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Evaluation of Mechanical Properties of High Strength Banana Fibre Concrete (HSBFC) incorporating Fly ash and Silica fume

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Abstract: Concrete is the most dynamic engineering material in construction industry because of its strength properties as well as its durability. The consumption of raw materials not only depleted natural resources but also increases the toxic material in the environment by the construction industries. Now a days the by using the banana fibre in concrete is an efficient sustainable method. The paper presents an Evaluation of Mechanical Properties of High Strength Banana Fibre Concrete (HSBFC) incorporating Fly ash and Silica fume in concrete. Banana fibers are widely available worldwide as agricultural waste from Banana cultivation. Banana fibers are environmentally friendly and present important attributes, such as low density, light weight, low cost, high tensile strength, as well as being water and fire resistant. Replacement of cement by Pozzolonic materials up to 40% in the proportion of 20%, 25% and 30% Fly Ash & 10% silica fume. Determination of strength parameters with different percentages of banana fibers at 0%, 1%, 1.5%, 2% by weight of cement. M70 grade concrete and ordinary Portland cement of grade 53 will be used. The banana fiber reinforced concrete will be tested for compressive strength, splitting tensile strength, flexural strength and Durability tests at different ages of 7,14 and 28 days. Detailed laboratory studies will be carried out with different proportions of banana fiber to determine property of concrete such as compressive strength test, split tensile test, Flexural strength test. Durability test such as Water Absorption, Rapid Chloride ion Permeability Test (RCPT), Carbonation Resistance test, Sulphate Attack test, Hydrochloric acid attack, Freeze–Thaw Test also worked out. The Strength of the concrete in compression and flexure by adding 1.5% of banana fibre with Cement; partially replaced by 20% of Fly Ash and partially replaced by 10% of silica fume reveals better strength as compared to other combinations as proposed in this study.
Keywords: High strength Concrete, Banana fiber, Fly ash, silica fume, partial replacement, mechanical performance, durability performance

I. INTRODUCTION

“Banana fibre concrete” is high performance fibre reinforced concrete with significant behavior under tension. Generally, The compressive strength of concrete relatively high but its tensile strength relatively low. Therefore, various fibers are added to fresh concrete. The contribution of fiber reinforcement increases the tensile strength by delaying the first cracks, minimizing cracks number, crack widths, and crack lengths.

The addition of Banana fibers to concrete makes it additional homogenized and isotropic and transforms it from a brittle to additional ductile materials.

Fiber reinforced concrete (FRC) is a material created with Portland cement, aggregate, and incorporating separate discontinuous fibers. Traditional unreinforced concrete is brittle with an occasional tensile strength and strain capability. The addition of Banana fibers to concrete makes it additional homogenized and isotropic and transforms it from a brittle to additional ductile materials. Banana fibre concrete is high performance fibre reinforced concrete with significant behavior under tension. Banana fibres are economical, ecological and perishable. Emphasis is placed on the influence of fibre content on the key micromechanics properties relevant to composite ductility. Generally, The compressive strength of concrete relatively high but its tensile strength relatively low. Therefore, various fibers are added to fresh concrete. The contribution of fiber reinforcement increases the tensile strength by delaying the first cracks, minimizing cracks number, crack widths, and crack lengths.

In presents study was to Evaluate the effectiveness of Banana fibre with Pozzolonic materials (Fly Ash & Silica fume) in High strength concrete. Also, the purpose of this study was to determine the optimum content of Banana fibre in High strength concrete.

A. Materials Used

1) *Cement:* Locally available Ultratech OPC 53 grade (conforming to IS 269) is used for the experimental work. Cement is the essential binding material used in the concrete. In the concrete binding material place a vital role in achieving the strength. Portland cement is the common form of cement. Cement of various strength is available. It depends on the requirement of concrete it is to be chosen. Composition limits of Portland Cement are shown in below table. (By Ultratech)

TABLE I
COMPOSITION LIMITS OF PORTLAND CEMENT

Sr no.	Ingredient	% Content
1	CaO(Lime)	60-67
2	SiO2(Silica)	17-25
3	Al2O3(Alumina)	3-8
4	Fe2O3(Iron Oxide)	0.5-6
5	MgO (Magnesia)	0.1-4
6	Alkalies	0.4-1.3
7	Sulphur	1-3

TABLE III
PHYSICAL PROPERTIES OF CEMENT

Sr. No.	Properties	Values Obtained	Standard values
1	Normal Consistency	29.50%	-
2	Initial Setting time	46 min	Not be less than 30 minutes
3	Final setting time	254 min	Not be greater than 600 minutes
4	Specific Gravity	3.13	

2) *Coarse Aggregate:* Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. They should be well graded, clean and hard. Crushed angular aggregate (conforming to Table-7 of IS-383-2016) 20 mm and 10mm downgrade was used as coarse aggregate.

TABLE IIIII
PHYSICAL PROPERTIES OF COARSE AGGREGATE (20MM)

Sr. No.	Characteristics	Value
1	Specific Gravity	2.83
2	Bulk density	1.47 kg/m3
3	Water absorption	0.71 %

TABLE IVV
PHYSICAL PROPERTIES OF COARSE AGGREGATE (10MM)

Sr. No.	Characteristics	Value
1	Specific Gravity	2.79
2	Bulk density	1.37 kg/m3
3	Water absorption	0.71 %

3) *Fine Aggregate (Sand):* Fine Aggregates are the important constituents in concrete. They fill the voids between the concrete. They should be well graded, clean and free from dust, dirt & other organic matters. Locally available river sand (Conforming to grading Zone II of Table 9 of IS-383) used as fine aggregate.

