RESEARCH ARTICLE OPEN ACCESS

Experimental Analysis of Fly Ash & Coir Fiber Mix Cement Concrete for Rigid Pavement

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ABSTRACT
In India Thermal power plants which use pounded coal as a fuel, generates million tones of fly ash every year as a waste. Conservative clearance of this material which gets easily air-borne and constitutes a serious health hazards to the community, is an expensive operation. A part from this compacted fly ash can be used in embankments, road sub-bases and also for structural fills. The major drawbacks of such materials are their limited load carrying capacity and poor settlement characteristics. The concert of such materials can substantially be improved by introducing reinforcing element in the direction of improving its compressive and flexural strength for superior durability. Use of natural materials such as Jute, coir and bamboo, as reinforcing materials to fly ash are very cheap and they are locally available in huge quantity, of all the natural fibers, coir has the greatest tearing strength and it retains this property even in wet conditions. In this framework a composite with fly ash, conventional concrete and treated coconut fibers, available in plenty in rural areas of India have been investigated. These composites can be a good proposition and with this, experimental investigation to study the effects of replacement of cement (by volume) with different percentages of fly ash and the effects of addition of processed natural coconut fiber on flexural strength, compressive strength, splitting tensile strength and modulus of elasticity was taken up. AS per IRC, A Design mix proportion was designed for the normally popular M30 concrete for pavement construction in India. In this, Cement was replaced with percentages (10, 20, 30 and 40%) of Class C fly ash and of coconut fibers (0.50 and 1.0 %) having 40 mm length were used. Test results show that the replacement of 43 grades ordinary Portland cement with fly ash showed an increase in compressive strength and flexural strength for the chosen mix proportion.
Key words: Concrete, coir, fly ash, mechanical properties.

I. INTRODUCTION

Concrete is a relatively brittle material, when subjected to normal stresses and tensile loads. Tensile strength of concrete is approximately one tenth of its compressive strength. As a result for these characteristics, plain concrete members could not support loads and tensile stresses that occurred, on concrete pavements. Concrete members are reinforced with continuous reinforcing bars to withstand tensile stresses and compensate for the lack of ductility and strength. The addition of steel reinforcement significantly increases the strength of concrete, and results in concrete with homogenous tensile properties; however the development of micro cracks in concrete structures must be checked. The introduction of fibers is generally taken as a solution to develop concrete in view of enhancing its flexural and tensile strength.

Fly ash is the fine powder produced as a side product from the combustion of pulverized coal and is collected by mechanic al and electrostatic separator from fuel gases of power plants. The disposal of fly ash is the one of the major issue for environmentalists as dumping of fly ash as a waste material may cause severe environmental problem. Therefore, the utilization of fly ash as an admixture in concrete instead of dumping it as a waste material can have great beneficial effects. It can be used particularly in mass concrete applications where main emphasis is to control the thermal expansion due to heat of hydration of cement paste and it also helps in reducing thermal and shrinkage cracking of concrete at early ages. The replacement of cement with fly ash in concrete also helps to conserve energy. The composite matrix that is obtained by combining cement, Fly ash, aggregates and fibers is known as “Fly ash Fiber reinforced concrete”. The fiber in the cement fly ash based matrix acts as crack- arresters, which restrict the growth of flaws and micro cracks in the matrix, and prevent these from enlarging under load. Prevention of the propagation of these cracks, originating from internal flows, can result in the improvement of static and dynamic properties of the matrix.

Coconut fiber is extracted from the outer shell of a coconut. The common name, scientific name and plant family of coconut fiber is Coir, Cocos nucifera and Arecaceae (Palm), respectively. Coconut cultivation is concentrated in the tropical belts of Asia and East Africa.

There are two types of coconut fibers, brown fiber extracted from matured coconuts and white fibers extracted from immature coconuts. Coconut fibers are stiff and tough and have low thermal conductivity coconut fibers are commercial available in three forms, namely bristle (long fibers), mattress (relatively short) and decorticated (mixed fibers).

These different types of fibers have different uses depending upon the requirement. In engineering, brown fibers are mostly used According to official website of International Year for Natural Fibers 2009, approximately, 500 000 tones of coconut fibers are produced annually worldwide, mainly in India and Sri Lanka. Its total value is estimated at $100 million. India and Sri Lanka are also the main exporters, followed by Thailand, Vietnam, the Philippines and Indonesia. Around half of the coconut fibers produced is exported in the form of raw fiber.

There are many general advantages of coconut fibers e.g. they are moth-proof, resistant to fungi and rot, provide excellent insulation against temperature and sound, not easily combustible, flame-retardant, unaffected by moisture and dampness, tough and durable, resilient, springs back to shape even after constant use, totally static free and easy to clean.

