Synergistic Effect Of Binary Agro-Ash Blends And Nylon Fiber Reinforcement On The Performance Of Sustainable Concrete

A CHIRU PAVAN KUMAR[1], K SURENDRA BABU[2]
[1]Dept of Civil Engineering
[2]Assistant professor, Dept of Civil Engineering
[1, 2] Lenora College of Engineering, Rampachodavaram

Abstract- *The The depletion of natural resources and the high carbon footprint associated with conventional Portland cement production have intensified the search for sustainable alternatives in the construction industry. This study investigates the synergistic effect of incorporating binary agricultural ash blends specifically Palm Oil Fuel Ash (POFA) and Sugarcane Bagasse Ash (SCBA) along with natural NYLON fiber reinforcement to produce an eco-efficient, high-performance concrete. A series of concrete mixtures were prepared where ordinary Portland cement was partially replaced by binary blends of POFA and SCBA at varying percentages while NYLON fibers were introduced at localized volume fractions (e.g., 0.5% to 1.5%) to mitigate the inherent brittleness of the ash-modified matrix.*

The present project involves a comprehensive laboratory experimentation program aimed at validating the application of these recycled waste materials. The primary objectives of this investigation is to systematically analyze the fresh, mechanical, and tensile behavior of the resulting concrete mixes, establishing the structural and environmental performance of the combined binary ash and natural fiber system and to evaluate the mechanical and strength properties of concrete developed by replacing varying percentages of ordinary Portland cement with binary blends of POFA and SCBA. To analyze the tensile and post-cracking behavior of the matrix upon the addition of natural NYLON fibers (ranging from 0.5% to 1.5% by volume fraction).

Keywords: Palm oil fuel ash, Sugarcane bagasse ash, workability, compressive strength, split tensile strength test, water absorption test, Durability studies.

I. INTRODUCTION

Making The escalating depletion of premium natural geological aggregates and the significant anthropogenic carbon footprint inextricably tied to conventional Ordinary Portland Cement (OPC) manufacturing have collectively accelerated the imperative for transformative, eco-efficient construction materials. This master thesis chronicles a systematic, comprehensive laboratory investigation into the synergistic mechanics of synthesizing binary agricultural ash blends—specifically Palm Oil Fuel Ash (POFA) and Sugarcane Bagasse Ash (SCBA)—cojoined with high-tensile natural Nylon fiber reinforcement to formulate a novel class of sustainable structural concrete. Driven by the architectural necessity to reconcile ecological mitigation with mechanical rigor, this study details a matrix configuration wherein conventional OPC was structurally substituted by combined POFA-SCBA binary blends across comprehensive weight replacements (0%, 10%, 20%, and 30%), under a fixed water-to-binder ratio. Simultaneously, alkaline-treated natural Nylon fibers were selectively integrated across distinct volume fractions (0.0%, 0.5%, 1.0%, and 1.5%) to strategically counteract the characteristic micro-structural brittleness and micro-crack propagation inherent within highly substituted pozzolanic cementitious matrices

Cement is the most important ingredient of the concrete which produces carbon dioxide which is May harmful. So it is a main concern to reduce the usage of cement. The increase in price of the cement not only will increase the budget of a construction however additionally poses a significant threat to the country's development.. Rapid industrial expansion produces severe difficulties all around the world, including as the depletion of natural resources and the creation of vast amounts of waste materials throughout the manufacturing, construction, and demolition stages; one option to mitigate this problem is to utilize wastes.

The impact of carbon dioxide emission due to production of Portland cement can be reduced by partial replacement of cement with supplementary cementitious materials. Palm ash and bagasse ash is a waste materials comprise pozzolanic properties but their disposal is causing acute environmental setbacks. The utilization of industrial and agricultural waste product in concrete has been a major step on waste reduction.

The present project involves a comprehensive laboratory experimentation study for the application of new waste materials in the preparation of concrete. The main objective of investigation is to study the strength properties of concrete with different percentages replacement of cement with palm oil fuel ash and sugarcane bagasse ash and to study the tensile behaviour on adding with NYLON fibres.Fresh concrete tests like compaction factor test and hardened concrete tests like compressive Strength at the age of 7 days and 28 days was obtained and also durability aspect of with palm oil fuel ash and sugarcane bagasse ash and the tensile behaviour on adding with NYLON fibresconcrete was tested.