TABLE V
PHYSICAL PROPERTIES OF FINE AGGREGATE (SAND)

Sr. No.	Characteristics	Value
1	Specific Gravity	2.63
2	Bulk density	1.57 kg/m3
3	Water absorption	0.91 %
4	Grading Zone	Zone II

4) *Fly Ash:* Fly Ash is one of the pozzolonic materials produced by burning the coal in thermal power plants. Fly ash conforming to Grade 1 of IS 3812 may be used as part replacement of ordinary Portland cement provided uniform blending with cement is ensured. (IS:456-2000). Utilization of fly ash in concrete minimizes the carbon dioxide emission problems to certain extent and also fly ash is less expensive compared to Portland cement. Fly Ash can be replaced by cement between 15% and 30% without having any impact on the compressive and flexural strength of concrete. (Recommended Dosages of Mineral Admixtures Materials for High Strength Mixes, Table-9-IS-10262-2019). Physical and Chemical Properties of Class-F Fly ash are shown in below tables. (By Conash infrastructure)

TABLE VI
PHYSICAL PROPERTIES OF CLASS-F FLY ASH

Sr no.	Properties	Value
1	Specific Gravity	2.37
2	Moisture content	0.40%
3	Particles retained on 45-micron I.S. Sieve (Wet Sieving)	2.20%
4	Fineness	385 m2/kg

TABLE VII
CHEMICAL PROPERTIES OF CLASS-F FLY ASH

Sr no.	Properties	Value
1	$SiO_2+Al_2O_3+Fe_2O_3$	72.09%
2	Total Chlorides	0.0108%
3	Loss on ignition	3.96%

5) *Silica fume:* Very fine pozzolanic material, composed mostly of amorphous silica produced by electric arc furnaces as a byproduct of the production of elemental silicon or ferro-silicon alloys. (From IS-15388-2003). Use of silica fume is generally advantageous for grades of concrete M50 and above and for high performance concrete with special requirements, like higher abrasion resistance of concrete. (From IS-10262: 2019). Silica fume can be replaced by cement between 5% and 10% without having any impact on the compressive and flexural strength of concrete. (Recommended Dosages of Mineral Admixtures Materials for High Strength Mixes, Table-9-IS-10262: 2019). Physical Properties of Silica fume is shown in below table. (By Conash infrastructure).

TABLE VIII
PHYSICAL PROPERTIES OF SILICA FUME

Sr no.	Characteristics	Value
1	Specific Gravity	2.29
2	Moisture content	0.63%
3	Particles retained on 45-micron	1.38%
4	Fineness	190m2/gm

6) *Banana Fibers*: Banana fibers are widely available worldwide as agricultural waste from Banana cultivation. Banana fibers are environmentally friendly and present important attributes, such as low density, light weight, low cost, high tensile strength. The Banana fibers used for this work are from the Esha biodegradable at Sarsa village, Anand District. The fibers are available in processed and ready-to- use fibers. Uniform length of fibers was obtained by using cutting machine. Table shows Physical Properties of Banana fibre. (By Vendor)

TABLE IX
PHYSICAL PROPERTIES OF BANANA FIBER

Sr no.	Properties	Value
1	Diameter (mm)	0.15–0.30
2	Length (mm)	15-30
3	Density (kg/m3)	1290-1320
4	Tensile strength (MPa)	275-350
5	Young’s Modulus (MPa)	12000-13500
6	Aspect ratio	100-150

7) *Water:* Clean tap water which is fit for drinking should be used for mixing and curing of concretes. Potable water available in laboratory with pH value of not less than 6.5 and not more than 8.5, conforming to the requirement of IS:456-2000 were used for mixing concrete and curing the specimen.

II. LITERATURE REVIEW

R Nurwidayati, A F Fardheny and Asyifha[10] studied Investigation on mechanical properties of fiber reinforced concrete. In this paper M25 grade was used by researchers. Banana fibers increased the mortar compressive strength, the concrete compressive strength, and the concrete tensile strength. The compressive strength of the mortar and the compressive strength of the concrete increased with age. The higher percentage of fiber caused the lower the compressive strength of the mortar and lower the compressive strength as the longer length of the fiber on all-fiber percentages. The addition of fibers to concrete significantly increases the relationship between tensile strength and compressive strength of concrete.

Rodgers B. Mugume , Adolph Karubanga, and Michael Kyakula [11] Studied Impact of Addition of Banana Fibres at Varying Fibre Length and Content on Mechanical and Microstructural Properties of Concrete. In this paper M20 grade was used by researchers. Addition of banana fibres to concrete only significantly imparts on compressive strength at lower fibre contents of up to 0.25% for all fibre lengths because higher compressive strength was observed in BFRC compared with Plain concrete. Incorporation of banana fibres in concrete improved its microstructure through better bonding between the fibres and the matrix. For optimal purposes, addition of banana fibres should be limited to a maximum of 1% fibre content preferably using shorter fibres instead of longer ones.

Piotr Smarzewski [14] Are doing Influence of silica fume on mechanical and fracture properties of high-performance concrete. In this paper M90 grade was used by researchers. The study indicates that the mechanical properties of HPC were improved to a great extent at 28 days when cement used in concrete was replaced by SF. A 10% content of silica fume resulted in a 26% increase in tensile splitting strength, a 13% increase in compression strength and a 5% increase in the static modulus of elasticity.

The brittleness of HPC increased with the presence of SF. The findings suggest that SF can effectively replace cement. Nevertheless, it is recommended that the replacement should not exceed 10%.

