

CONDENSATION OF NANO PALM OIL FUEL ASH AND SUGARCANE BAGASSE ASHAS PARTIALLY REPLACEMENT OF CEMENT IN CONCRETE

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Abstract

Purpose/Objective: The increasing demand for green and sustainable construction materials has promoted the use of industrial and agricultural waste as alternatives to traditional cementitious materials. The present study aims to study the use of sugarcane bagasse ash (SCBA) and nano palm oil fuel ash (NPOFA) as pozzolanic materials to enhance the workability of M40 concrete.

Design/methodology/approach: Experimental investigation was carried out on concrete mixtures with different proportions of cement, SCBA and NPOFA. The cement proportions of the studied mixtures were 100, 90, 75, 60 and 45%. The NPOFA proportions were 0, 5, 15, 25 and 35%. The SCBA proportions were 0, 5, 10, 15 and 20%. The physical and chemical properties of SCBA and NPOFA were compared with those of ordinary Portland cement and workability of the resultant concrete mixtures was assessed.

Findings: The results show that the addition of SCBA and NPOFA has a significant impact on the workability of M40 grade concrete. The maximum increase in slump of 85 mm was obtained for the mix containing 45% cement, 35% NPOFA and 20% SCBA.

Research Limitations/Implications: The study is restricted to the considered material proportions and workability characteristics of M40-grade concrete; consequently, further investigations are needed to determine the other mechanical and durability features. The results have practical implications for the sustainable use of agricultural and industrial ash waste in concrete production.

Originality/Value: The study shows the potential of SCBA and NPOFA as alternative pozzolanic materials for partially replacing traditional cementitious constituents, contributing to the creation of more sustainable and resource-efficient concrete materials.

Keywords: Agricultural waste; M40-grade concrete; Nano palm oil fuel ash; Pozzolanic materials; Slump; Sugarcane bagasse ash; Sustainable construction.

1. INTRODUCTION

As the world is heading to a new age of where the extinction of material is possible and is also facing the problem of Global Warming as well as high value of land is occupied by waste material which is causing soil contamination. Concrete is widely used all over the world therefore, demand of concrete

is increased day by day. Preparation of Concrete requires huge amount of cement as binding material. To manufacture cement natural resources are used which leads to depletion of resource in near future. So, we needed an alternative of cement so we introduced a material which has Cementous properties. Cement industries is accountable for 12-15% of industrial energy usage as well as the producer of 5-7% of Green House Gases such as COA and Co2.

As a conclusion, we are exploiting waste materials from the palm tree, including fibres, shells, and empty fruit bunches, in our research. Every one tonne of palm oil mill effluent creates 0.6 tonnes of garbage, or about 6 tonnes every ten tonnes, which is bad for our soil and takes up a lot of space. Palm-oil-fuel-ash (POFA) is an industrial byproduct of burning palm oil waste to generate electricity in power plants. POFA has potent pozzolanic properties, which is why we use it to replace some of the cement in concrete. This will also reduce the amount of CO2 released into the atmosphere as a result of the production and processing of cement.

2. LITERATURE REVIEW

T. Joo-haw et al. 1995 discovered that the production of palm oil generates a substantial amount of trash. They burn the empty oil-palm fruit bunches in an incinerator in the palm of the mill to dispose of them. The workability of concrete while dealing with ash is rated as acceptable and no segregation was found. Palm oil waste has cement-like properties. The ash content of the cement reduces the concrete's compressive strength. When cubes were aged for a year, adding up to 10% by weight of ash had no detrimental impact on their strength.

P. Chindaprasirt et al 2007 In this study, a partial cement substitute was created using the husks of rice using fuel ash and palm oil, both of which are leftovers from nuclear reactors that are discarded in landfills. 20%, 40%, and 55% by the weight of binder were crushed up and mixed into the concrete, correspondingly. Concretes incorporating grounded ash, the compressive characteristics and water penetration of ground rice husk-bark ash and palm oil fuel were evaluated. When we compared to normal concrete made using conventional Portland cement, which has a relatively comparable workability, the test results showed that substituting both components for Portland cement raised the water demand in mixtures of concrete.