The objective of the present study was to investigate experimentally the properties of Concrete with the following test results

1. Workability
2. Compressive strength
3. Flexure strength
4. Tensile strength

II. REVIEW OF LITERATURE

Considering above background, an experimental investigation was carried out to consider the both types and amount of contents of different types of cement and sand replacement materials on the properties of concrete. A lot of work has been done to explore the benefits of using pozzolanic materials in making and enhancing the properties of concrete. Literature review of with palm oil fuel ash and sugarcane bagasse ash and to study the tensile behaviour on adding with NYLON fibresis presented in the following sections.

Chindaprasirt et al. (2007) & Amran et al. (2021): Investigated the long-term durability of POFA concrete, noting that its high silica content enhances sulfate resistance and reduces water permeability by refining the interfacial transition zone (ITZ).

Khan et al. (2023) & Mishra et al.: Focused on SCBA, highlighting its pozzolanic activity and its role in enhancing compressive and flexural strength when used at 10–15% replacement levels. They emphasized the importance of controlling the burning process of bagasse to ensure low carbon content and high amorphous silica reactivity.

A.N.Dancygier andZ.Savirstudied the influence of NYLON fiber on flexural performance of high strength concrete beam with low longitudinal reinforcement magnitude relation, that tried that NYLON fiber enhance crispiness of beam compared to it of beam with minimum longitudinal reinforcement magnitude relation. Compared to NYLON fiber concrete, the hybrid fiber with completely different kind and size will improve effectively strength and toughness of concrete, kind hybrid result throughout completely different fiber, play various useful influence from completely different level. However, few researches on flexural performance of hybrid fiber strengthened RC beam were studied.

Omualdi and Batson (1963) after conducting impact check on fibre concrete specimens, they over that 1st crack strength improved by addition of closely spaced continuous NYLON fibres in it. The NYLON fibres forestall the adverting of small cracks by applying pinching forces at the crack tips and so delaying the propagation of the cracks. Further, they established that the rise in strength of concrete is reciprocally proportional to the root of the wire spacing.

Charles H.Henage (1976) developed an analytical technique supported final strength approach that has taken into consideration of bond stress, fibres stress and volume fraction of fibres. Once his investigations, he all over that the incorporation of NYLON fibres considerably will increase the last word flexural strength, reduces crack widths and initial crack occurred at higher hundreds.

Deb, P. S., Nath, P., & Sarker, P. K. (2014): Sugar cane bagasse ash (SCBA) with mixture of flyash content showing huge improve in the consequences of workability and high strength contrasted with Ordinary Portland Cement (OPC). By changing dissimilar (0%,10% and 20%)contents of Sugar cane bagasse ash (SCBA) with various proportions of flayash content showing a few blemishes, One of them is with increment in SCBA content workability is diminishing simultaneously strength is expanding. By keeping up silicates to alkaline proportions of 1.5 to 2.5 and following ACI 318 and AS 3600 codes for curing we can accomplish above outcomes when contrasted with OPC.

Goriparthi, M. R., & TD, G. R. (2017): He arranged geopolymer concrete consolidating fly ash and Sugar cane bagasse ash (SCBA) as a limiting material, Alkaline materials Sodium silicate (Na_2SiO_3) and Sodium Hydroxide (NaOH) as activators. And contrasted the consequences of both OPC and geopolymer concrete and closed the accompanying aftereffects of two evaluations of concrete GPC20 AND GPC50. Significant boundaries of corrosive mass misfortune factor (AMLF) by submerging in 5% of H_2SO_4 solution and strength properties (Compressive, Tensile and Flexure) were resolved..

III. MATERIALS AND METHODS

The experimental investigation work is started with various tests on the constituent materials. The constituent materials are given below.

1. Cement
2. Coarse aggregate
3. Water
4. Sugarcane bagasse ash
5. Palm oil fuel ash

1. Cement

Ordinary Portland cement of 43 grades manufactured by Shree Ultratech Cement was used throughout the Experimental investigation. The quality of the cement was confirming to IS 8112:1989 was used in the field.