A. Dhawan et al [18] Investigation carried out on an Evaluation of mechanical properties of concrete manufactured with fly ash, bagasse ash and banana fibre. In this paper M20 grade was used by researchers. The strength of the concrete in compression and flexure by adding 2.5% of banana fibre with Cement; partially replaced by 20% of Fly Ash, and Sand; partially replaced by 10% of Bagasse Ash reveals better strength. Concrete with partial replacement of cement by fly ash and partial replacement sand by bagasse ash with adding optimum percentage of banana fibre can be considered for heavy section member for any building.

Syed Haseeb Ali, Mohammed Tanveer Ahmed, Shaik Khaja Patel, Mir Wahib Ali [20] Are Study on Strength Parameters of Concrete by adding Banana Fibers. In this paper M30 grade was used by researchers. The experimental tests unconcealed that the strength properties of concrete improved with the addition of banana trunk fibers to the concrete. Compressive, flexural and split tensile strength of Banana Fiber Reinforced Concrete are Maximum at 0.5% fiber content with 50mm fiber length. It was observed that cracking resistance of the concrete specimens improved and making it a non-brittle failure.

III. RESEARCH METHODOLOGY

For Evaluation of Mechanical Properties of High Strength Banana Fibre Concrete (HSBFC) incorporating Fly ash and Silica fume. Carry out Mix design of M70 grade concrete as per IS 10262:2019 code. Replacement of cement by Pozzolonic materials up to 40% in the proportion of 20%, 25% and 30% Fly Ash & 10% silica fume. Determination of strength parameters with different percentages of banana fibers at 0%, 1%, 1.5%, 2% by weight of cement. Determination of Durability to understand the effects of varying Silica Fume and banana fiber contents. Nine mixtures of HSBFC made with three different % of Fly Ash and three different % of Banana fibre were prepared for the evaluation. The Nine different tests considered where the parameters under study are Strength and Durability. Detailed laboratory studies will be carried out with different proportions of banana fiber to determine property of concrete such as compressive strength test, split tensile test, Flexural strength test. Durability test such as Water Absorption, Rapid Chloride ion Permeability Test (RCPT), Carbonation Resistance test, Sulphate Attack test, Hydrochloric acid attack, Freeze–Thaw Test also worked out.

A. Mix Preparation

The concrete mix is designed as per standard of IS 10262 – 2019 for the conventional concrete. A polycarboxylic based admixture Sika plast 407 is used as a super plasticizer. The dosage of this admixture which is added during the manufacture of concrete is taken as 0.90% by weight of cementitious content. M70 grade of concrete was adopted and the w/c ratio of 0.29 was initially considered for the design mix. The quantity of the ingredients and the mix proportion obtained after the design mix. Quantity of ingredients and mix proportion for 1 m3 of concrete are mentioned in Table. X.

TABLE X
QUANTITY OF INGREDIENTS AND MIX PROPORTION FOR 1 M3 OF CONCRETE

Trial Mix	Water (Litre)	Cementitious material (OPC+SF) (kg)	F.A (kg)	C.A (kg)
Per m3	158.10	545.17 (436.14+109.03)	579.34	1201.78
By proportions	0.29	1	1.06	2.20

Fig. 1 Mix preparation and specimen casting

B. Specimen Casting

Concrete mix of M70 was manufactured through mix design in the ratio of 1:1.06:2.2 and tested for mechanical and durability performance. Thereafter, 9 different samples of 9 cubes and 6 cylinders each were cast. The size of the cube is 150 mm x150 mm x 150 mm. The silica fume replacement of cement was kept at 10 percent while fly ash was used to replace cement in the range of 0–30 percent at the interval of 10 percent. The banana fibre was added in the range of 0–2 percent %. The cubes and cylinders were tested after 7 days, 14 days and 28 days of curing for compressive strength, and 28 days for splitting tensile strength, flexural strength and durability studies also.

TABLE XI
PERCENTAGE PROPORTION OF EACH INGREDIENT FOR PREPARATION OF SAMPLES

Sample Description	Cement	Fly Ash	Silica fume	Banana Fiber	Sand	Coarse Aggregate	Water
Conventional	100	0	10	0	100	100	100
HSBFC1	70	20	10	1	100	100	100
HSBFC2	65	25	10	1	100	100	100
HSBFC3	60	30	10	1	100	100	100
HSBFC4	70	20	10	1.5	100	100	100
HSBFC5	65	25	10	1.5	100	100	100
HSBFC6	60	30	10	1.5	100	100	100
HSBFC7	70	20	10	2	100	100	100
HSBFC8	65	25	10	2	100	100	100
HSBFC9	60	30	10	2	100	100	100

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IV. RESULT AND DISCUSSION.

A. Workability of Concrete by Slump Cone 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. It is not a suitable method for very wet or very dry concrete. It does not measure all factors contributing to workability, nor it is always representative of the place ability of the concrete. It indicates the characteristic of concrete in addition to the slump value. If the concrete slumps evenly it is called true slump. If one half of the cone slides down, it is called shear slump. In case of a shear slump, the slump value is measured as the difference in height between the height of the mould and the average value of the subsidence.

Fig. 2 Workability of Concrete by Slump Cone Tes

B. Compressive Strength (fc)

Compressive strength test was carried out in standard cube specimens of size 150 mm × 150 mm × 150 mm using a constant compressive load of 140 kg/cm2 per minute until failure in accordance with IS 516 (1959). Ratio of the load at which the specimen fails and the contact surface area gives the compressive strength of concrete. The test specimens are stored in air for 24hours and after, the specimens are removed from the moulds and cured in clear fresh water until taken out prior to test after 7, 14 and 28 days.

