A BRIEF STUDY ON THE STRENGTH PROPERTIES OF CONCRETE MODIFIED WITH SINTERED FLY ASH AGGREGATES AND SILICON DIOXIDE (NANO MATERIAL)

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Abstract : *With the ever increasing demand for electricity as energy source due to rapid industrialization and urbanization there is a growing need for disposing of the resulting waste fly ash from burning of coal in Thermal plants. A mix design was done for M20 grade concrete by IS code methods. ACC 53 grade cement was used and natural aggregate is fully replaced with Sintered fly ash aggregates. In this experimental investigation partial replacement of cement (11%)with three number of pozzolanic materials like silica fume, slag and fly ash in equal proportions along with varying percentages of Nano silicon dioxide at 0, 0.5, 1 and 1.5 on 11% of pozzolanic materials. Silicon dioxide possesses more pozzolanic action. Because of pozzolanic action, silicon dioxide reacts with free lime during hydration and produces more C-S-H gel. After 28 days, various tests has been carried out i.e compressive strength test, flexural strength test, modulus of elasticity test, impact test, Mode-II fracture test for concrete with silicon dioxide and without silicon dioxide. The concrete made with silicon dioxide gives better results compared to without silicon dioxide.*

Key Words: Sintered fly ash aggregates, admixtures, ACC 53 grade, concrete, silicon dioxide, various tests

1. INTRODUCTION

Disposing of the waste fly ash which results from burning coal is a major problem especially severe in India, the world's second largest coal consumer, which produces an estimated 150 million tons of fly ash per annum. The process which converts waste fly ash into structural light weight aggregate, a product which can be used to electronically replace mined stone in concrete, as well as other uses. The process uses approximately 95% fly ash mixed in some cases with water and in some cases a small volume of additives. After agglomeration and pelletizing, the green pellets are Sintered, creating an aggregate whose characteristics are superior to natural aggregates.

The basic purpose of using Nano sized materials in concrete is to improve compressive and flexural strengths at early age, it is possible due to the high surface to volume ratio. It also helps to improve the pore structure of concrete. Nano sized materials help to reduce porosity as they absorb less water compared to traditional cementitious materials. The presence of Nano materials reduces the amount of cement content in concrete than the conventional concrete. This can be achieved without sacrificing strength characteristics; thereby it is possible to produce ecofriendly concrete called green concrete.

Light weight aggregate preparation is shown in plate 1.

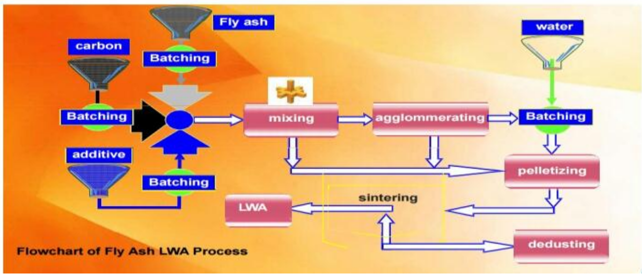

Plate 1: Flow chart of light weight aggregate process

Plate 1.1: Sintered fly ash aggregates

2. Review of literature

Luciano senff et al., (1) In his research amorphous Nano silica particles were incorporated in cement pastes and mortars and their effect on fresh properties was analyzed.

Hongjian Du et al., (2) This paper investigates the durability properties of concrete containing Nano silica at the dosages of 0.3% and 0.9% respectively.

A.M Said et al., (3) This paper investigates the effect of colloidal Nano silica on concrete incorporating single and binary binders.

Prakash Desai, Raghu Prasad B.K, and Bhaskar Desai V (4) arrived at double central notched specimen geometry which fails in predominant Mode-II failure, they also made finite element analysis to arrive at stress intensity factor. Using this DCN geometry lot of experimental investigation using cement paste, mortar, plain concrete have been studied. Details of this geometry are presented in Plate 2.1.