2. Fine Aggregate

Fractions from 4.75 mm to 150 microns are termed as fine aggregate. Locally available river sand passed through 4.75mm IS sieve is applied as fine aggregate conforming to the requirements of IS 383:1970.

3. Coarse Aggregate

Coarse aggregate shall be of hard broken stone of granite shall be of hard stone, free from dust, dirt and other foreign matters. The stone ballast shall be of 20mm and down and should me retained in 5mm square mesh and well graded such that the voids do not exceed 42 percent. Aggregate most of which is retained on 4.75-mmIS Sieve and containing only so much finer material as is permitted for the various types described in this standard.

4. Palm oil fuel ash

Palm oil fuel ash is a waste product of the palm mill industry; this industry extracts oil from oil palms fruits. The palm oil fuel ash is used in this current work was taken from Ruchi industries, Samarlakot.

5. Sugar cane bagasse ash

Sugar cane bagasse ash (SCBA) has recently been tested in some parts of the world for its use as a cement replacement material. The bagasse ash was found to improve some properties of the paste, mortar and concrete including compressive strength and water tightness in certain replacement percentages and fineness.

IV. MIX DESIGN

The property of workability, therefore, becomes of vital importance. The mix design is done as per IS 10262-2009. Percentage dosage of super plasticizer (high range water reducers) is an additional parameter to be considered for designing an OPC mix. Percentage dosage of super plasticizer was fixed as per the mix design method described in IS 10262-2009. Mix proportion was arrived through various trial mixes. The grade of concrete prepared for the experimental study was M35.

V. RESULTS AND DISCUSSIONS

This session provides an outline of the experimental results and endeavors to draw some conclusions. The take a look at result covers the workability, mechanical properties and sturdiness properties of concrete with and while not admixtures. The results of the experimental investigation on Palm oil fuel ash concrete wherever Sugar cane bagasse ash (SCBA) and Palm oil fuel ash has been used as partial replacement of cement in concrete mixes. On commutation cement with completely different percentages the workability, compressive strength, split tensile strength and flexural strength is studied.

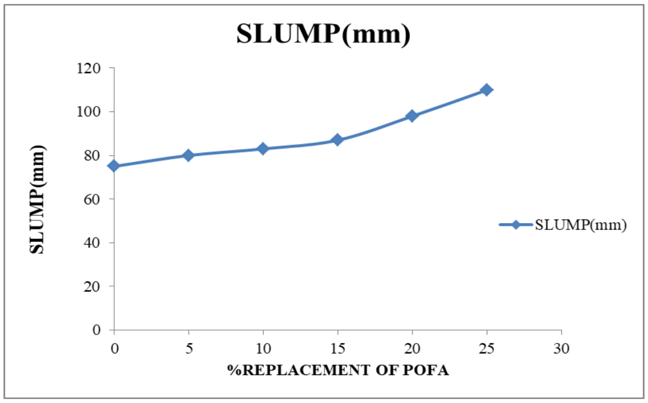
5.1 REPLACEMENT DETAILS

The replacement details of Palm oil fuel ash and Sugar cane bagasse ash has been given in the below table. The replacement of cement percentages by 0, 5, 10, 15, 20 and withSugar cane bagasse varying the cement replacement percentagesby 0, 10, 20, 30, 40.

5.2 VARIATION OF SLUMP VALUES

Slump test is used to determine the workability of concrete. The apparatus used for doing slump test are slump cone and tamping rod. Slump test is used to determine the workability of concrete. The apparatus used for doing slump test are slump cone and tamping rod. This is the most commonly used test of measuring the consistency of concrete.

The slump of the freshly mixed concrete was measured by using a slump cone in accordance to ASTM C143. It can be observed from Figure 5.1 that all mixtures have a slump of less than 45mm and are observed that slump values increasing with increase in slag content.