After curing period, Specimen are removed from water and cleaned the bearing surface of cubes. Then it is applied in compressive testing machine.

Compressive strength (fc): = Load / Area

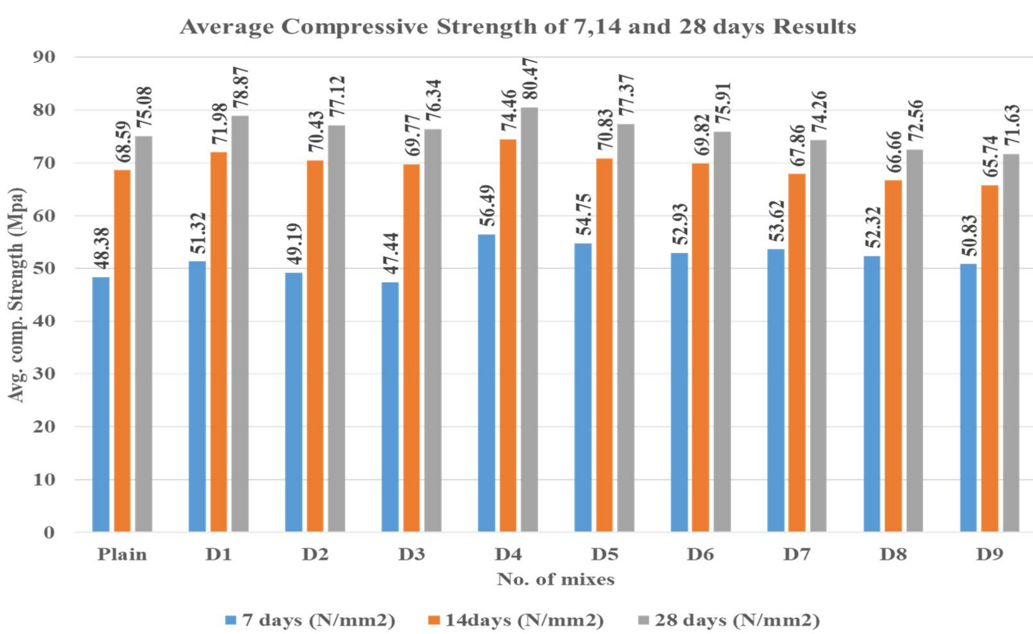

Fig. 3 Average Compressive Strength of 7,14- and 28-days Results

C. Split Tensile Strength (fst)

Tensile strength of concrete was indirectly measured by the split tensile test based on IS 5816 (1999), on cylindrical specimens of 150 mm diameter and 300 mm height after 28 days of water curing using a compression testing machine. Calculate the splitting tensile strength of the specimen as following formula:

fst = (2P) / (πLD)

Where: fst = Splitting tensile strength, P = Load in KN

L = Length in meter (0.300m)

D = Diameter in meter (0.150m)

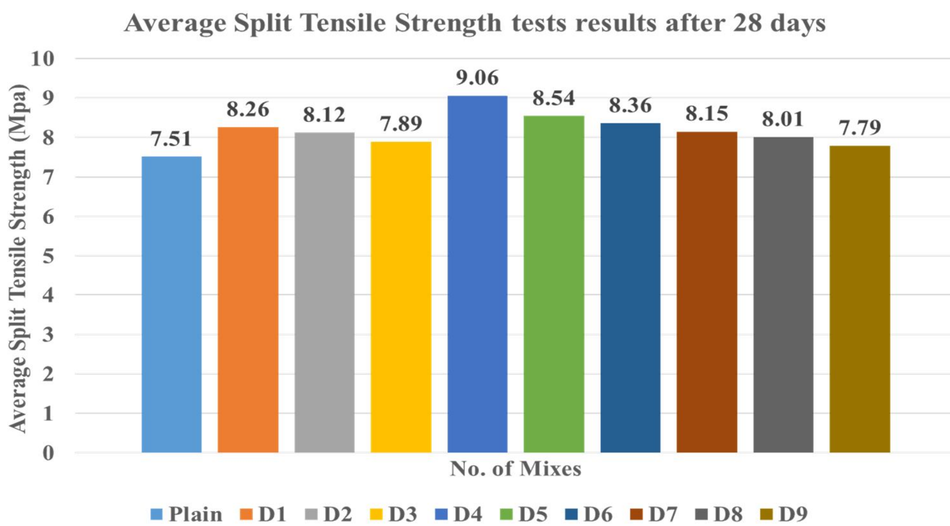

Fig. 4 Average Split Tensile Strength tests results after 28 days

D. Flexural Strength Test (fcr):

Empirical Formula for Estimating Flexural Strength of Concrete:

As per IS 456:2000, the flexural strength of the concrete can be computed by the characteristic compressive strength of the concrete

