EXPERIMENTAL STUDY ON MECHANICAL PROPERTIES OF CONCRETE BY REPLACEMENT OF CEMENT WITH SCBA AND NANO SILICA

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Abstract: Influence of Nano silica and sugar cane bagasse ash (SCBA) on the mechanical properties of concrete are investigated in this study. Concrete mixtures are designed with particular water to binder ratio. Test specimens were prepared with 1% to 5% replacement of cement weight with Nano silica and a 5% to 20% replacement of cement weight with SCBA. A compressive strength test was conducted to evaluate the mechanical performance of concrete containing Nano silica and SCBA. In addition, Split tensile test, Flexural test and Modulus of elasticity test on performed to investigate the influence of replacement materials on mechanical properties of concrete. Nano silica improves mechanical properties of concrete, while SCBA have a substantial influence on concrete performance according to strength at early ages. The addition of SCBA in mixtures containing Nano silica intensely increases compressive strength at the early age.

***Keywords* – Nano Silica, Bagasse ash, Partial replacement, Mechanical Properties, Strength, Concrete.**

1. INTRODUCTION

1.1 GENERAL

The civil construction consumes great part of the natural resources extracted from the planet and concrete is the greatest cause of this consumption, Ordinary Portland cement (OPC) is the primary cement that is produced around the world. According to US government statistics, it is estimated that in 2018 alone, 4.1 billion tons of OPC was produced worldwide. The OPC has been incorporated as the primary binder material in concrete production since the invention of concrete. However, OPC utilization in concrete has been criticized widely over the past decades due to the environmental effects of the clinker manufacturing process. The economic and environmental problems of OPC have encouraged researchers to assess the potential of other materials to be replaced for OPC. Supplementary cementitious materials (SCM) are beneficial for concrete properties in various aspects, such as the consumption of calcium hydroxide (an unfavourable product of cement hydration), and contribution to some additional C-S-H gel production. The idea of partially replacing OPC by other materials can be supported by the fact that there is an enormous amount of waste, produced by various industries, with suitable properties for usage in concrete. These waste materials usually need lots of effort and energy for disposal purposes. Fly ash, GGBS, RHA and Bagasse ash are widely used industrial by-products in concrete. Besides industrial by-products, some materials obtained from agricultural activities have shown good performances when used in concrete.

1.2 Sugarcane SCBA

The Sugarcane is one of the exceeding crops grown in over 109 countries and its total production is approximately over 1500 million tons. In India sugarcane production is over 300 million tons/year that cause around 10 million tons of sugarcane SCBA as an un-utilized and waste material. Near about 40-45 percent fibrous residue is obtained, After the extraction of all economical sugar from sugarcane, which is reused in the industries as fuel in boilers for heat or power generation leaving behind 8 -10 percent ash as waste, known as sugarcane SCBA. Each ton of sugarcane generates approximately 26% of bagasse (at a moisture content of 50% and 0.62% of residual ash) the residue after combustion presents a chemical composition dominates by silicon dioxide (SiO_2). The major oxide observed in SCBA is silica (SiO_2), which is about 77.25%, the total summation of SiO2 + $Al2O_3$ + Fe2O3 is 87.83%, the calcium oxide, CaO is 4.05%, and hence this ash classifies as class F pozzolan according to ASTM C 618 (2009). The X-Ray Diffraction (XRD) analysis of the SCBA shows the amorphous silica formation with traces of low quartz.

Figure 1 - Sugar cane Bagasse

1.2 NANO SILICA

In concrete structure there is great interest in replacing a long time used materials by a new material to reach more durable concrete. Nano material is well studied in Physics, Chemistry and Mechanics that concrete production with well designed and developed materials result in much Strongest and economical concrete one of the new materials that can enhance the mechanical and physical properties of concrete. Nano material can change the concrete world due to their properties at ultra-fine level. Nanotechnology means varies from place to place and widely used as "catch all" narration for anything very small, nanotechnology is generally defined as the understanding, control, and restructuring of matter in order of nanometers (i.e. less than 100 nm) to create materials with fundamentally new functions and properties.

The properties and processes at the Nano scale define the interactions that occur between particles and phases at the micro scale. Processes occurring at the Nano scale ultimately affect the engineering properties and performance of the bulk material.