T. Weerachart et al 2007 One industrial waste product of the palm oil industry that is disposed of in landfills is palm oil fuel ash (POFA). The results showed that depending on the POFA's fineness, using it in concrete resulted in a delay in both the initial and final setting times. The crystallite size of 15.9 microns is known as MP, whereas the starting size of POFA is known as OP., as well as the particle size of 7.4 micron is known as SP. However, replacing 10% MP and 20% SP for Portland cement produced in a stronger nominal mix concrete.

T. Weerachart et al 2009 found out whether high-fineness ground palm oil fuel ash may be used as a cementitious material to create high-strength concrete is the aim of this research. The compressive strength follows, which permeability to water, and sulphate resistivity of a sample created by blending the first type of Portland cement with varied volumes of milled palm oil fuel ash were studied. The compression strengths for those concrete samples have been determined to be in the spectrum of 59.5-64.3Mpa after 28 days of ageing, and After 90 days, the concrete with a 20% GPA had a breaking strength of up to adm70 Mpa. According to research, GPA is a reactive pozzolanic substance that might be used as an additional cementitious component to create high-strength concrete. 0 days, the breaking strength of concrete contained GPA 20% reached as high as adm70 Mpa. Investigations indicate that GPA is a reacting pozzolanic material that might be employed as a supplemental cementitious element in the production of high-strength concrete.

Abdul Awal, et al 2016 This report describes the findings of an experimental study on the performance of concrete including waste carpet fiber (WCF) and POFA as a partial replacement for conventional cement (OPC). Six different volume fractions ranging from 0 to 1.25 percent of 20 mm long carpet fiber were combined with an OPC concrete mix, and additional six mixes were created by substituting 20% of POFA with OPC. The combination of WCF with POFA results in an increase in flexural and high-tension strength, which results in concrete ductility, greater energy absorption, and improved fracture dispersion.

Zeyad M. Abdullah et al 2017 POAF is used in this research is being done on using varying proportions of pozzolanic material to create high strength concrete (HSCx) with a strength more than 90 MPa.. HSCx INCLUDING UPOFA has the potential to boost strength by decreasing water solubility/permeability, setting, and chlorides penetration/migration rates. As a result, in regards to durability and reliability, HSCx is the better option for hot weather.

M.H Hussein, ETAL 2018 In this investigation, traditional, lightweight, self-compacting concrete was made using sugarcane bagasse ash in lieu of some of the cement. In addition to a control specimen, specimens with 5, 10, 15, 20, and 25% SCBA were papered for this purpose. Tensile strength, compressive strength, impact value, workability, water absorption, and ultrasonic pulse velocity tests were used to assess the mechanical characteristics of concrete samples.

B. Farnaz, ETAL 2019 In this work, the impact of using sugarcane bagasse ash as a pozzolan-based material on the hardened characteristics of concrete was investigated. Using X-ray diffraction (XRD), the chemical, physical, and mineralogical properties of bagasse ash were examined. Additionally evaluated were hardened qualities such as heat conductivity, flexural strength, compressive strength, and tensile strength. In this instance, concrete mixtures were made by substituting bagasse ash and cement, but their conductivity was also investigated. Bagasse ash was used to generate the concrete mixes while maintaining all of the pozzolanic qualities of cement. It has

been shown that the best results for increasing compressive, flexural, and tensile strength come from bagasse ash blends with 10% replacement.