Flexural strength of concrete = 0.7 (fck)^0.5

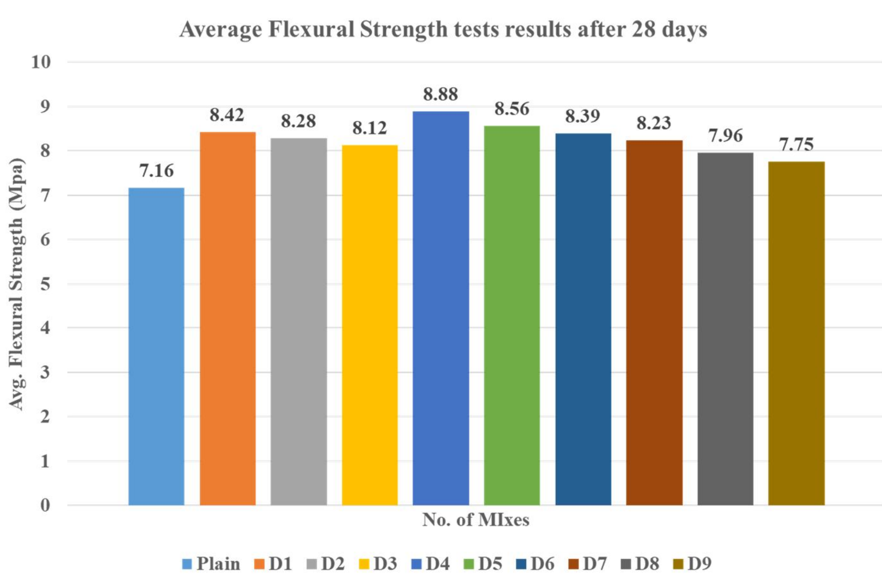

Fig. 5 Average Flexural Strength tests results after 28 days

E. Water Absorption Test

The water absorption test was done in compliance with the BS 1881: Part122 (1983) specification, which specified an immersion method used to assess the percentage of water absorbed by concrete. The apparatus that was required in this test were water tank, heating and drying oven. This test was conducted on three (3) set of water-curing cube specimens with dimension 150 mm × 150 mm × 150 mm for the plain concrete and also three (3) set for each percentage of design mixes. The water curing process or immersion of concretes in water were kept at (20±2) °C for 28 days. After that, separation for each sample and was shaken thoroughly, followed by wiping up with a cloth to remove free water. The weights of these wet specimens were subsequently measured and recorded. After the specimens were removed from the curing tank, the cured specimens were first oven dried at (105±5) °C for (72±2) h and subsequently cooled down to room temperature for (24±0.5) h before being weighed. The weights of these dry specimens were subsequently measured and recorded. In addition, each specimen's absorption was calculated as an increase in the mass resulting from immersion and was expressed as a percentage differential between the wet and dry specimens' weights. Based on a specification in BS 1881: Part 122 (1983), the calculation was performed using the following equation.

Wa = $(Ww - Wd)/Wd$ x 100%

Where: Wa = Percentage of water absorbed (%)

Ww = Weight of wet specimen (g), Wd = Weight of dry specimen (g)

TABLE XII
AVERAGE PERCENTAGE OF WATER ABSORBED (%) AFTER 28 DAYS

Mixes	Average Percentage of water absorbed (%) after 28 days
PLAIN	3.82
D1	3.72
D2	3.54
D3	3.19
D4	3.03
D5	3.28
D6	3.46
D7	3.35
D8	3.66
D9	3.81

F. Rapid Chloride ion Permeability Test (RCPT)

Rapid Chloride Permeability Test Equipment (RCPT) as per ASTM:C1202-19 is used to evaluate the resistance of a concrete sample to the penetration of chloride ions. The test is performed by placing a 100 mm diameter, 50mm height of concrete core into the sample cells that contain 0.3 molarity of NaOH solution, while the other was filled with 3% NaCl solution. A voltage of 60 V DC is maintained across the ends of the sample throughout the test and the charge that passes through the sample is recorded. Based on the charge, a qualitative rating can be made of concrete's permeability in coulombs. If the current is recorded at 30 minutes intervals, the following formula based on the trapezoidal rule, can be used:

Q = 900 x [I0 +2 (I Cumulative) + I360]

Where: Q = Charge passed (coulombs),

I0 = Current (amperes) immediately after voltage is applied,

It = Current (amperes) at t min. after voltage is applied,

I Cumulative = I30 +I60 + I90 + I120 +I150 + I180 +I210 + I240 +I270 + I300 + I330