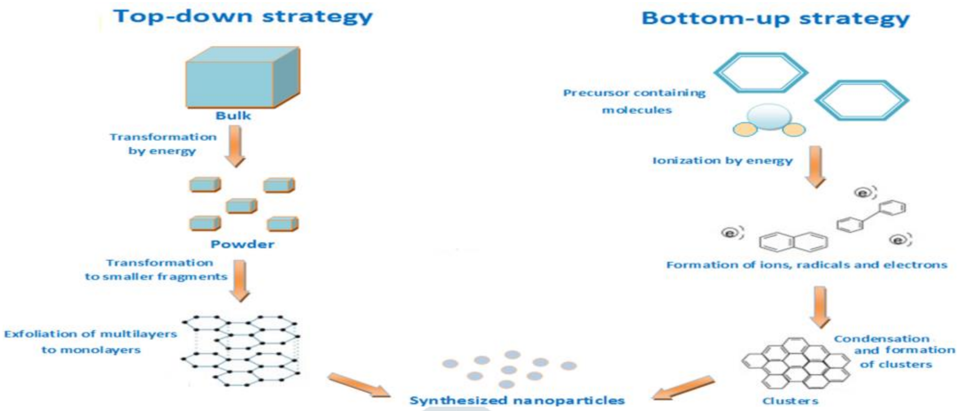

Figure 2. Example of top-down and bottom-up strategies for synthesis of NPs.

1.3 Need for present study

Partial replacement of SCBA will also help in meeting the increasing demand for cement in future. Nowadays the results of the chemical analyses of the Nano silica and SCBA from sugar factories seeks that sugarcane bagasse combustion products (ash) correspond to pozzolana in chemical nature. Therefore, it should be deemed as an important mineral resource. It is successfully used as an engineering material for a wide variety of applications. The chemical investigations on the SCBA is shows that it has had more or less the same chemical composition of other artificial pozzolanic material (i.e. fly ash or any other conventional pozzolana).

2. MATERIAL AND RESEARCH METHODOLOGY

2.1 LITERATURE SURVEY

M. Berra et al (2012), suggest that, because of the water retention in the NS containing mixes and the consequent need of increasing the w/b ratio to obtain a proper workability, it is not correct to compare data with conventional OPC at the same w/b ratio. The proper comparison must be carried out between mixes with the same workability and the same w/b ratio, obtained by adding superplasticizers. The comparison in this case shows a limited increase of for samples containing Nano silica, to be attributed mostly to the accelerating effect of superplasticizer on cement hardening. **Prashant O Modani, M R Vyawahare (2013)**, untreated SCBA has been partially replaced in the ratio of 0%, 10%, 20%, 30% and 40% by volume of fine aggregate in concrete. Along with hardened Concrete, the fresh concrete tests were also undertaken. The compressive strength results represent that, the strength of the mixes with 10% and 20% SCBA increases at later days (28 days) as compared to 7 days that may be due to pozzolanic properties of SCBA. **T. S. ABDULKADIR, et al (2014)** investigate of SCBA as partial replacement of cement , SCBA is a pozzolana and can be recommended for use as partial replacement of cement in concrete production at a percentage up to 20%. For environmental sustainability, SCBA can be utilized for the production of lightweight, durable and cheap concrete. **B. A. Hase , Prof. V. R.Rathi (2015),** studied that colloidal Al_2O_3 Nano particles are very effective in improvement of mechanical properties of concrete. Compressive, split tensile, flexural strength of concrete specimen containing 0%, 1%, 2%, 3% and 4% of colloidal nano-Al_2O_3 particles were investigated. Samples containing 3% colloidal Al_2O_3 Nano particles, shows better mechanical properties than normal control concrete. Increasing colloidal nano-Al_2O_3 more than 4 % by wt. of cement, reduces the mechanical strength of concrete. Colloidal nano-Al_2O_3 particles are very effective in improving the mechanical properties of the concrete. **Dr. H.Eramma, Mahesh (2015),** studied the cement is partially replaced with the 10% and 20% of SCBA and Nano-silica 1%, 2% and 3% by mass. The impact of shared utilization of SCBA and Nano-silica on compressive strength, split tensile strength and flexural strength of M25 grade of concrete is studied. Based on the test results, Obtained that 10% of SCBA is create to be well replacement for cement. Compressive strength results it is obtained that 10% of SCBA substitute with cement can produce higher compressive strength compared to conventional concrete. From the experimental work the addition of 0% of SCBA and percentage of variation of Nano-silica (i.e. 1%, 2% and 3%) which gives the increasing orders of compressive strength and split tensile strength respectively. Also 10% of SCBA and add 2% of Nano silica can be a good substitute for concrete.