II. METHODOLOGY & EXPERIMENTAL PROGRAM

I. Fly Ash

Fly ash is the residue obtained from combustion of pulverized coal collected by the mechanical or electrostatic separators from the fuel gases of thermal power plants. Its composition varies with the type of fuel burnt, load on boiler and type of separator etc. Fly ash consists mainly of spherical glassy particles ranging from 1 to 150 micrometers in diameter, out of which the bulk passes through a 45 -micrometer sieve. The fly ash obtained from electrostatic precipitators is finer then Portland cement. The fly ash obtained from cyclone separators is comparatively coarse. The carbon content in fly ash should be as low as possible, where as the silicon content should be as high as possible. The fly ash may be used in concrete either as an admixture or in part replacement of cement. The pozzolanic activity is due to the presence of finely divided glassy silica and lime, which produce calcium silicate hydrate (CS H) responsible for strength development. Due to the difference in densities of cement and fly ash, a part replacement by equal mass increases the volume of cementitious material; whereas replacement by equal volume reduces the mass in practice the replacement of cement by fly ash is usually on the mass basis. Fly ash was obtained from Sarini Power Plant which is situated near the Betul district, Madhya Pradesh which is having specific Gravity of 2.3. The fly ash which is obtained for testing purpose id in dry powdery form. It was carried in the required amount in plastic bags and the properties of it is further tested in the civil engineering laboratory.

S.No.	Chemical Analysis	Class F-Fly Ash (%)	ASTM Requirement (%).
1.	Silicon dioxide sio_2	55.3	-
2.	Aluminum oxide al_2o_3	25.70	-
3.	Ferric oxide, fe_2O_3	5.30	-
4.	$Sio_2 + al_2o_3 + fe_2O_3$	85.9	70.0 minimum
5.	Calcium oxide, cao	5.60	-
6.	Magnesium oxide mgo	2.10	5.0 maximum
7.	Titanium oxide tio_2	1.30	-
8.	Potassium oxide k_2o	0.60	-
9.	Sodium oxide nao	0.40	1.5 maximum
10.	Sulfur trioxide so3	1.40	5.0 maximum
11.	LOI (1000˚c)	1.90	6.0 maximum
12.	Moisture	0.30	3.0 Maximum.

Table.1: Chemical composition of F-fly ash.

II. Coir Fiber

Fibers can be defined as a small piece of reinforcing material possessing certain dimensional characteristics. The most important parameter describing a fiber is its Aspect ratio. “Aspect ratio” is the length of fiber divided by an equivalent diameter of the fiber. The properties of fiber reinforced concrete are very much affected by the type of fiber. Fibers are secondary reinforcement material and acts as crack arrester. Prevention of propagation of cracks originating from internal flaws can result in improvements in static and dynamic properties of the matrix. Coir fiber is Coconut fiber which is extracted from the outer shell of a coconut. It can be obtained through many places such as nearby temple area or oil industries. In this study the coir fiber is collected from temple areas. After collecting it was cleaned through any external particles and shredded in appropriate shape and size.

Fig.1: Sample of Coir Fiber.

III. Cement

The cement used was Ordinary Portland Cement supplied by Ultra Tech Cement Manufacturing Company, which confirming with IS 8112:2013. The cement is in dry powdery form with the chemical compositions and physical characteristics listed in Table 2 and Table 3 respectively.

Chemical Composition	**Percentage**
Silica, SiO2	20.0 – 22.5
Alumina, Al2O3	4.8 – 6.0
Ferum Oxide, Fe2O3	2.4 – 2.5
Calcium Oxide, CaO	Min 62.0
Magnesium Oxide, MgO	Max 3.5
Sulphuric Anhydrite, SO3	2.1 – 2.4
Insoluble Residue, IR	Max 2.5
Loss of Ignition, LOI	Max 2.0
Density	Max 0.4
Lime Saturated Factor, LSF	Min 0.85

Table.2: Typical chemical compositions of Portland cement.

Fineness:	
Surface Area (m^2’kg)	290 – 325
90 micron (%)	1.5 – 2.5
45 micron (%)	15.0 – 2.0

Setting Time (minute): Initial Set Final Set	 90 – 180 180 – 270
Compressive Strength (N/mm^2): 1 day 3 days 7 days 28 days	 20 30 40 50
Soundness (mm)	Max 10

Table.3: Typical physical characteristics of Portland cement.

IV. Aggregates :

Coarse Aggregates

A few properties required for mix design are shape and texture, size gradation, and moisture content. Aggregates' shape affects the workability of the concrete and the surface of the texture affects the bond between matrices. In this study crushed aggregates from quarry with the nominal size of 20 mm and 10 mm in accordance to IS 4031-1968 were used.

Fine Aggregates

Fine aggregates or more commonly known as sand should comply with the Coarse, Medium, or Fine grading requirements of IS 383-1970. The fine aggregate was air dried for 24 hours to obtain a saturated surface dry condition to ensure that water-cement ratio is not affected. In this study, sand was used and sieve analysis was done prior to using it to determine the fine aggregate passing the 4.75 mm to 75 μm sieve. This was the percentage needed for the mix design calculations.

V. Water

Water is an important element in concrete mix and should contain no impurities as impurities affect the hydration process. Water which is safe for drinking purpose is used and Water standard must be in accordance to Indian Standards 456-2000. Water used for both mixing and curing should be free from injurious amount of deleterious materials such as acids, alkalies, salts, organic materials etc. filtered water is generally considered satisfactory for mixing and curing concrete. In present work filtered tap water was used.