Graph 5.1 Slump valueson replacements

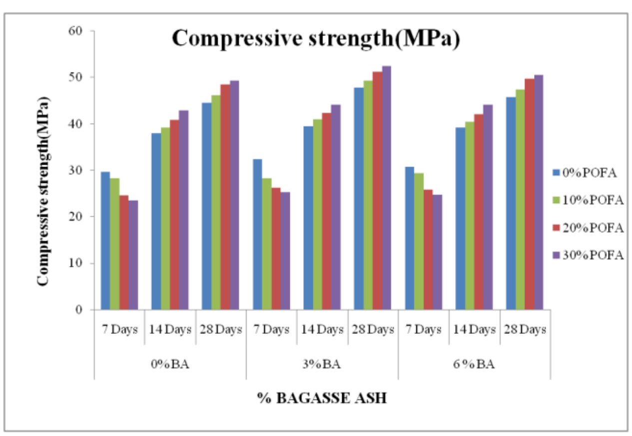
5.3 COMPRESSIVE STRENGTH

The main function of the concrete in structure is mainly to resist the compressive forces. When a plain concrete member is subjected to compression, the failure of the member takes place, in its vertical plane along the diagonal.

Cubes are prepared of size 150 mm x 150 mm x 150 mm are checked for compressive strength. The specimens tested for 7, 14 and 28 days. The specimen were tested for compressive strength parallel to the plane of the board by applying increasing compressive load until failure occur. The arrangement of load is applied to the specimen by placing the specimen length vertical between the surfaces of the testing machine.

5.4 VARIATION OF COMPRESSIVE STRENGTH FOR DIFFERENT MIXES

Compressive strength of concrete replaced with palm oil fuel ash for curing period of 7-days, 14-days and 28-days respectively and TABLE 6.2 shows the summarized Compressive strength Results for different curing periods– M40 grade.



Graph 5.1 Plot shows the Variation in Compressive Strength for % Replacement of POFA

As the percentage of Palm oil fuel ash & Bagasse ash increases the compressive strength of concrete tends to increase upto certain percentage and then start's decreasing with the increase of ash content. The provided chart illustrates the compressive strength of M40 grade concrete across three curing periods (7, 14, and 28 days) by varying the percentages of Bagasse Ash (BA) and Palm Oil Fuel Ash (POFA). Generally, compressive strength increases as the curing period extends from 7 to 28 days for all combinations. Furthermore, the addition of POFA and BA tends to enhance the compressive strength up to a specific threshold before the strength begins to decline with further increases in ash content. Based on the data, the 3% BA mixes exhibit higher compressive strength values at the 28-day mark compared to the 0% and 6% BA mixes.

5.5 SPLIT TENSILE STRENGTH TEST

The size of specimens 150 mm dia and 300 mm length was used and the specimens were cured in normal water. Concrete specimen cubes are used to determine compressive strength of concrete and were tested as per as per IS 516 (1959 Split tensile strength of concrete keeping 10% palm oil fuel ash and 20% SCBA as constant and with different percentages of NYLON fibre for curing period of 7-days, 14-days and 28-days respectively and Table shows the summarized Split tensile strength Results for different curing periods– M35 grade..

Compressive stress = $2P/\pi LD \{D^2 / (D-r)-1\}$

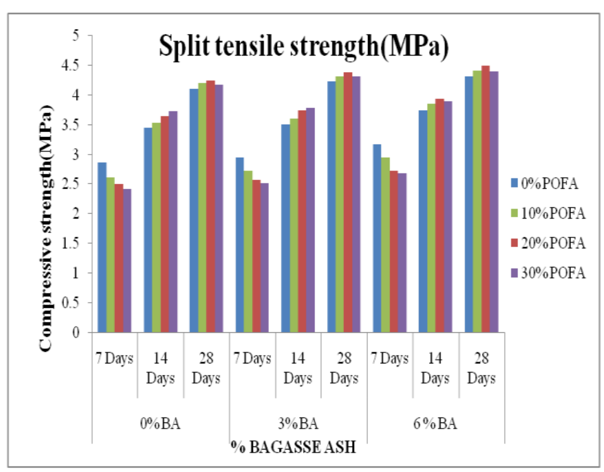
Tensile stress $=2P / \pi LD$

Where, P = Compressive load on cylinder

L = Length of cylinder =300 mm

D = Diameter of cylinder = 150mm

r& (D-r) are distance of the element from the two loads respectively.