2.2 METHODOLOGY

2.2.1 Cement

Table 1- Properties of cement

Sr.No	Properties of cement	Results
1.	Fineness of cement	3.17 %
2.	Specific gravity of cement	3.15
3.	Standard Consistency of Cement	30 %
4.	Initial setting time of cement	85 min
5.	Final setting time of cement	376 min
6.	Compressive strength of cement at 7 days and 28 days	35.80 MPa and 54.33 MPa

2.2.2 Fine Aggregate (sand)

Aggregate is tested in laboratory and is as follows;

Table 2- Properties of fine aggregate (sand)

Sr.No	Properties of fine aggregate	Results
1.	Particle Shape, size	Round, below 4.75 mm
2.	Fineness modulus of fine aggregate (sand)	2.80
3.	Zone as per IS 383-1970	II
4.	Specific gravity of fine aggregate (sand)	2.65
5.	Water absorption of fine aggregate (sand)	1.02 %
6.	Free (surface) moisture of fine aggregate (sand)	Nil

2.2.3 Coarse Aggregate

Table 3 - Properties of coarse aggregate

Sr. No	Properties of coarse aggregate	Results
1.	Particle Shape, size	Angular, Maximum 20 mm
2.	Specific gravity of coarse aggregate	2.74
3.	Water absorption of coarse aggregate	0.96 %
4.	Free (surface) moisture of coarse aggregate	Nil

2.2.3 Sugarcane bagasse ash (SCBA)

It is the by-product of sugar cane i.e. SCBA particles that were used as a replacement of cement by volume. Following are the chemical properties of SCBA.

Table 4- Chemical Properties Bagasse Ash

Sr.No	Chemical compound	Abbreviation	%
1.	Silica	Sio_2	68.42
2.	Aluminium oxide	Al_2O_3	5.812
3.	Ferric Oxide	Fe_2O_3	0.218
4.	Calcium Oxide	CaO	2.56
5.	Phosphorous Oxide	P_2O_5	1.28
6.	Magnesium Oxide	MgO	0.572
7.	Sulphide Oxide	SO_3	4.33
8.	Loss on Ignition	LOI	15.90

2.2.4 Nano Silica

Following are the characteristics of colloidal Nano silica

Table 5 - Properties of Nano Silica

Sr. No.	Characteristics	Value obtained
1	Parameter	CemSynXTX
2	Active Nano content	30 – 32%
3	pH(20 ° C)	9 – 10
4	Specific Gravity	1.20 – 1.22
5	Particle Size	5 – 40 nm

2.2.5 Mix Proportion

Following are the mix proportions obtained for the trial

Table 6 - Mix Proportion for trial

Sr.No	Description	Results
1.	Cement	383.16 kg/m^3
2.	Fine Aggregate	685.75 kg/m^3
3.	Coarse Aggregate	1157.55 kg/m^3
4.	Water-Cement ratio	0.50
5.	C : FA : CA	1 : 1.789 : 3.02

3. RESULTS AND DISSCUSSIONS

3.1 Slump cone test

The slump cone test is used to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of work. The effect of Nano Silica and SCBA on workability of concrete for various mixtures is given in Table 7 and is demonstrated in Figure-3.

Table 7- Slump cone test results

Mix ID	Percentage of replacement of		Slump Value (mm)
	Nano Silica (%)	SCBA (%)	
NSBC0	0	0	75
NSBC1	1	5	86
NSBC2	1	10	96
NSBC3	1	15	105
NSBC4	1	20	114
NSBC5	2	5	83
NSBC6	2	10	93
NSBC7	2	15	102
NSBC8	2	20	111
NSBC9	3	5	80
NSBC10	3	10	90
NSBC11	3	15	99
NSBC12	3	20	108
NSBC13	4	5	78
NSBC14	4	10	88
NSBC15	4	15	97
NSBC16	4	20	106
NSBC17	5	5	75
NSBC18	5	10	85
NSBC19	5	15	94
NSBC20	5	20	102