Mix Design

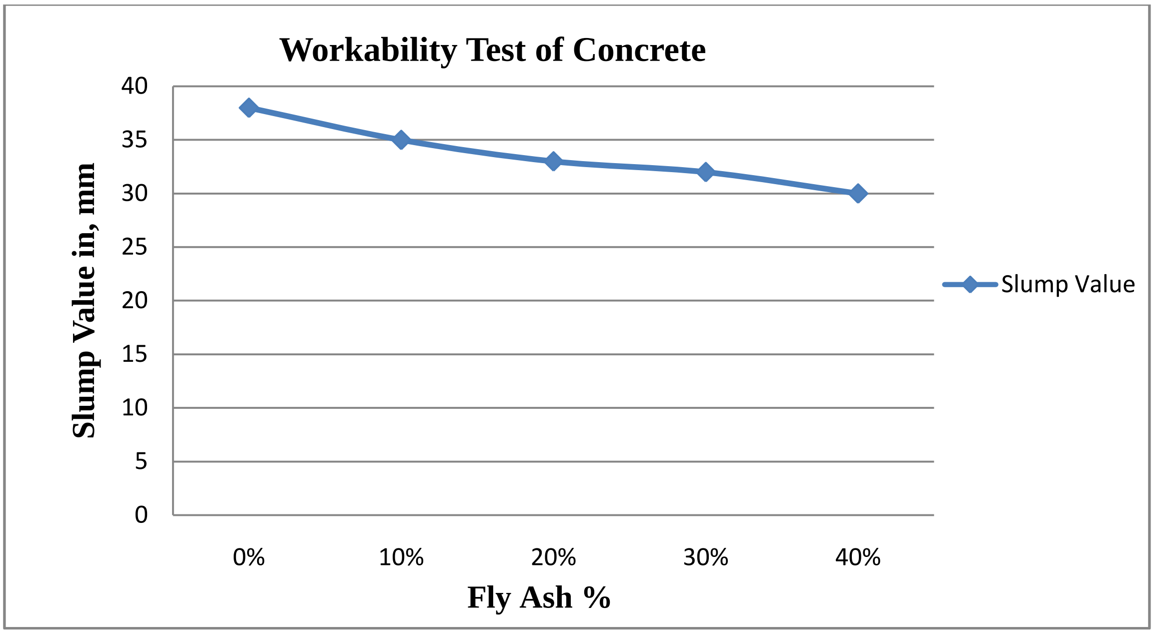
The preferred characteristic strength of 30 N/mm^2 at 28 days was used in this study. IS 456 method was applied in designing the mix. The cubes and beams were prepared for this study in 5 sets in two batches B1 and B2. All set were prepared in control mix of water cement ratio 0.42. Three samples from each set of the mix were tested at the age of 7, 14, and 28 days for compressive strength and 7 and 28 days for flexural strength.

Preparation of Specimens

Moulds were checked for the cleanliness and proper assembling of joints. The interior surface of the moulds was coated with a thin layer of oil to ease in removing. It was then set aside and covered up to prevent unwanted elements in the moulds. The details of specimens prepared are as follows:

Details of Mix (Batch 1)					
S.No	**Mix**	**Fly Ash (%)**	**Weight of Fly Ash in Mix (gm)**	**Weight of Coir Fiber, gm (0.50 %)**	**Slump Value (%)**
1	M 0	0	00	00	38
2	M 1	10	156	7.80	35
3	M 2	20	312	15.60	33
4	M 3	30	468	23.40	32
5	M 4	40	624	31.20	30

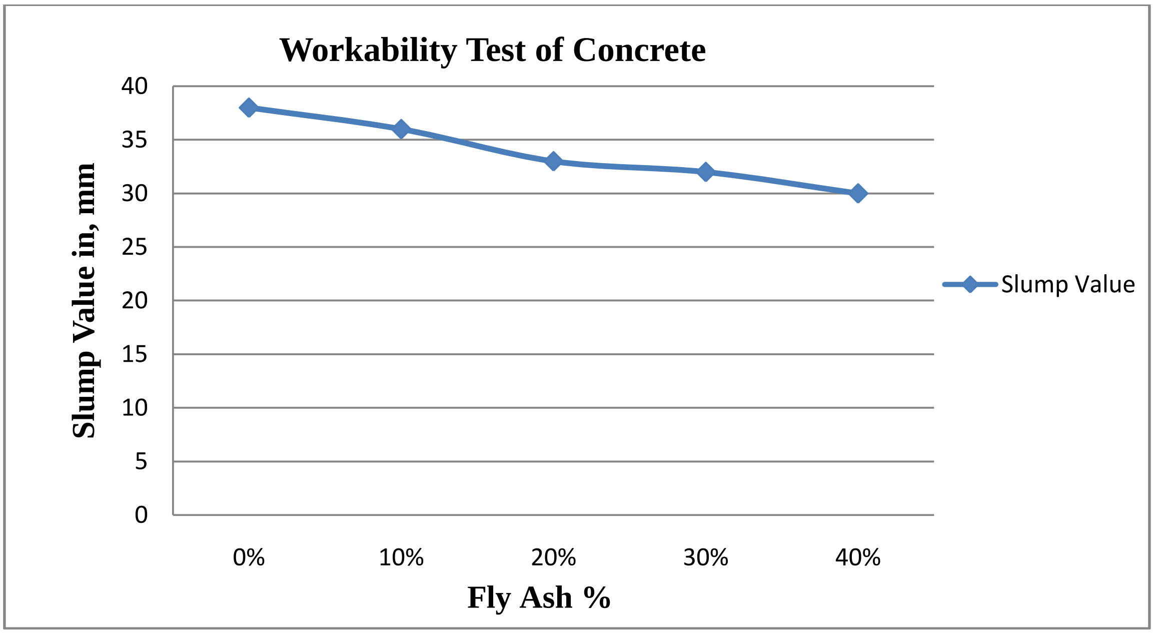
Table.4: Slump cone test results with 0.50 % fiber and different percentage of fly ash.