S.N. Minnu, ETAL 2020 The researchers employed bagasse ash from sugar cane as an additional cementitious material in their investigation. The qualities of ash from bagasse during fresh and strengthened, and durable concrete are investigated in this study. Bagasse ashes, fly ash, & slag replacement levels have been established to be 20%, 30%, & 50%, respectively. In spite of the fact that the bagasse ash blended cements showed adverse impacts such increased consistency, reduced workability, and delayed initial set; nevertheless, the strength enhancement of bagasse ash blended concrete was found to be more than that of fly ash/slag mixed concrete.

H. Hussein, ETAL 2022 This work investigates the use of Nano Palm Oil Fuel Ash (NPOAF) as a binding material in conjunction with Palm Oil Clinker as aggregate to improve the poor performance of light weight concrete (LWC). NPOFA is partially substituted as cement in amounts of 0, 10, 20, and 30%, while coarse aggregate is replaced by POC in amounts of 0, 50, and 100%.

3. RESEARCH GAP

Concrete is a crucial material that is utilized extensively worldwide in civil engineering. One of the primary ingredients used as a binder in concrete is cement. Other waste materials including egg shell, fly ash, and rice husk ash are utilized to strengthen concrete and enhance other concrete mix characteristics. In order to get novel findings, we are mixing sugarcane bagasse ash with palm oil fuel ash in this study, which is not often done.

4. OBJECTIVE

- To determine how sugarcane bagasse ash and nano palm oil fuel ash (NPOFA) interact to affect the workability of new concrete.
- To determine how sugarcane bagasse ash and nano palm oil fuel ash (NPOFA) interact to affect the hardened qualities of concrete, namely its compressive strength.

5. METHODOLOGY

5.1 MATERIAL REQUIRED

5.1.1 CEMENT: -

It is the major binder materials utilised in this study. Cement is a vital building material in nowadays world. In this study, we used grade 53 ordinary Portland cement (OPC) in accordance with IS: 8112-1989. We acquired the following results from a cement test:

Table 1. Test on cement

SR. NO.	NAME OF TEST	READING
1	Fineness of cement	1%
2	Consistency of cement	34%
3	Initial setting time of cement	30 min
4	Final setting time of cement	10 hrs.
5	Soundness of cement	3mm

5.1.2 Fine Aggregate

Fine aggregate is used in concrete as a filler material to fill spaces between cementitious material and coarse aggregate, and it is also utilised to improve the performance of concrete. Fine aggregate (sand) may also be used as a binder material; thus, we employed it to minimise the amount of binder material. The sand is locally accessible and passes through a 4.75mm IS sieve. We acquired the following results from testing Fine Aggregate: -

Table 2. Experiment Performed on Fine Aggregate

SR. NO.	NAME OF TEST	READING
1	Sieve analysis of sand	Zone 3
2	Specific gravity of sand	2.56
3	Bulking of sand	1%

5.1.3. Coarse Aggregate

To increase the strength of concrete, coarse aggregate is added. Locally accessible crushed stone according to IS: 383- 1970 Grading Aggregate of nominal size 12.5 mm. Several studies have found that the maximum size of coarse aggregate in the composite should be limited. We acquired the following results from testing coarse aggregate: -

Table 3. Experiment Performed on Coarse Aggregate

SR. NO.	NAME OF TEST	READING
1	Sieve analysis	20mm
2	Specific gravity	3.01
3	Impact value	13.46%
4	Bulking of coarse aggregate	0.5%

5.1.4. Nano Palm Oil Fuel Ash (NPOFA)

We develop Nano Palm oil fuel ash that has substantial pozzolanic properties by pulverising POFA to nano particles, which is a by-product of igniting palm oil waste. The percentages of NPOFA used in this study are 5%, 15%, 25%, and 35%.