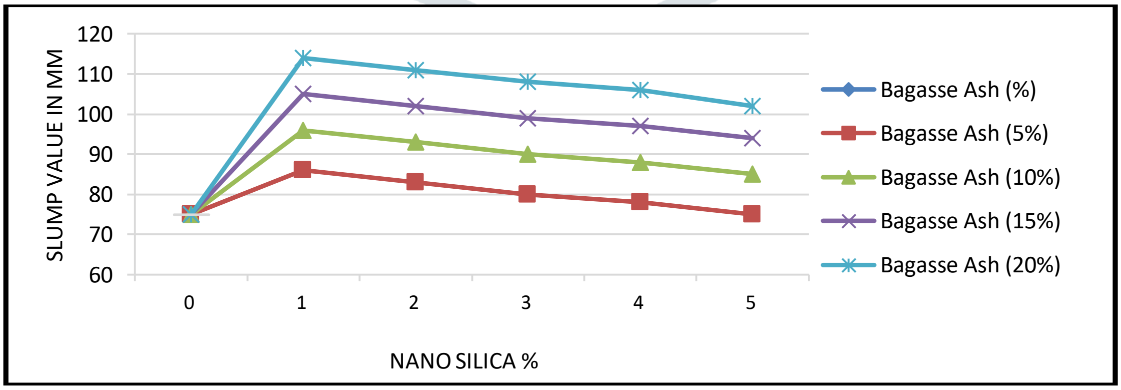

Figure 3 -Average slump of all mixes

The results demonstrated that slump value (workability) of fresh concrete increased with increase in replacement of SCBA. As seen in Figure-3, the lowest slump value happened on the reference concrete with 100 % cement i.e. NSBC0 whereas the NSBC4 mixture incorporating Nano Silica (1%) and Baggage Ash (20%) replacement reached the highest one.

3.2 Compressive Strength Test

Especially for concrete compressive strength is an important parameter to determine the performance of material during service conditions. The effect of Nano Silica and SCBA on compressive strength of concrete for various mixtures is given in Table 8 and is demonstrated in Figure 4, 5 and 6.

Table 8- Compressive strength test results

Mix ID	Percentage of replacement of cement		Mean value Compressive Strength in N/mm^2		
	Nano Silica (%)	Bagasse Ash (%)	7 Days	28 Days	56 Days
NSBC0	0	0	17.25	23.91	27.22
NSBC1	1	5	18.05	24.71	28.02
NSBC2	1	10	18.25	24.91	28.22
NSBC3	1	15	19.05	25.71	29.02
NSBC4	1	20	19.25	25.91	29.22
NSBC5	2	5	20.15	26.81	30.12
NSBC6	2	10	20.15	27.08	30.48
NSBC7	2	15	21.05	27.58	31.12
NSBC8	2	20	21.15	27.81	31.22
NSBC9	3	5	22.12	28.79	32.34
NSBC10	3	10	22.59	28.98	32.48
NSBC11	3	15	23.49	30.24	33.79
NSBC12	3	20	23.53	30.4	33.96
NSBC13	4	5	24.53	31.53	35.40
NSBC14	4	10	24.97	31.57	35.22
NSBC15	4	15	25.87	32.83	36.53
NSBC16	4	20	24.91	31.77	35.35
NSBC17	5	5	23.91	30.77	33.91
NSBC18	5	10	23.47	30.33	34.09
NSBC19	5	15	22.57	29.43	32.78
NSBC20	5	20	22.53	28.15	31.96