Graph 1: Workability test of concrete mix with different percentage of Fly Ash (Batch 1).

Details of Mix (Batch 2)					
S.No	**Mix**	**Fly Ash (%)**	**Weight of Fly Ash in Mix (gm)**	**Weight of Coir Fiber, gm (1.0 %)**	**Slump Value (%)**
1	M 0	0	00	00	38
2	M 1	10	156	15.60	36
3	M 2	20	312	31.20	33
4	M 3	30	468	46.80	32
5	M 4	40	624	62.40	30

Table.5: Slump cone test results with 1.0 % fiber and different percentage of fly ash.



Graph 2: Workability test of concrete mix with different percentage of Fly Ash (Batch 2).

Details of specimen prepared

Batch 1								
Details of Cube Specimen					**Details of Beam Specimen**			
S.No	**Name of Cube Sample**	**Fly Ash (%)**	**Weight of Fly Ash in Mix (gm)**	**Weight of Coir Fiber, gm (0.50 %)**	**Name of Beam Sample**	**Fly Ash (%)**	**Weight of Fly Ash in Mix (gm)**	**Weight of Coir Fiber, gm (0.50 %)**
1	C1- 0	0	00	00	B1- 0	0	00	00
2	C1- 10	10	156	7.80	B1- 10	10	235	11.75
3	C1- 20	20	312	15.60	B1- 20	20	470	23.75
4	C1- 30	30	468	23.40	B1- 30	30	705	35.25
5	C1- 40	40	624	31.20	B1- 40	40	940	47.00

Table.6: Details of Specimens prepared for test in batch 1.

Batch 2								
Details of Cube Specimen					**Details of Beam Specimen**			
S.No	**Name of Cube Sample**	**Fly Ash (%)**	**Weight of Fly Ash in Mix (gm)**	**Weight of Coir Fiber, gm (1.0 %)**	**Name of Beam Sample**	**Fly Ash (%)**	**Weight of Fly Ash in Mix (gm)**	**Weight of Coir Fiber, gm (1.0 %)**
1	C2- 0	0	00	00	B2- 0	0	00	00
2	C2- 10	10	156	15.60	B2- 10	10	235	23.50
3	C2- 20	20	312	31.20	B2- 20	20	470	47.00
4	C2- 30	30	468	46.80	B2- 30	30	705	70.50
5	C2- 40	40	624	62.40	B2- 40	40	940	94.00

Table.7: Details of Specimens prepared for test in batch 2.