Table 4. Physical Properties

Material type	Median particle size d50(micron)	Specific surface area (m ² /g)	Specific gravity
NPOFA	0.982	1.962	2.52

Table 5. Chemical Composition of NPOFA

Chemical composition		NPOFA
SiO ₂		68.5
Al ₂ O ₃		4.2
Fe ₂ O ₃		8.12
CaO		3.97
MgO		2.72
K ₂ O		8.4
SO ₃		0.53

5.1.5 Sugar Cane Bagasse Ash

It is a by-product of sugar cane residue, which is formed by burning sugar cane residue after extracting juice from it. We obtain bagasse ash, which has a high silica value and aids in bonding, by burning sugar cane. The percentages employed in this study are 5%, 10%, 15%, and 20%.

Table 6. Physical Properties of SCBA

Sr. no.	Particulars	Results
1	Specific gravity	1.971
2	Fineness	2.516%
3	Colour	Black colour
4	Particle shape	Powder form

Table 7. Chemical Composition of SCBA

Mineral	Percentage (%)
SiO ₂	73
Al ₂ O ₃	6.7
Fe ₂ O ₃	6.3
CaO	2.8
MgO	3.2
P ₂ O ₅	4.0
Na ₂ O	1.1
K ₂ O	2.4
Loss of Ignition	0.9

5.2 Concrete Mixtures

In this research we are partially replacing OPC with palm oil fuel ash (NPOFA) and sugarcane bagasse ash (SCBA). OPC is taken in proportion of 100%, 90%, 75%, 60% and 45%, while the proportion of NPOFA is 0%, 5%, 15%, 25% and 35% and SCBA proportion is 0%, 5%, 10%, 15%, and 20%.

Table 8. Proportions used of Cement NPOFA and SCBA

CEMENT	NPOFA	SCBA
100%	0%	0%
90%	5%	5%
75%	15%	10%
60%	25%	15%
45%	35%	20%

5.3 Testing

5.3.1 Workability

The ease and a consistency with which freshly mixed masonry mortar or concrete is able to be worked is referred to as the concrete's workability. Workability is the comfort with which concrete-making operations like mixing, placing, compacting, and finish may be carried out on freshly mixed concrete. Consistency of concrete also describes how workable it is. Workability is used to gauge the fluidity/mobility of newly mixed concrete. It is considered that wet concrete is simpler to deal with than dry concrete.

5.3.1.1 Type of test

- Slump cone Test

The slump cone test, also known as the concrete slump cone test, is the most widely used method for

assessing the workability of freshly mixed concrete. Either a laboratory or the work site may be used for it. The slump test is the most easy and affordable method for determining if concrete is workable since it yields results fast.



Fig 1 Slump test Apparatus

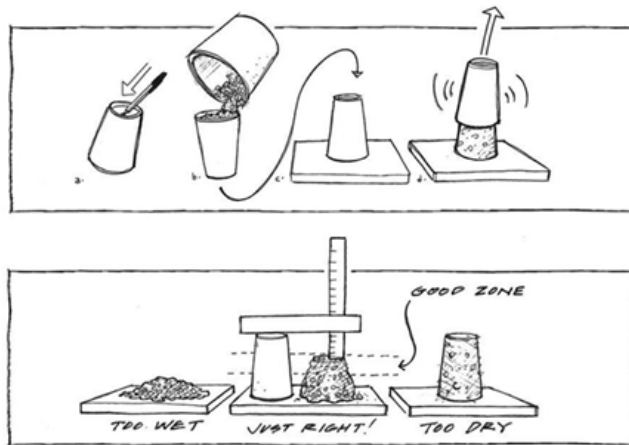


Fig.2 Procedure of Slump Test

5.3.2 Strength of Compression

Compressive strength refers to the intrinsic ability of a material or structure to endure and resist deformation or fracture under a compressive load—that is, a force that acts to squash or shorten it. When a material is compressed, its volume typically contracts, while under tension, its volume tends to expand. This duality is fundamental in understanding how materials behave under different stresses. In structural engineering, concrete is renowned for its exceptional compressive capacity. However, due to its brittle nature, it struggles with tensile and flexural stresses, which are typically addressed through reinforcement techniques like steel bar integration. The compressive strength of

concrete is determined through standardized tests where a specimen—often cylindrical or cuboidal—is subjected to increasing pressure on opposing surfaces until it fractures. The maximum stress endured before failure is recorded as its compressive strength. This form of testing is crucial as it isolates the concrete's response to compression, allowing engineers to evaluate its load-bearing potential. While axial and tensile stresses are relevant in design, compressive strength remains the cornerstone of assessing concrete's structural integrity, especially in vertical elements like columns and load-bearing walls.