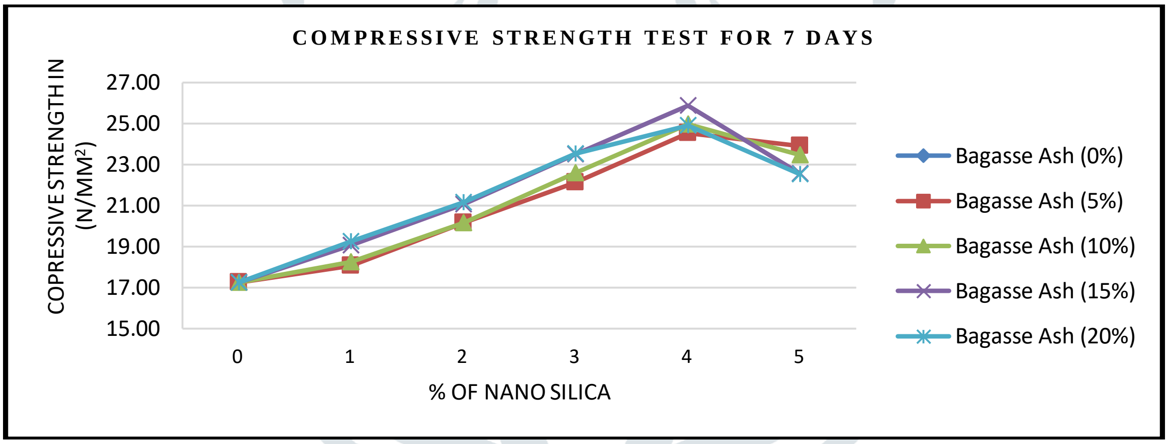

Figure 4 -Compressive strength of 7 days.

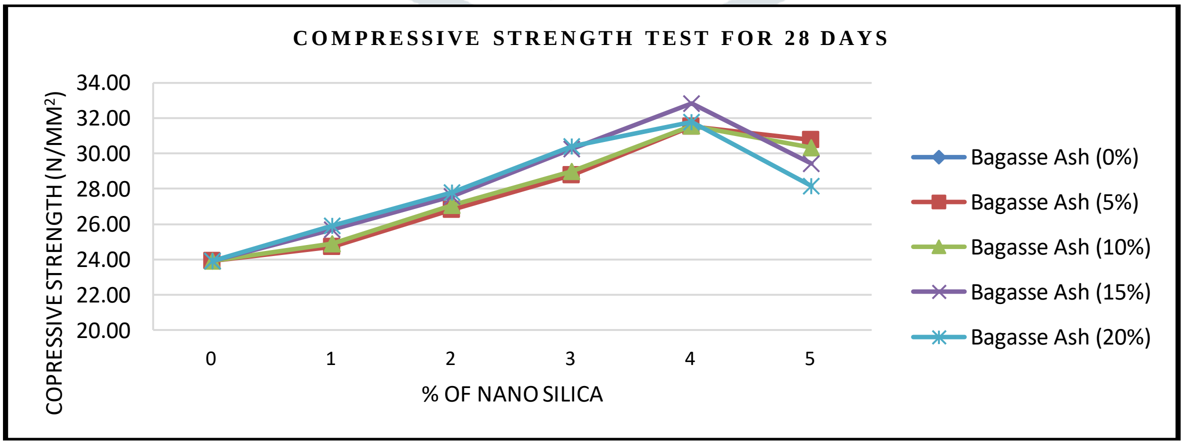

Figure 5 -Compressive strength of 28 days.

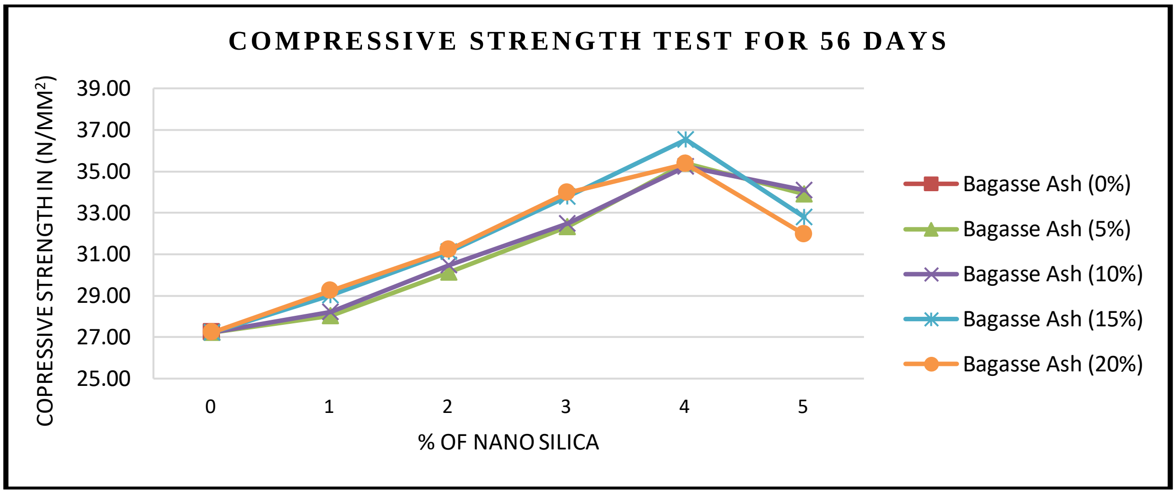

Figure 6 -Compressive strength of 56 days.