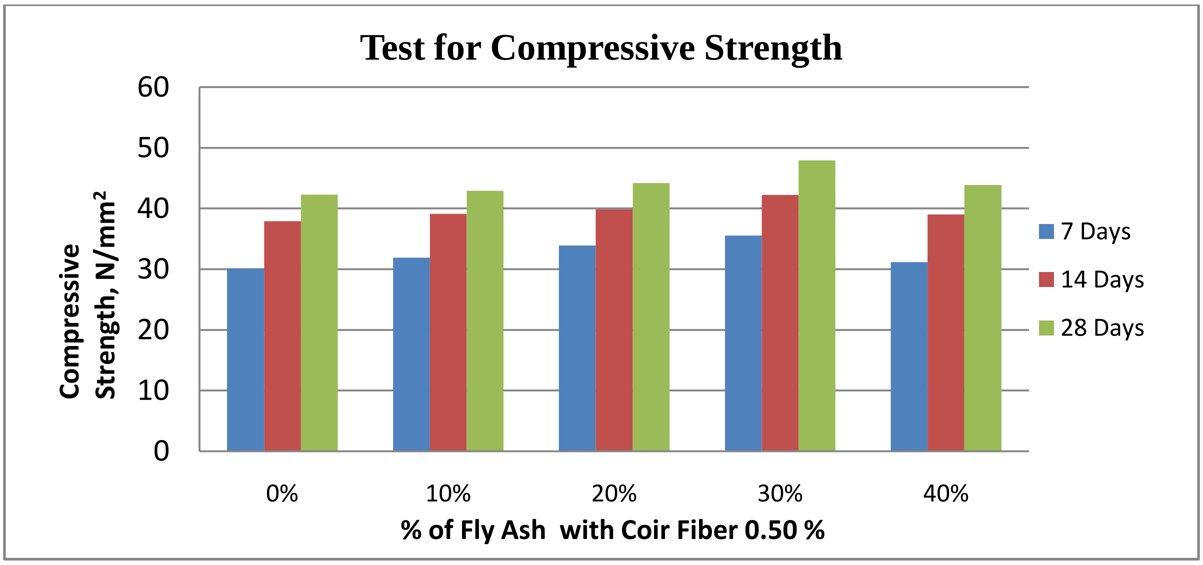
Fig.2: Wet curing of specimens

Tests on Hardened Concrete
The compressive strength and flexural strength of all concrete specimens was determined following Indian standard testing procedure [IS 516:1959]. The specimens were removed from the moulds after 24 hours and subsequently immersed in water for different age of testing. For each test three specimens were tested for the determination of average compressive and flexural strength. Test was performed on compression testing machine having capacity of 200 Ton. The compressive strength tests was conducted on a Compression testing machine and flexural strength was carried on third point loading machine. Average value of samples has been reported below.

I. Compressive Strength
Compressive strength of concrete can be represented as the performance of concrete subjected to ultimate load. This concrete property is represented in Table 4.1 and Graph 4.1. The tests were performed on concrete specimens varying from the age of 7 days to 28 days and each point presented in the graphical plots were taken from the average of 3 readings.

S.No	Cube Sample name	7 Days strength, N/mm^2	14 Days strength, N/mm^2	28 Days strength, N/mm^2
		Average of 3 samples		
1	C1- 0	30.11	37.89	42.27
2	C1- 10	31.89	39.12	42.92
3	C1- 20	33.90	39.88	44.20
4	**C1- 30**	**35.55**	**42.22**	**46.50**
5	C1- 40	31.15	39.00	43.85

Table.8: Compressive strength test results of mix Batch 1.

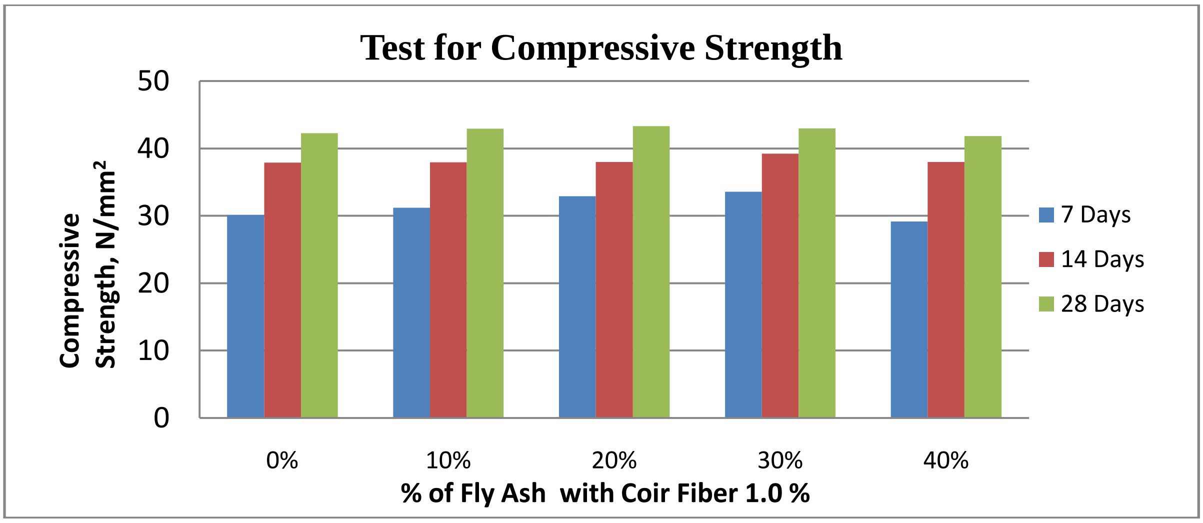


Graph 3: Compressive Strength variation of mix Batch 1.

Fig.3: Compressive strength test of cube specimen on Compression testing machine.

S.No	Cube Sample name	7 Days strength, N/mm^2	14 Days strength, N/mm^2	28 Days strength, N/mm^2
		Average of 3 samples		
1	C2- 0	30.11	37.89	42.27
2	C2- 10	31.20	37.95	42.92
3	C3- 20	32.90	37.98	43.30
4	C4- 30	33.55	39.22	42.95
5	C5- 40	29.15	38.00	41.85

Table.9: Compressive strength test results of mix Batch 2.