5.3.2.1 Casting of specimen

To aid cube removal, the moulding moulds are made of cast iron and must be rubbed using oil on the inside. To avoid the formation of honeycombs, the examination specimen must be cast in three distinct layers (5cm every) & gently compacted. 35 strikes must be performed in all sections of a cube for proper compacting with the tamping bar. This tamping bar measures 16mm in diameter and 0.6m in length. The compressive strength cube test should be done on day one, three, seven, fourteen and 28. In some cases, older-age strength is required, which is achieved throughout the age range between 13 or 52 weeks.



Fig no. 3 Casting of Specimen

5.3.2.2 Procedure for Compressive strength of Concrete

Fill the steel cube mould with the ready-to-cast concrete mixture. Remove the concrete cubes from the mould after a day. Immerse the specimens being investigated in the water for the appropriate amount of time. The sample must be immersed in water lasting seven, fourteen, as well as twenty-eight days, including an alteration of water each day for seven days, as previously stated. Make sure the concrete specimen is absolutely dry before placing it on the CT. For the experiment to continue with testing, the total weight of the samples must be more than 8.1 kg. Testing specimens are positioned in between the

bearing surfaces. Any loose debris or grit must be kept away from the instrument's or specimen block's metallic surfaces. The concrete cubes are properly aligned and have the precise centre pressure point in the inspection equipment plates after being set on bearing plates. As long as the specimen collapses, the force must be delivered axially to it without causing shock and increased to 140 kg/cm²/min. The repeated application of force causes the specimen to burst at a certain point, and it is necessary to record the specimen's eventual annihilation.

6. RESULTS AND DISCUSSION

6.1 Fresh Properties of concrete

To measure the workability for concrete for all mixtures in this study, a slump test is performed in accordance with Indian standard IS:1199-1970. The Slump test results to obtain all five combinations are represented. Likewise, emphasises the graphical fluctuation of new property test findings.

A workability test was conducted by testing the concrete by slump test. Workability is one of the important characteristics to identify the concrete quality. In this test firstly we start from the 0% of NPOFA (Nano Palm Oil fuel Ash) and 0% of SCBA (Sugarcane bagasse ash) and we prepare the concrete as per the mix design M1 shown in table below and performing the slump test on the concrete and measure the slump value the slump value is 60mm. which is referred as the low workable as per is code 456:2000. after this we are increasing the quantity of NPOFA and SCBA 0% to 5% and 0% to 5% respectively this name M2. And we are preparing the concrete mix as per mix proportion shown in table below. After preparing the concrete mix we are proceeding to next step slump test reading will be measured is 77mm. again repeating the process increasing the proportion of NPOFA and SCBA 5% to 15% and 5% to 10% respectively name as M3. Preparing the concrete mix according to the mix proportion and performing the slump test on it and collect the value of the test is 79.5mm. After this increasing the proportion of the NPOFA and SCBA 15% to 25% and 10% to 15% and prepare the mix according to mix design shown in table below and checking slump value is 82mm. after this we are continuing the increasing the proportion of NPOFA and SCBA 25% to 35% and 15% to 20% respectively. And prepare the concrete mix according to the mix design shown in table below and performing the slump test on it and check the reading is 85mm.

As per the test result, we conclude the workability is continuously increasing after adding the combined NPOFA and SCBA shown in table below.