From the results it is observed that the compressive strength increase in percentage of cement replacement by SCBA and Nano silica. Test results as shown in table no 8 and figure 4 to figure 6. It is indicated that, Addition of Nano silica 4% and SCBA 15% (NSBC15) by weight of cement in concrete results, enhancing strength from 23.91 MPa (NSBC0) to 32.83 MPa (NSBC15) which is equivalent to about 37 % increase in strength on day 28 (fig.5), similarly for 7 and 56 days age of concrete strength is increasing about 49% and 34 % respectively. Further addition of Nano silica 4% and SCBA 20% (NSBC4) by weight of cement in concrete results, the strength is decreases.

3.3 Splitting tensile strength

Splitting tensile strength is used to determine the tensile strength of concrete in an indirect way. The effect of Nano Silica and SCBA on splitting tensile strength of concrete for various mixtures is given in Table 9 and is demonstrated in Figure- 7.

Table 9 - Splitting tensile strength test results

Mix ID	Percentage of replacement of cement		Splitting Tensile Strength for 28 Days
	Nano Silica (%)	Bagasse Ash (%)	Mean value in N/mm^2
NSBC0	0	0	3.02
NSBC1	1	5	3.14
NSBC2	1	10	3.16
NSBC3	1	15	3.29
NSBC4	1	20	3.35
NSBC5	2	5	3.47
NSBC6	2	10	3.49
NSBC7	2	15	3.62
NSBC8	2	20	3.68
NSBC9	3	5	3.80
NSBC10	3	10	3.82
NSBC11	3	15	3.95
NSBC12	3	20	4.01
NSBC13	4	5	4.13
NSBC14	4	10	4.29
NSBC15	4	15	4.42
NSBC16	4	20	4.34
NSBC17	5	5	4.18
NSBC18	5	10	4.16
NSBC19	5	15	4.03
NSBC20	5	20	3.97

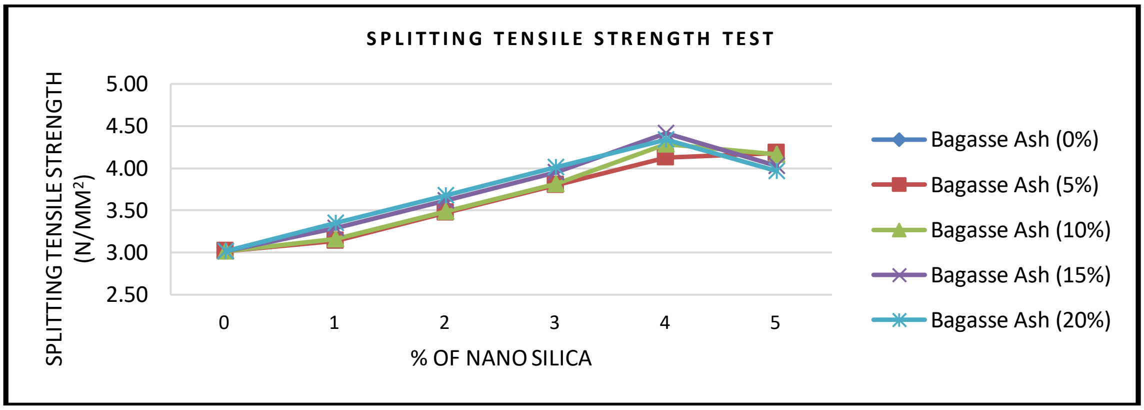

Figure 7 -Splitting tensile strength of all mixes

It is indicated that, Addition of Nano silica 4% and SCBA 15% (NSBC15) by weight of cement in concrete results, the split tensile strength is increases from 3.02 MPa (NSBC0) to 4.42 MPa (NSBC15) which is equivalent to about 46 % of strength increase on day 28 and after addition on Nano silica 4% and 20 % SCBA split tensile is decreases.