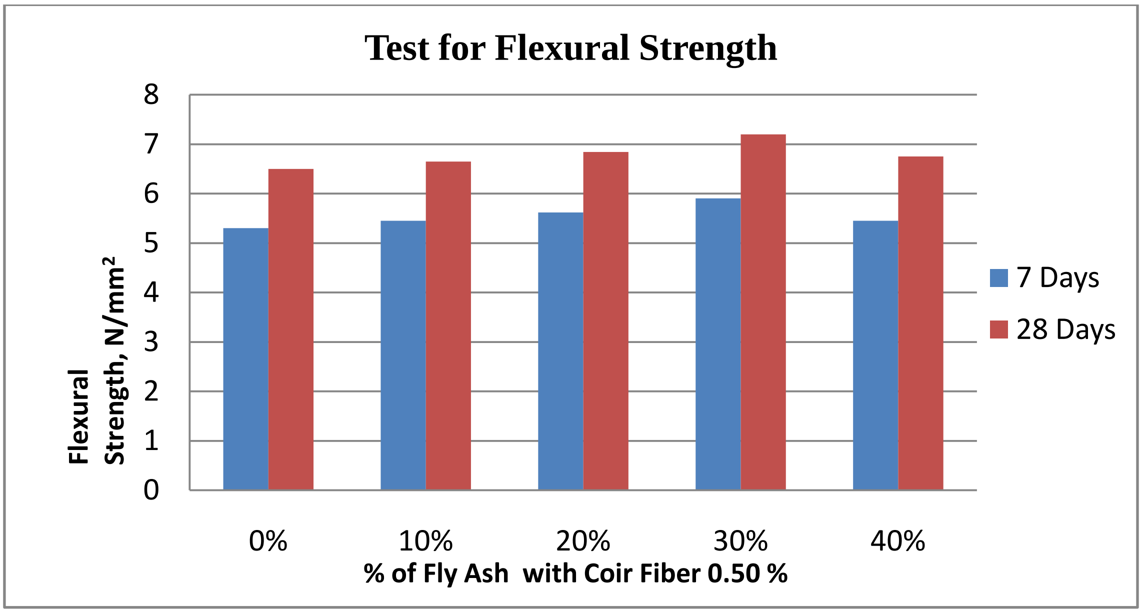
Graph 4: Compressive Strength variation of mix Batch 2.

II. Flexural Strength

Flexural strength of concrete can be represented as the performance of concrete subjected to ultimate load under loading condition. This concrete property is represented in Table 4.3 and 4.4 to Graph 4.3 and 4.4. The tests were performed on concrete specimens varying from the age of 7 days and 28 days and each point presented in the graphical plots were taken from the average of 3 readings.

S.No	**Beam Sample name**	**7 Days strength, N/mm^2**	**28 Days strength, N/mm^2**
		Average of 3 samples	
1	B1- 0	5.30	6.50
2	B1- 10	5.45	6.65
3	B1- 20	5.62	6.84
4	**B1- 30**	**5.90**	**7.20**
5	B1- 40	5.45	6.75

Table.10: Flexural strength test results for Batch 1.

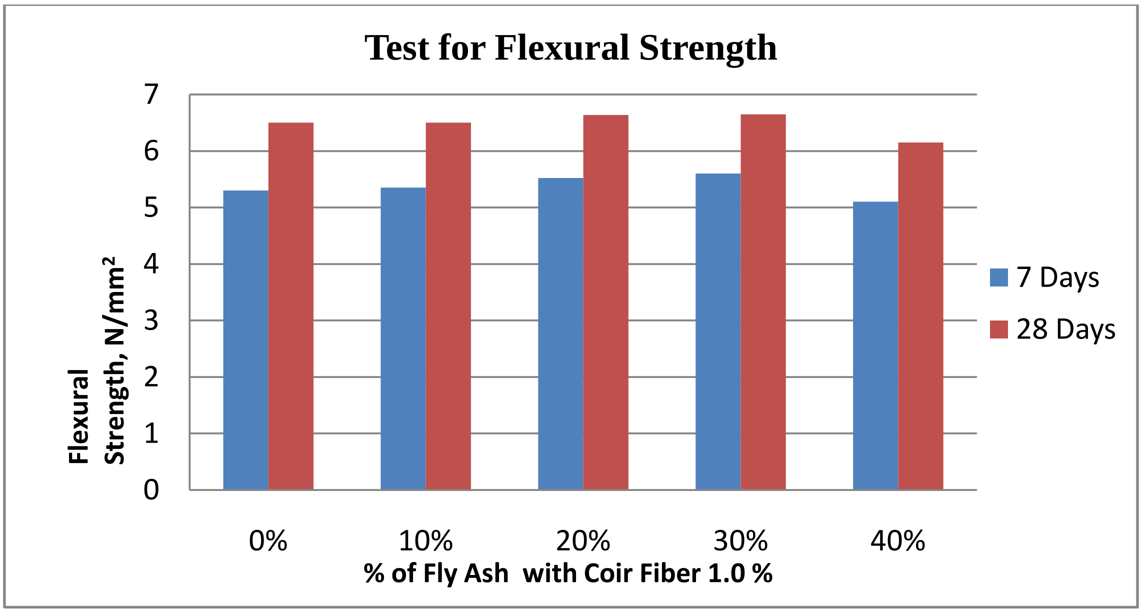


Graph 5: Flexural Strength variation of mix Batch 1.