Table 9. Mix Proportion for Concrete

Mix No.	OPC (kg)	Water (litre)	Fine Aggregate (kg)	Coarse Aggregate (kg)	NPOFA (kg)	SCBA (kg)
M1	476	214	560	1221	0	0
M2	428.4	214	560	1221	23.8	23.8
M3	357	214	560	1221	71.4	47.6
M4	333.2	214	560	1221	119	71.4
M5	214.2	214	560	1221	166.6	95.2

Table 10. Workability of concrete with added NPOFA and SCBA

Mix No.	Cement	NPOFA	SCBA	Workability
M1	100%	0%	0%	60mm
M2	90%	5%	5%	77mm
M3	75%	15%	10%	79.5mm
M4	60%	25%	15%	82mm
M5	45%	35%	20%	85mm

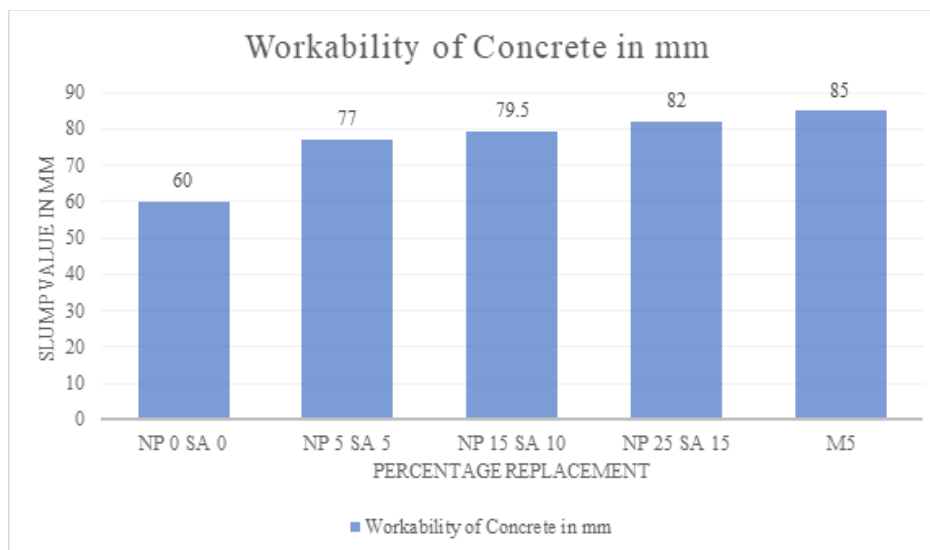


Fig no. 4 Workability of concrete

6.2 Compressive Strength of Concrete

This experiment was carried out to figure out the combined proportion of NPOFA and SCBA required to attain the desired strength of 40 Mpa. As a result, the percentages reported in Table 11 are applied to both NPOFA and SCBA materials. Figure 5 shows the compressive strength findings after 7, 14, and 28 days.

Table 10. Compressive strength of concrete on various combined proportions for NPOFA and SCBA

Mix No.	OPC (kg)	Water (litre)	Fine Aggregate (kg)	Coarse Aggregate (kg)	NPOFA (kg)	SCBA (kg)
M1	476	214	560	1221	0	0
M2	428.4	214	560	1221	23.8	23.8
M3	357	214	560	1221	71.4	47.6
M4	333.2	214	560	1221	119	71.4
M5	214.2	214	560	1221	166.6	95.2

Note: NP 0 SA 0 = NPOFA 0%+ SCBA ,NP 5 SA 5 = NPOFA 5%+ SCBA 5%

Fig 5 show that results of cube test in Compressive strength result after combining NPOFA & SCBA in one concrete mix. According to the data, the combination of 15% NPOFA and 10% SCBA (NP 15 SA 10) had the maximum compressive strength at 28 days when compared to other combinations. Compressive strength for NP15 SA10 was 44.7Mpa at 28 days, which was 1.1% less than the controlled specimen. Compressive Strength is somewhat decreased when NPOFA and SCBA percentages are increased. owing to the distinct physical and chemical characteristics of NPOFA and SCBA materials, which cause particle packing issues and reduced calcium silicate hydrate gel owing to a lack of silica, the decrease is caused. Only NP5 SA5, NP15 SA 10, and NP25 SA 15 had pressures greater than 40 MPa at 28 days, though. Therefore, 15% NPOFA and 10% SCBA was chosen as the ideal ratio of NPOFA and SCBA in concrete based on the research's objectives.