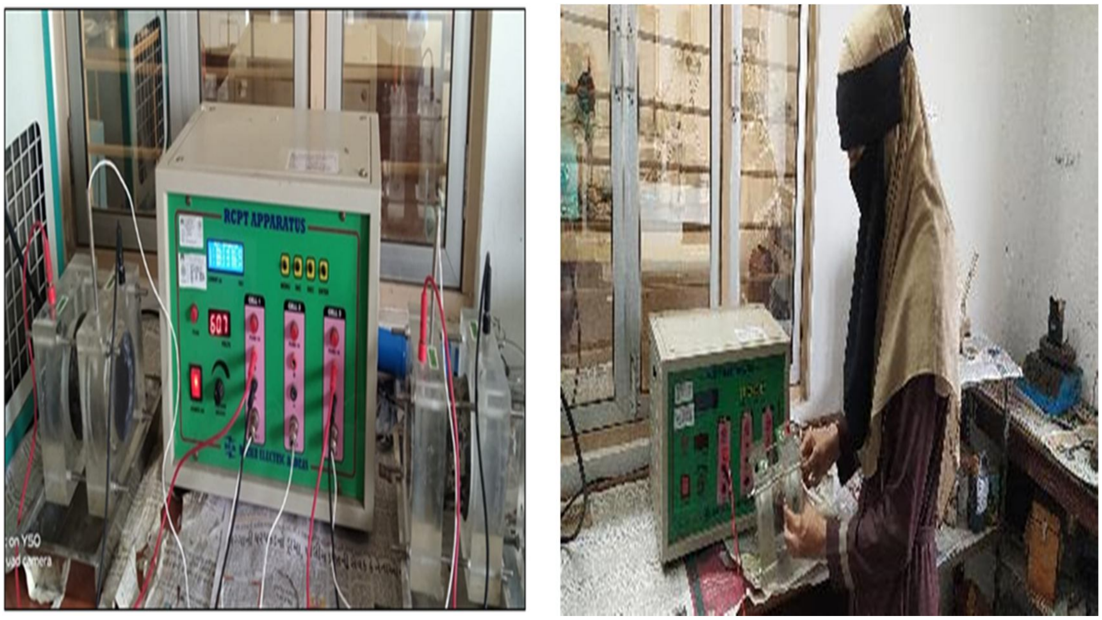

Fig. 6 Rapid Chloride Permeability Test Equipment (RCPT) as per ASTM:C1202-19

TABLE XIII
AVERAGE PERCENTAGE OF WATER ABSORBED (%) AFTER 28 DAYS

Mixes	Chloride ion Permeability (Coulombs) after 28 days
PLAIN	1986
D1	1940
D2	1892
D3	1725
D4	1612
D5	1672
D6	1763
D7	1819
D8	1876
D9	1920

G. Carbonation Depth Test: (As per IS-516(Part 5/Sec 3):2021

“Carbonation is a process in which carbon dioxide from the atmosphere diffuses through the porous cover concrete and may reduce the pH to 8 or 9, at which the passivating/oxide film is no longer stable.” Carbonation process involves the following two stages: First, the atmospheric carbon dioxide (CO2) reacts with water in the concrete pores to form carbonic acid (H2CO3). Carbonation of concrete is one of the main reasons for corrosion of reinforcement. Oxygen and moisture are the other components required for corrosion of embedded steel. In this test, the depth of carbonation is determined. The rate of carbonation depends on the grade of concrete, permeability of concrete, whether the concrete is protected or not, depth of cover, time, etc. The test shall be performed on freshly exposed concrete surface. This may be either freshly broken surface of concrete or extracted concrete core sample which may preferably be split and the test may be conducted on the split face. If facility for splitting is not available, then the core may be surface dried and sealed to prevent further carbonation. After breaking, the concrete surface shall immediately be cleared of any dust or loose particles. The freshly exposed concrete surface prepared as per above shall be sprayed with a fine mist of indicator (phenolphthalein) solution. Care shall be taken to avoid the formation of flow channels on the test surface. The measurements shall be conducted soon after the color has stabilized. The demarcation between the region, which turns into magenta (dark pink color) and the region showing no change in color will indicate the carbonation front. The carbonation depth shall be measured on the exposed face.

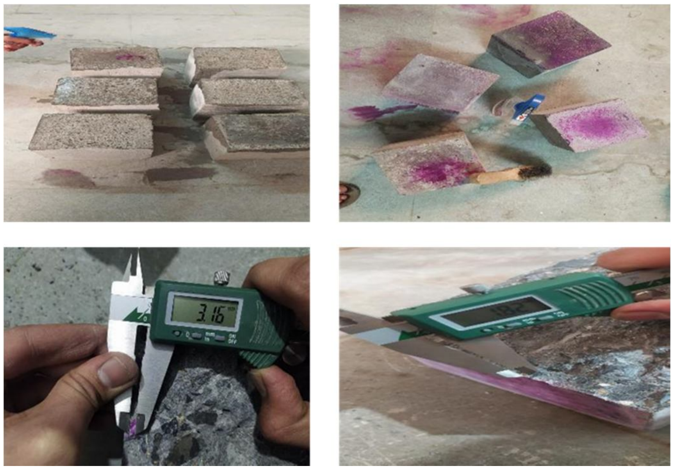

Fig. 7 Carbonation Depth Test: (As per IS-516(Part 5/Sec 3):2021

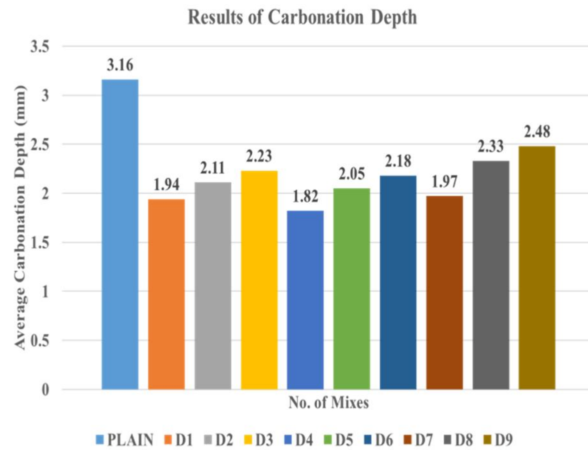

Fig. 8 Result of Carbonation Depth Test

H. Sulphate Attack Test (Na2SO4): As per ASTM C1012-04

Sulphate Attack is a Chemical breakdown mechanism where sulphate ions attack components of the cement paste. The most common forms of sulphates are Sodium sulphate (Na2SO4), Potassium sulphate (K2SO4), Magnesium sulphate (MgSO4), Calcium sulphate (CaSO4). This sulphate reacts with hydrated cement paste and forms Gypsum or a compound called ettringite (sulphoaluminate). During this phase, concrete expansion and disruption process starts. Sulphate attack of concrete leads to expansion, extensive cracking, spalling and loss of strength of concrete. The resistance of concrete to sulphate attack is studied by determining the loss in the compressive strength of concrete when it is immersed in sulphate solution. For this test, cubes of 150 x 150 x 150 mm size were casted and water cured. After 28 days of water curing the cubes are dried for one day and immerse in water containing 5% Sodium sulphate (Na2SO4) for 28 days. After 28 days of immersion, the concrete cubes shall be taken out of the sulphate water and tested for compressive strength (CO2). Weight loss (%) was added as a measure for evaluating concrete deterioration. Therefore, equation 1 was used to compute both average weight loss (Wl) for each cubic specimen (15x15x15) cm in Sulphate attack respectively.