3.4 Flexural Strength Test

Flexural strength test is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. The effect of Nano Silica and SCBA on flexural strength of concrete for various mixtures is given in Table 10 and is demonstrated in Figure-8.

Table 10- Flexural strength test results

Mix ID	Percentage of replacement of cement		Flexural Strength for 28 Days
	Nano Silica (%)	Bagasse Ash (%)	Mean value in N/mm²
NSBC0	0	0	3.35
NSBC1	1	5	3.39
NSBC2	1	10	3.42
NSBC3	1	15	3.47
NSBC4	1	20	3.59
NSBC5	2	5	3.71
NSBC6	2	10	3.83
NSBC7	2	15	3.95
NSBC8	2	20	4.06
NSBC9	3	5	4.18
NSBC10	3	10	4.30
NSBC11	3	15	4.42
NSBC12	3	20	4.54
NSBC13	4	5	4.66
NSBC14	4	10	4.78
NSBC15	4	15	4.90
NSBC16	4	20	4.81
NSBC17	5	5	4.57
NSBC18	5	10	4.43
NSBC19	5	15	4.15
NSBC20	5	20	3.87

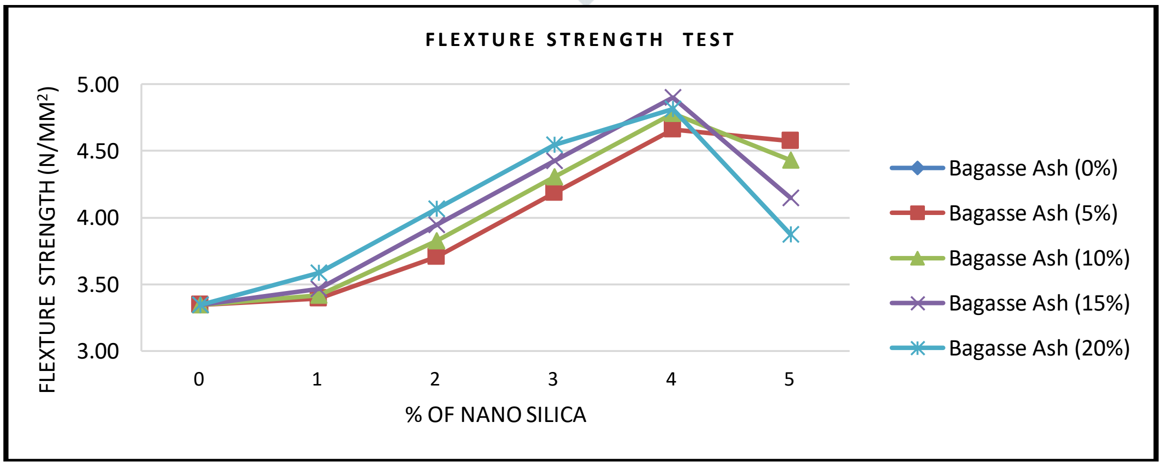

Figure 8 -Flexural strength of all the mixes

It is indicated that, normal concrete has lesser flexural strength as compared to the concrete which is incorporated by Nano silica and SCBA. As the strength increases from 3.35 MPa (NSBC0) to 4.90 MPa (NSBC15) which is equivalent to about 46.26 % of strength on day 28.

3.5 Modulus of Elasticity Test

The modulus of elasticity (MOE) is a material property that describes its stiffness and is therefore one of the most important property of solid materials. The effect of Nano Silica and SCBA on modulus of elasticity of concrete for various mixtures is given in Table 11 and is demonstrated in Figure-9.

