence of coir and increasing the porosity. Compressive strength of CFR FAC was about 8% higher compared to control concrete as FA with its spherical particle shape and its lower relative density than ordinary Portland cement is a better void filler. It also reduces concrete voids and porosity through contribution of both silica and alumina in hydration process and improve concrete strength additionally. Besides, introduction of coir in mix, improves the flexural tensile strength of CFRC, CFR DSFC, CFR FAC by about 9%, 7%, and 23% respectively. It should be pointed out that reduction of micro cracks, significantly affects the stress-strain characteristic of concrete so that comparing to the control concrete, the dynamic elasticity modulus of CFRC, CFR DSFC and CFR FAC improved by about 4%, 1%, and 9% respectively. Densities of CFR FAC and CFR DSFC are slightly lower compared to CFRC because FA and DSF have a lower specific gravity compared to cement. Coir also causes reduction in concrete density by increasing concrete voids content.

REFERENCES

[1] VanchaiSata, Chai Jaturapitakkul, KraiwoodKiattikomol., Influence of Pozzolan from various byproduct materials on mechanical properties of high-strength concrete, Journal of Construction and Building Materials, Vol. 21, (2007), 1589–1598.

[2] V. Kasselouri, N. Kouloumbi, Th. Thomopoulos., Performance of silica fume–calcium hydroxide mixture as a repair material, Journal of Cement and Concrete Research, Vol. 23, (2001), 103–110.

[3] Bhikshma, V. Nitturkar, K. &Venkatesham, Y., Investigation on mechanical properties of strength silica fume concrete, Asian journal of civil engineering. Vol. 10 (2009), 335-346.

[4] M.J. Shannag. High strength concrete containing natural pozzolan and silica fume, Journal of Cement & Concrete Composites, Vol. 22, (2000), 399-406.

[5] G.C. Isaia , A.L.G. Gastaldini, R. Moraes, Physical and pozzolanic action of mineral additions on the mechanical strength of high-performance concrete., Journal of Cement & Concrete Composites , Vol. 25, (2003), 69–76.

[6] Chai Jaturapitakkul, KraiwoodKiattikomol, VanchaiSata, TheerarachLeekeeratikul., Use of ground coarse fly ash as a replacement of condensed silica fume in producing high-strength concrete, Journal of Cement and Concrete Research, Vol. 34, (2004), 549–555.

[7] RafatSiddique., Performance characteristics of high-volume Class F fly ash concrete. Journal of Cement and Concrete Research, Vol. 34, (2004), 487 – 493.

[8] J. Saravanan, K. Suguna and P. N. Raghunath., Ductility behavior of composite fibre reinforced polymer-high strength concrete columns under compression, Asian Journal of Civil Engineering (BHRC), Vol. 14, No. 1, (2013), 87-100.

[9] Kyung-Oh Van, Hyun-Do Yun, Sun-KyoungGwang., Effect of confined high strength concrete columns, Journal of the Korea Concrete Institute, Vol.15 No.5(2003), 747-758

[10] Brown R, Shukla A, Natarajan K.R., Fibre reinforcement of concrete structures, University of Rhode Island, URTIC, project No. 536101 (2002), 14.