However, the average loss (%) of strength after immersion in Sodium sulphate (Na2SO4) were performed by using the equation 2.

$Wl = (Wu - Wp)/Wu$ x100%

Where: Wp = Weight (kg) of specimen after 28 days in Na2SO4 solution

Wu = Initial weight (kg) of specimen before immersion in Na2SO4 solution

$f1 = (fw - fh)/fw$ x 100%

Where: $f1$ = Average loss (%) of strength after immersion in Na2SO4

fw = Average compressive strength after 28 days of normal portable water curing (MPa)

fh = Average compressive strength after 28 days of immersion in 5% Na2SO4 (MPa)

Fig. 9 Sulphate Attack Test (Na2SO4): As per ASTM C1012-04

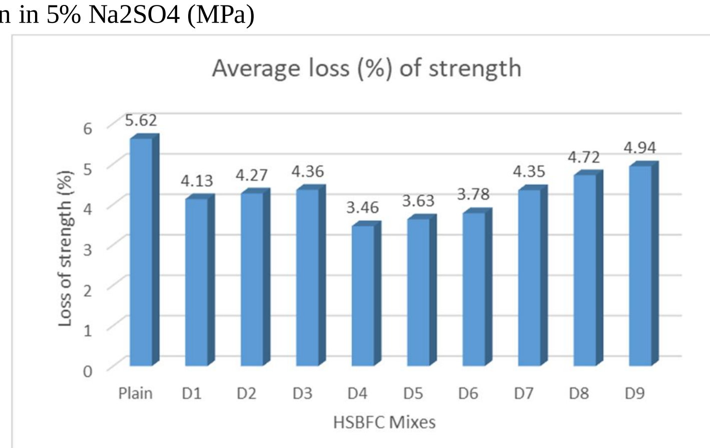

Fig. 10 Average Comp. strength loss (%) Result after Sulphate attack

I. Hydrochloric acid attack: As per ASTM C1898 – 20:

The chemical resistance of concrete to acid attack was determined according to Standard ASTM C1898 – 20. Initially, three (3) set of concrete cubes with dimension 150 mm x 150 mm x 150 mm were prepared respectively for HSBFC mixes. The cubes were weighted and immersed in water mixed with hydrochloric acid for 28 days following 28 days of curing. The acid solvent was stirred every week in order to retain concentration. The cubes were analysed physically after 28 days of immersion, and changes in size were observed. Finally, the weights of the specimens were identified after 28 days of immersion and the weight loss or change in mass were hence assessed. The compressive strengths of the specimens were established after 28 days of immersion and observed the deterioration phase for each concrete samples. Weight loss (%) was added as a measure for evaluating concrete deterioration. Therefore, equation 1 was used to compute both average weight loss (Wl) for each cubic specimen (15x 15 x 15) cm in acid attack respectively. However, the average loss (%) of strength after immersion in hydrochloric acid were performed by using the equation 2.

$Wl = (Wu - Wp)/Wu$ x100%

Where: Wp = Weight (kg) of specimen after 28 days in acid solution

Wu = Initial weight (kg) of specimen before immersion in acid solution

$f1 = (fw - fh)/fw$ x 100%

Where: $f1$ = Average loss (%) of strength after immersion in hydrochloric acid

fw = Average compressive strength after 28 days of normal portable water curing (MPa)

fh = Average compressive strength after 28 days of acid immersion in hydrochloric acid (MPa)

Fig. 11 Hydrochloric acid attack: As per ASTM C1898 – 20:

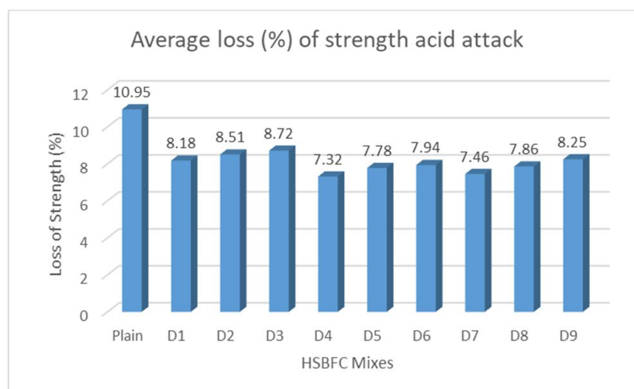

Fig. 12 Average Comp. strength loss (%) Result after Acid attack

J. Freeze–Thaw Tests of Concrete: (ASTM-C 666/C 666M – 03):

This test method covers the determination of the resistance of concrete specimens to rapidly repeated cycles of freezing and thawing in the laboratory by two different procedures: Procedure A, Rapid Freezing and Thawing in Water, and Procedure B, Rapid Freezing in Air and Thawing in Water. Both procedures are intended for use in determining the effects of variations in the properties of concrete on the resistance of the concrete to the freezing-and-thawing cycles specified in the particular procedure. The nominal freezing-and-thawing cycle for both procedures of this test method shall consist of alternately lowering the temperature of the specimens from 40 to 0 °F [4 to -18 °C] and raising it from 0 to 40 °F [-18 to 4 °C] in not less than 2 nor more than 5 h. For Procedure A, not less than 25 % of the time shall be used for thawing, and for Procedure B, not less than 20 % of the time shall be used for thawing. The period of transition between the freezing-and thawing phases of the cycle shall not exceed 10 min, except when specimens are being tested. The decrease in the compressive strength of concrete specimens after a freeze resistance test is calculated according to the following formula:

$\Delta fc = (fk - fg)/fk \times 100\%$

Were, Δfc is the decrease in the compression strength of concrete specimens compared to the plain samples;

fk is the mean value of the compressive strength of the plain samples;

fg is the mean value of the compressive strength of the specimens after a certain number of freezes–thaw cycles.