Fig.4: Flexural strength test of Beam specimen on third point loading apparatus.

S.No	Beam Sample name	7 Days strength, N/mm^2	28 Days strength, N/mm^2
		Average of 3 samples	
1	B2- 0	5.30	6.50
2	B2- 10	5.35	6.50
3	B3- 20	5.52	6.64
4	B4- 30	5.60	6.65
5	B5- 40	5.10	6.15

Table.11: Flexural strength test results for Batch 2.



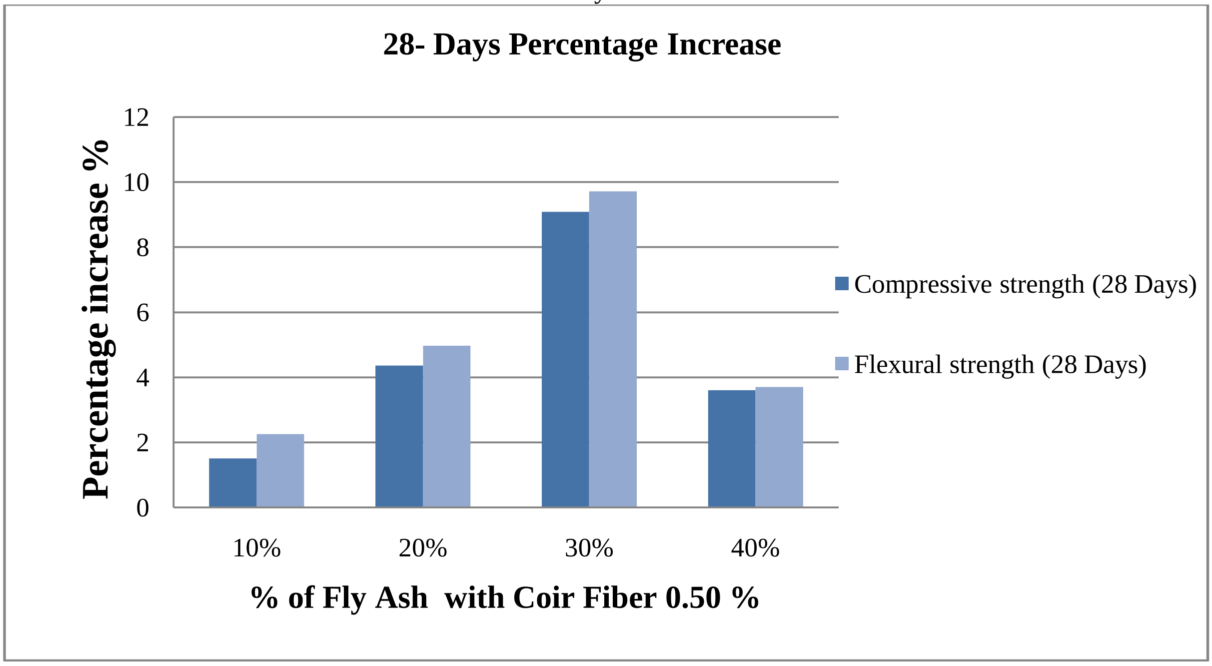
Graph 6: Flexural Strength variation of mix Batch 2.

Calculation of Optimum content for mix

The test result conducted in different days with the different percentage of fiber and fly ash mix, it is observed that the optimum content of mix in concrete is 0.50 % with 30 % of fly ash replacing by weight of cement. The variation of compressive and flexural strength with the different percentage of mix can be concluded from the curve shown in graph 4.1, 4.2, 4.3, 4.4 and table 4.5. However at the same percentage of fiber and fly ash in the mix, the flexural strength improvement is comparatively more.

S.NO	No. of Days	Fly Ash, % with 0.50 % Fiber	Compressive strength, %	Flexural strength, %
1	28	10	1.51	2.25
2	28	20	4.36	4.97
3	**28**	**30**	**9.09**	**9.72**
4	28	40	3.60	3.70

Table.12: Compressive strength and Flexural strength percentage increase with comparison to traditional concrete in 28 days of Mix Batch 1.



Graph 7: 28 Days percentage increase

CONCLUSIONS AND RECOMMENDATIONS

Based on the results and observations made in this experimental research study, the following conclusions are drawn:

- Compressive strength and Flexural Strength of fly ash based coconut fiber reinforced concrete specimens were higher than the conventional concrete at all the ages.
- The maximum 28 day cube compressive strength obtained was 46.50 mpa, for a mix with fiber length of 40mm, 30% fly ash and fiber content of 0.50 % by weight of cement.
- The maximum value of flexural strength obtained was 7.20 mpa, for the mix with fiber length of 40mm, 30% fly ash and fiber content of 0.50% by weight.
- The workability of concrete decreases with the increase in fly ash, the particles of Fly ash reduces the amount of water required to produce a given slump. The circular shape of the fly ash particles and its dispersive ability provide water reducing characteristics.
- Incorporation of fly ash in concrete can save the coal & thermal industry disposal costs and produce a ‘greener’ concrete for construction.