Table 11 - Modulus of elasticity test results

Mix ID	Percentage of replacement of cement		Modulus of elasticity strength for 28 Days
	Nano Silica (%)	Bagasse Ash (%)	Mean value in GPa
NSBC0	0	0	23.72
NSBC1	1	5	24.41
NSBC2	1	10	24.57
NSBC3	1	15	25.03
NSBC4	1	20	25.19
NSBC5	2	5	25.68
NSBC6	2	10	25.87
NSBC7	2	15	26.17
NSBC8	2	20	26.34
NSBC9	3	5	26.78
NSBC10	3	10	26.92
NSBC11	3	15	27.19
NSBC12	3	20	27.34
NSBC13	4	5	27.56
NSBC14	4	10	27.76
NSBC15	4	15	27.80
NSBC16	4	20	27.72
NSBC17	5	5	26.87
NSBC18	5	10	26.40
NSBC19	5	15	25.48
NSBC20	5	20	24.82

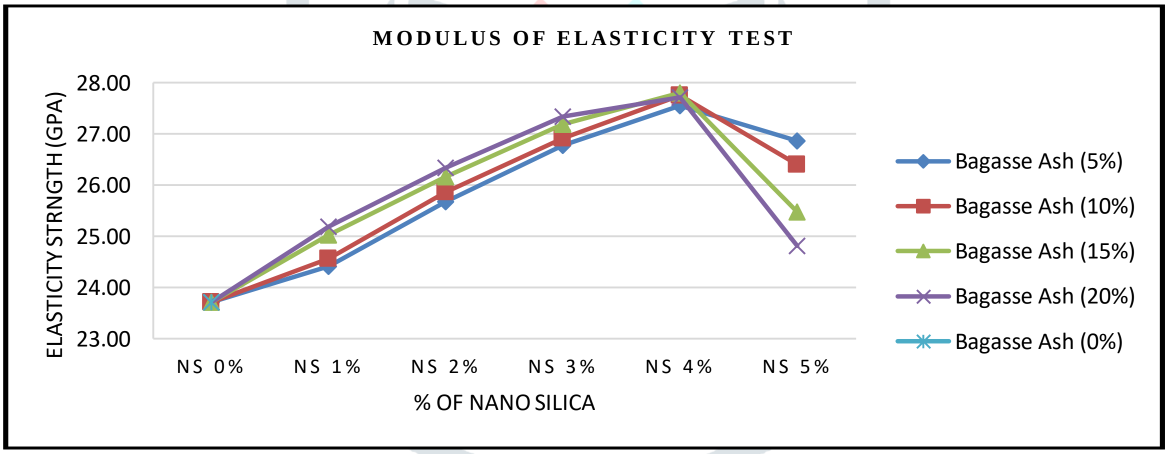

Figure 9-Modulus of elasticity of all the mixes

Modulus of elasticity is increases from 1% to 3% addition of Nano Silica and 5% to 15 % addition of SCBA in concrete specimen and after 4% Nano Silica and 20% SCBA it decreases. Addition of Nano silica 4% and SCBA 15% (NSBC15) by weight of cement in concrete results, the strength is increases from 23.72 GPa (NSBC0) to 27.80 GPa (NSBC15) which is equivalent to about 17% of strength increases on day 28.

CONCLUSIONS

After studying the several test results of different specimens ranging in Nano Silica and SCBA content from 0% to 5% and 0% to 20% respectively in replacement of Cement, the following conclusions are made:

1. The workability of concrete improves due to addition SCBA and is acceptable in terms of the ease in handling, the placing and finishing of wet concrete as compared to normal concrete.
2. The dry density and compressive strength of concrete reduces as the percentage of SCBA content increases at the time it is increases as Nano silica is increases.
3. Good compressive strength was recorded at Nano Silica and SCBA contents at the mix Nano Silica 4% and SCBA 15%. Further addition of Nano Silica 4% and SCBA 20%. Then strength is decreased in replacement of Cement.
4. The splitting tensile strength, flexural strength and of concrete increases as the Nano Silica and SCBA percentage increases at 4% NS and 15% SCBA further it decreases.
5. Although the strength of concrete is reduced with increase in Nano Silica and SCBA content, its lower unit weight meets the criteria of light weight concrete.
6. This is an ultimate solution of minimum use of cement and their production which will help to reduce the CO_2.

Future Scope

It is recommended that the future research should be perform to evaluate the use of SCBA and Nano silica in concrete as a replacement of cement material. However, future studies required on following issues.

1. Durability
2. Mechanical Properties of with the use of chemical admixture.
3. Working on cost analysis.
4. Sustainable aspect with use of Nano silica and bagasse ash.

ACKNOWLEDGMENT

I would like to acknowledge the great contribution and support I received in this endeavor from Dr. V. R. Rathi for his depth knowledge, guidance and inspiration.

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