Graph 5.2 summarized results on the effect of Palm oil fuel ash & Bagasse Ash on Split tensile strength of concrete

5.6 FLEXURAL STRENGTH TEST

In the flexural strength test theoretical maximum tensile stress reached at the bottom fibers of the test beam is known as the modulus of rupture. When concrete is subjected to bending stress, compressive as well as tensile stresses are developed at top and bottom fibers respectively. If the largest nominal size of aggregate does not exceed 20mm, the dimension of specimen may be 150mm×150mm×700mm.

$$f = \frac{M}{Z} = \frac{(PL/6)}{(bd^2/6)}$$

$$f_b = \frac{PL}{Bd^2}$$

When 'a' greater than 20 cm for a 15cm specimen,

$$f_b = \frac{3Pa}{bd^2}$$

The Flexural strength of the concrete mix for M-35 with partial replacement of cement by POFA and SCBA respectively showed higher Flexural Strength after 7 and 28 days. The 7 days and 28 days Flexural strength of mix with 10% partial replacement of Palm oil fuel ash, 20 % replacement of SCBA and 1.5% of NYLON fibre showed higher strength compared to other mixes

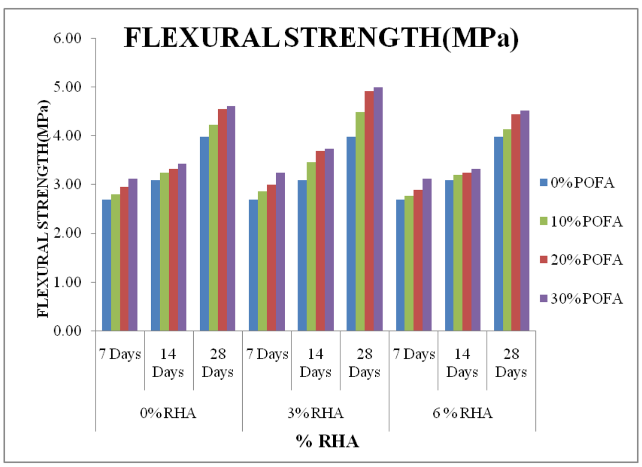


Fig 5.3 shows the summarized results on the effect of Palm oil fuel ash & Bagasse Ash on Split tensile strength of concrete

From the workability test, it was observed that there is decrease in the slump value with increase in both the BAGASSE ASH & Palm oil fuel ash quantities. The slump value was decreased by 68% at 64% Cement + 6% Bagasse Ash + 30% Palm oil fuel ash compared with conventional concrete. Results (Figure 1) show that Compressive strength of M40 grade concrete gradually increased with the increase in % Bagasse Ash and Palm oil fuel ash up to 20%, but for 30% Palm oil fuel ash it decreased for 6% Bagasse Ash. The compressive strength at 64% Cement + 3% Bagasse Ash + 30% Palm oil fuel ash was improved by about 11% when compared with conventional concrete

5.7 EFFECT OF NYLON FIBER ON COMPRESSIVE SPLIT TENSILE AND FLEXURAL STRENGTH USING PALM OIL FUEL ASH AND SCBA

The compressive, split tensile and flexural strength of the concrete mix for M-40 with partial replacement of cement by POFA and SCBA respectively showed higher Strength after 7,14 and 28days.The 28 days strength of mix with 30% partial replacement of palm oil fuel ash, 3% replacement of SCBA showed higher strength compared to the mixes.

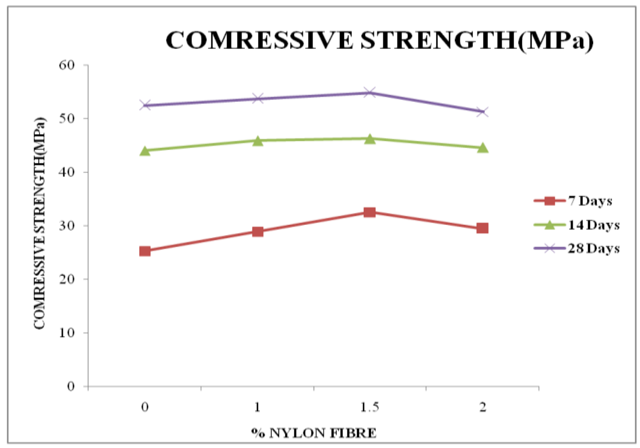


Fig 5.4: Plot shows the Variation in Compressive Strength for different percentages of Nylon fibers