Fig. 13 Freeze–Thaw Tests of Concrete: (ASTM-C 666/C 666M – 03)

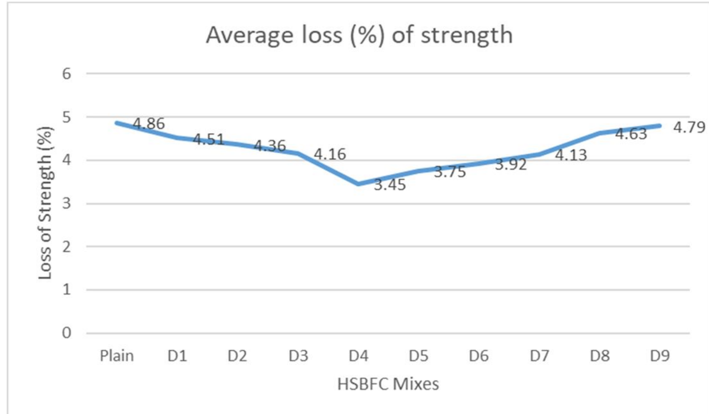

Fig. 14 Average Comp. strength loss (%) Result after Freeze–Thaw Tests

V. CONCLUSION

The effect on the characteristics of high strength concrete with partial substitution of cement with fly ash and silica fume respectively with banana fiber as an additive were studied. The properties obtained from the various samples made up of different composition leads to following conclusions in the present study:

1) The Strength of the concrete in compression and flexure by adding 1.5% of banana fibre with Cement; partially replaced by 20% of Fly Ash and partially replaced by 10% of silica fume reveals better strength as compared to other combinations as proposed in this study.
2) It was found that the replacement of cement with fly ash up to 20% and silica fume up to 10% gives improvement in concrete properties such as compressive strength, split tensile strength and durability. The strength reaches its maximum value for D4 having silica fume as 10% and fly ash as 20% cement replacement with 1.5% of banana fibre.
3) It was found also that the 7 days compressive strength was higher than the Plain mix which shows that incorporating silica fume increases strength at early ages.
4) It was found that the compressive strength of D4 was 8.56% & 7.18% higher than Plain mix at 14 days & 28 days respectively. Higher split tensile has been achieved for D4 (10% silica fume and 20% fly ash with 1.5% of banana fibre) which was 20.64% higher than the Plain mix at 28 days.
5) The Flexural strength has been achieved for D4 (10% silica fume and 20% fly ash with 1.5% of banana fibre) which was 24.02% higher than the Plain mix at 28 days.
6) Carbonation test was performed on each design mixture and concluded that there is no evidence of carbonation occurring on the initial level of the concrete. The Average Carbonation Depth (mm) value of concrete is 3.16 mm for Plain Mix while D4 (10% silica fume and 20% fly ash with 1.5% of banana fibre) shows the least Carbonation Depth with 1.82 mm compared to Plain mix.
7) The water absorption value of concrete is 3.03% for Plain Mix while D4 (10% silica fume and 20% fly ash with 1.5% of banana fibre) shows 3.82% compared to Plain mix.
8) The RCPT value of concrete is 1986 coulomb for Plain Mix while D4 (10% silica fume and 20% fly ash with 1.5% of banana fibre) shows the least chloride penetration with 1612 coulombs compared to Plain mix.
9) After exposing to sulphate Attack all the concrete mixes show decrement in compressive strength. The results of sulphate attack test show 5.62% loss in compressive strength of plain mix however the D4 (10% silica fume and 20% fly ash with 1.5% of banana fibre) shows reduction of 3.63% in compressive strength compared to Plain mix.
10) After exposing to hydrochloric acid all the concrete mixes show decrement in compressive strength. The results of Hydrochloric acid attack test show 10.95% loss in compressive strength of plain mix however the D4 (10% silica fume and 20% fly ash with 1.5% of banana fibre) shows reduction of 7.32% in compressive strength compared to plain mix.
11) After exposing to cyclic frost resistance all the concrete mixes show decrement in compressive strength. The results of Freeze-thaw test show that 4.86 % loss in compressive strength of plain mix, however the D4 (10% silica fume and 20% fly ash with 1.5% of banana fibre) shows reduction of 3.45% in compressive strength. It showed that the D4 has lowest percentage of 3.45% for compressive strength loss while D9 has highest percentage of 4.79% for compressive strength loss.

12) The important role of banana fibres is to recover the cracks that get develop in the concrete and increase the ductility of concrete elements, improvement on post cracking behavior of concrete.
13) It increases more resistance to tensile loads, controls plastic shrinkage cracking and drying shrinkage cracking and lowers the permeability of concrete matrix and thus reduce the bleeding of water. The fibre increases the toughness property of concrete

VI.FUTURE SCOPE

The future scope of the project is extended by doing the experimental analysis on different proportion of binding agents and the banana fiber content in the samples and performs the mechanical and durability properties test on the specimen. Effect of silica fume on the interfacial zones of fibers should be studied using scanning electron microscopy and effect of different silica fume contents on corrosion resistance can also be studied. Moreover, combined effect of Fly ash and Silica Fume on different strength classes of concrete should also be investigated and compared. So, further investigation is needed on the technical, environmental, economic aspects and educating the public through the use of industrial waste materials (Silica fume, Fly ash, Metakaolin, GGBFS etc.) as a sustainable approach.

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