It has been observed from the test results that the optimum content of fly ash is 30 % and for coir fiber is 0.50 % by weight of cement in concrete mix.

References

[1.] **"**I.S: 10262-198**"**. *Recommended guidelines for concrete mix design, Bureau of Indian Standards*, reaffirmed, New Delhi 1999 and IS: 456:2000 Indian standard recommended guidelines for concrete mix design.
[2.] **"**IS: 8112-1989**"**. *Specifications for 43-Grade Portland cement*, Bureau of Indian Standards, and New Delhi, India
[3.] **"**I.S: 516-1959**"**.*Method of test for strength of concrete*, Bureau of Indian Standards, New Delhi, 1959.
[4.] **"**I.S:2386 (Part I, IV, VI)-1988**"**.
[5.] *Indian standard Method of test for aggregate for concrte*, Bureau of Indian Standards, Reaffirmed, New Delhi, 2000.
[6.] **"**IS: 1199-1959**"**. *Indian Standards Methods of Sampling and Analysis of Concrete*, Bureau of Indian Standards, New Delhi, India.
[7.] Ramaswamy H.S., Ahuja B.M., Krishnamoorthy S. 1983. **"***Behaviour of Concrete Reinforced With Jute*, Coir and Bamboo Fibers**"**.
[8.] The Intl. J. of Cement Compotes and Light Weight Concrete. pp. 3-12.
[9.] Gram H-E. 1983. **"***Durability of Natural Fibers in Concrete***"**.
[10.] Report No. 1, Swedish Cement and Concrete Research Institute, Stockholm, p. 255.
[11.] Jorillo P., Shimizu G. 1992.
[12.] **"***Coir Fiber Reinforced, Cement - Based Composite, Part 2: Fresh and Mechanical Properties of Fiber Concrete*. Proc. of 4th Intl. Symp of RILEM, Fiber Reinforced Cement and Concrete**"**, Sheffield, U.K. Swamy R.N. (Ed.), E and FN Spon, London. pp. 1096-1109.
[13.] **"***Utilization of Discarded Fly Ash as a Raw Material in the Production of Portland cement***".**
[14.] Bhatty, JI., J Gajda, PE., Botha, F. and MM Bryant, PG. 2006 Journal of ASTM International, Vol. 3, No. 10.
[15.] **"***Effect of partial replacement of cement with fly ash on the strength and durability of HPC***".**
[16.] Gopalakrishna, S., Rajamane, N.P., Neelamegam, M., Peter, J.A. and Dattatreya, J.K. 2001. The Indian Concrete Journal, pp. 335-341.
[17.] **"***Nucleation and Pozzolanic Factors in Strength Development of Class F Fly Ash Concrete***"**.
[18.] Gopalan, M. K. (1993), ACI Materials Journal, Vol.90, No.2, pp. 117 – 121.
[19.] **"***Effects of water / powder ratio, mixing ratio of fly ash, and curing temperature on pozzolanic reaction of fly ash in cement paste***"**.
[20.] Hanehara, S., Tomosawa, F., Kobayakawa, M., Hwang, K. (2001), Cement and Concrete Research, Vol.31, pp. 31 – 39.
[21.] **"***Prediction model of compressive strength development of fly ash concrete***"**, Hwang, K., Noguchi, T., Tomosawa, F. (2004), Cement & Concrete Research, Vol.34, pp. 2269 –2276.
[22.] Saravana raja mohan, P.Jayabalan, A Rajaraman on **"***properties of fly ash based coconut fiber composite***"**,
[23.] American Journal of Engg and Applied Science 5(1):29-34,2012
[24.] A.Zutaida, S.Norshahida, I.Sopian and H.Zahurin (malaysia) on **"***Effect of fiber length variation on mechanical and physical properties of coir fiber reinforced cement albumen composite***"**.
[25.] IIUM Engg Journal Vol.12 No 1, 2011.
[26.] 16..Alida Abdullah, Shamsul Baharin Jamaludin, Mazlee Mohd Noor, Kamarudin Hussin on **"***Composite Cement Reinforced Coconut Fiber: Physical and Mechanical Properties***"**
[27.] Australian Journal of Basic and Applied Sciences, 5(7): 1228-1240, 2011
[28.] Wilson o. tablan **"***Flexural Strength of Concrete Beams Containing Twinned Coconut Fibers***"**
[29.] Vol 5 No.1 December 2007 ISSN: 2094-1064
[30.] Majid Ali Coconut fiber: **"***A versatile material and its applications in engineering***"**. Journal of Civil Engineering and Construction Technology Vol. 2(9), pp. 189-197.
[31.] Tan eng slang **"***Effect of coconut fiber and egg albumen in concrete for greener environment***"**.
[32.] Baruah and Talukdar **"***Properties of plain concrete and coconut fiber reinforced concrete***"**
[33.] Journal of Civil Engineering and Construction Technology Vol. 2(9), pp. 189-197, 2 September, 201.
[34.] Siddique R., **"** *Performance characteristics of high volumes of class F fly ash***"**,
[35.] Cement and Concrete Research, Vol.34,2004,pp.487 -493.