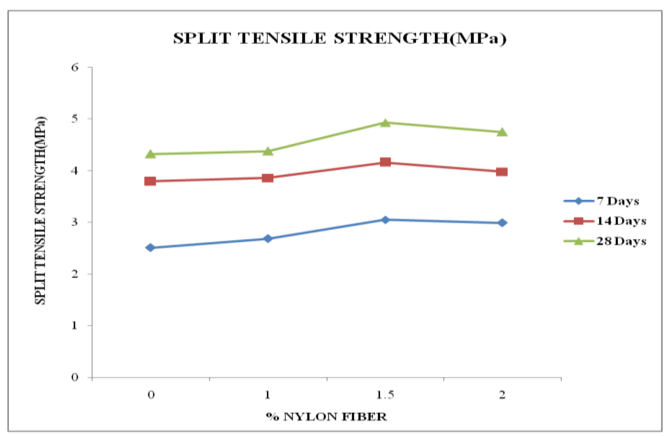


Fig 5.5: Plot shows the Variation in Split Tensile strength for different percentages of Nylon fibers

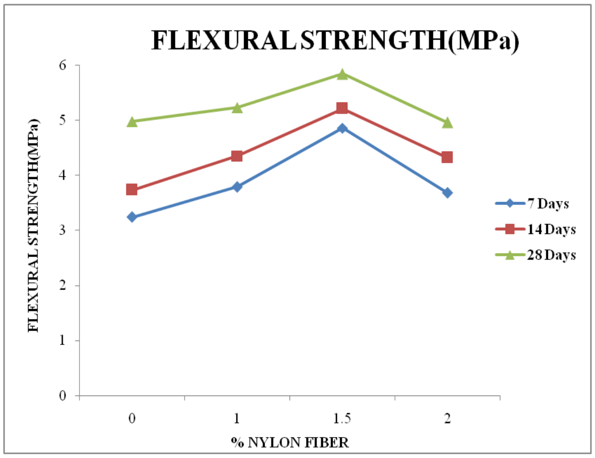


Fig 5.6: Plot shows the Variation in Flexural strength for different percentages of Nylon fibres

From the results, it is evident that with the increase of fiber content, the tensile nature of the concrete also increases, resulting in higher values compared to that of plain concrete.

The figure shows that the test results of splitting tensile strength of specimens after water curing lead to the conclusion that the percentage increase in strength increases with the increase in percentage of fiber content. Also, from the results, it is evident that compressive and flexural strength also increase with the increase of fiber content.

VI. CONCLUSIONS

The Conclusions Based on the results and discussions, the following conclusions can be drawn regarding the use of industrial waste materials (Palm Oil Fuel Ash and Sugarcane Bagasse Ash) and Nylon fibers in concrete:

1. Effect of POFA and SCBA on Concrete Properties

Workability: There is a notable decrease in the slump value as the percentages of Palm Oil Fuel Ash (POFA) and Bagasse Ash (BA/SCBA) increase. Specifically, a 68% reduction in slump was observed in the mix containing 64% cement, 6% Bagasse Ash, and 30% POFA compared to conventional concrete.

Compressive Strength: The compressive strength of M40 grade concrete increases with the addition of POFA and BA up to an optimal point. The 3% BA mix series generally exhibited higher compressive strength values at the 28-day mark compared to the 0% and 6% BA series. The combination of 67% cement, 3% Bagasse Ash, and 30% POFA improved compressive strength by approximately 11% over conventional concrete, which is attributed to enhanced gel formation from the reactive silica in the ash.

Split Tensile Strength: Similar to compressive strength, partial replacement of cement with these ashes generally enhances the split tensile strength. The 6% BA mix series demonstrated the highest overall split tensile strength values, particularly at 28 days.

2. Effect of Nylon Fiber Reinforcement

- Mechanical Performance: The introduction of Nylon fiber into the POFA and SCBA blended mix further improves the concrete's mechanical properties.
- Optimal Dosage: Across compressive, split tensile, and flexural strength tests, the 1.5% Nylon fiber dosage consistently emerged as the optimal content.
- Compressive Strength: The 1.5% fiber mix achieved a peak value of 54.89 MPa.
- Flexural Strength: The mix with 30% POFA, 3% SCBA, and 1.5% Nylon fiber showed the highest flexural strength at both 7 and 28 days compared to other fiber percentages.
- Fiber Dispersion: Increasing fiber content to 2% resulted in a decline in strength, likely due to challenges regarding fiber dispersion and compaction at higher concentrations.