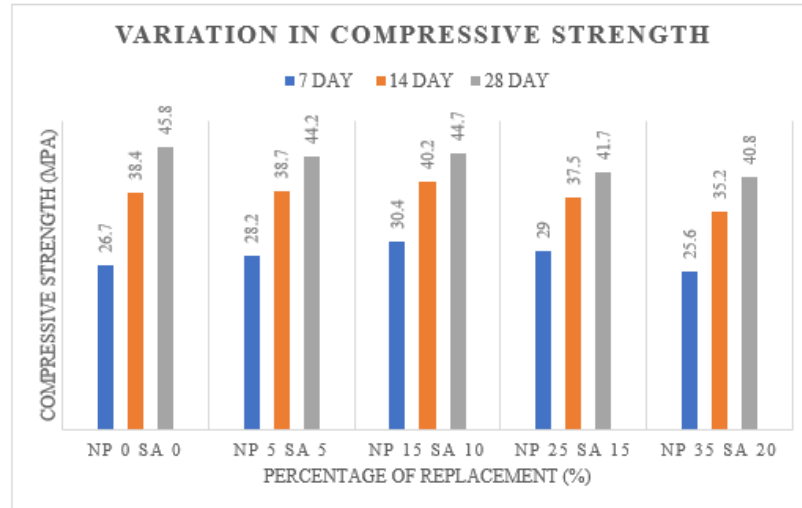


Fig no. 5 Compressive strength of concrete on various combined proportions for NPOFA and SCBA

7. CONCLUSION

This Research mainly focused on analysis of workability of concrete and Compressive strength of Concrete with partially substitution of Cement with NPOFA and SCBA in different proportion. Based on the research findings, The following findings were reached:

- Partially substitution of cement with NPOFA & SCBA shows the variation Workability of Concrete.
- Increase in NPOFA and SCBA results in the increase in the workability of the concrete.
- When we add NPOFA and SCBA in concrete in 5% and 5% respectively (M2) we are obtaining the maximum increase in percentage of workability but in further increasing the proportion of NPOFA and SCBA we get small percentage of increasing in workability as compare to M2 mixture but they still increasing. so, obtain the maximum workability at M5 mix which have containing cement, NPOFA and SCBA proportion 45%,35%,20% respectively at this 85mm workability is determined.
- It has been shown that the compressive strength of concrete is increased by the inclusion of SCBA and NPOFA as supplementary cementitious materials. Even though both materials' compressive strengths were higher than the control specimen's at seven days, the strength differential diminished with age. The strength decreases in line with the pozzolanic reaction process, which densified the concrete's microstructure after 28 days.
- Replacement of 15% NPOFA and 10% SCBA in concrete mix shows the maximum strength as compare to other replacements at 28 days. Increasing in the replacement percentage after this show reduction in compressive strength. However, NP5 SA 5 and NP25 SA15 substitution of both materials still achieved the target strength of 40 MPa at 28 days. Therefore, it can be inferred that grade M40 concrete may be created by mixing two distinct pozzolan ingredients, particularly NPOFA and SCBA.

8. FUTURE SCOPE

As, we can observe from tables of chemical composition given above that the chemical composition of Silica (SiO_2) which helps in binding property in cement is in major constituent in Cement as well as in NPOFA and SCBA.

So, taking the chemical composition in consideration one can expand this research in the field of Flexural Strength and Durability using NPOFA and SCBA as a partial substitution in Cement.

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