The use of agricultural waste materials (POFA and SCBA) as a partial cement replacement, combined with the addition of Nylon fibers, provides a sustainable solution for agricultural waste disposal while simultaneously yielding concrete with enhanced mechanical strength and improved tensile properties.

REFERENCES

[1] IS 456 (2000): Plain and Reinforced Concrete - Code of Practice.
[2] IS 516 (1959): Method of Tests for Strength of Concrete.
[3] IS 5816 (1999): Method of Test Splitting Tensile Strength of Concrete.
[4] IS 10262 (2009): Guidelines for concrete mix design proportioning.
[5] IS: 12269-1987. Specification for 53 grade ordinary Portland cement, New Delhi, and India Bureau of Indian Standards.
[6] IS: 383-1970. Specifications for coarse and fine aggregates from natural resources for concrete, New Delhi, India: Bureau of Indian standards.
[7] IS: 10262-2009. Recommended guidelines for concrete mix design, New Delhi, India Bureau of Indian Standards.
[8] Camargo, M., Adefrs Taye, E., Roether, J., Tilahun Redda, D., & Boccaccini, A. (2020). A review on natural

fiber-reinforced geopolymer and cement-based composites. *Materials*, *13*(20), 4603. https://doi.org/10.3390/ma13204603 Cited by: 184

[9] K. Ganesan, K. Rajagopal, et al, "Evaluation of palm oil fuel ash as supplementary cementitious material" Cement & Concrete Composites 29 515–524 | March 2007.

[10] D. Suresh, K. Nagaraju, et al, "Ground Granulated Blast Slag (SCBA) In Concrete – A Review" IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE), e-ISSN: 2278-1684, p-ISSN: 2320-334X, Volume 12, Issue 4 Ver. VI | Aug. 2015.

[11] Shamila Habeeb, et al, "Strength and Durability Studies on Ternary Blended Concrete containing SCBA and Palm oil fuel ash" International Journal of Scientific & Engineering Research, Volume 5, Issue 7, ISSN 2229-5518 | July-2014.

[12] Christina Mary V., et al, "Experimental investigation on strength and durability characteristics of high performance concrete using SCBA and m sand" ARPN Journal of Engineering and Applied Sciences ISSN 1819-6608, Vol. 10, No. 11 | June 2015.

[13] Dr. P. Srinivasa Rao et al., "Durability studies on JUTE fibre reinforced metakaolin blended concrete".

[14] Mallikarjuna Rao, G., & Gunneswara Rao, T. D. (2018). A quantitative method of approach in designing the mix proportions of fly ash and SCBA-based geopolymer concrete. Australian Journal of Civil Engineering, 16(1), 53-63.

[15] Rangan, B. V., Hardjito, D., Wallah, S. E., & Sumajouw, D. M. (2005, June). Studies on fly ash-based geopolymer concrete. In Proceedings of the World Congress Geopolymer, Saint Quentin, France (Vol. 28, pp. 133-137).

[16] The Energy Conservation Center (ECC), Output of a Seminar on Energy Conservation in Cement Industry, United Nations Industrial Development Organization, 1994.

[17] Rao, G. M., & Rao, T. G. (2015). Final setting time and compressive strength of fly ash and SCBA-based geopolymer paste and mortar. Arabian Journal for Science and Engineering, 40(11), 3067-3074.

[18] Goriparthi, M. R., & TD, G. R. (2017). Effect of fly ash and SCBA combination on mechanical and durability properties of GPC. Advances in concrete construction, 5(4), 313.

[19] Denamo Addissie, Handling of Concrete making materials in the Ethiopian construction industry, Addis Ababa University department of civil engineering, school of graduate studies, October 2005.

[20] M. Vijaya Sekhar Reddy, I. V. Ramana Reddy P. N. Rao (2010) "High performance of concrete with SCBA" published in International journal of engineering, science & technology.

[21] S. P. Sangeetha, P. S. Joanna "flexural behavior of RC beam with partial replacement of SCBA, American journal of engineering research, volume 03, Issue No 01, 2014.