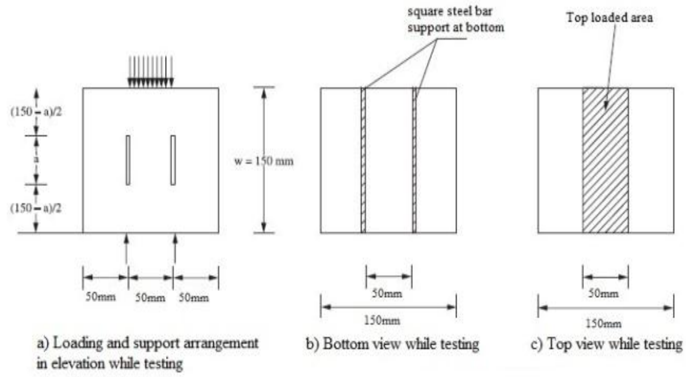

Plate 2.1: Details of DCN specimen geometry

Thorenfeldt, E (5) reported that Light Weight Aggregate Concrete has a faster hardening factor in the initial setting phase than conventional concrete, normally reaching 80 % of the 28 day strength within 7 days. The strength growth from 28 to 90 days is generally low and decreases with increasing concrete strength level. This is assumed to be a consequence of the strength limiting effect of the light weight aggregate.

Arvind Kumar, Dilip Kumar (6) To increase the speed of construction, enhance green construction environment we can use lightweight concrete. The possibility exists for the partial replacement of coarse aggregate with Sintered fly ash aggregate to produce in thermal power plants west material. Sintered fly ash is compatible with the cement. Use of Sintered fly ash as coarse aggregate can reduce the cost of construction and it is useful in environmental point of view. From the brief literature summary conducted here it appears that much less attention has been paid earlier on the study of Sintered fly ash aggregate concrete modified with Nano material such as silicon dioxide. Hence the present investigation has been under taken.

3. Objective

- Determining of solution for disposal of industrial wastes hazardous to environment as a useful material in the construction industry.
- By replacing of coarse aggregate in concrete to produce light weight concrete.

4. Materials used

The following materials were used for preparing the concrete mix.

1. ACC cement of 53 grade
2. Fine aggregate i.e sand
3. Coarse aggregate i.e Sintered fly ash aggregates
4. Fly ash
5. Silica fume
6. Slag
7. Water

4.1 Cement: ACC 53 grade cement with specific gravity 3.26 is used as binder.

S.NO	Name of the material	Properties of materials	
1	Cement	Specific gravity	3.26
		Initial setting time	50 minutes
		Final setting time	460 minutes
		Normal consistency	30%
		Fineness of Cement	5%
2	Fine aggregate	Specific gravity	2.4
		Fineness modulus	2.63
3	Coarse aggregate	Specific gravity	2.6
		Fineness modulus	3.47

Sintered fly ash aggregates: Sintered fly ash aggregate is procured from Litagg Company, Ahmedabad is used in this investigation.

Typical physical characteristics of Sintered fly ash aggregates

Aggregate Size mm : 8-12

Bulk Density : @800 kg/m3

Bulk Porosity : 35-40%

Aggregate Strength : >4.0 M Pa

Water Absorption : < 16 %

Shape : Round pellets

4.3 Casting of specimens:

The M20 concrete mix is designed using ISI method which gives a mix proportion of 1:1.49:2.88 with water cement ratio of 0.50. Four different mixes which are designated as follows.

Name of the MIX	% Volume replacement of Coarse aggregate	% of Admixtures in equal proportions	% of Nano (SiO_2) on 11% of cement	% of cement
TA0	100	0	0	100
TA1	100	11	0.5	88.945
TA2	100	11	1.0	88.890
TA3	100	11	1.5	88.835

To proceed with the experimental program initially steel moulds of size 150x150x150 mm were cleaned brushed with machine oil on all inner faces to facilitate easy removal of specimens afterwards. First fine aggregate and cement along with admixtures silica fume, slag, fly ash and Nano Silicon dioxide in required percentages were mixed thoroughly and then Sintered fly ash aggregates were added with them. All of these were mixed thoroughly by hand mixing. Each time 150X150X150mm cube specimens out of which 12 no of DCN specimens with replacement of cement by 11% of its weight by pozzolanic materials (Silica fume, fly ash and Slag) and Nano silicon dioxide with varying percentages (0%, 0.5%, 1%, and 1.5%) on 11% weight of cement and 4no's of different mixes for each of 3 no's of plain cubes, 3 no's of plain beams are casted. The concrete was poured into the moulds in three layers with each layer being compacted thoroughly with tamping rod 25 times each time to avoid honey combing. Finally all specimens were kept on the table vibrator after filling up the moulds up to the brim. The vibration was effected for 7 seconds and it was maintained constant for all specimens and all other castings. The steel plates forming notches were removed after 3 hours of casting carefully and neatly finished. After 28 days of curing the specimens were taken out of water and were allowed to dry under shade for few hours.

4.4Testing of specimens

4.4.1 Compressive strength of cubes: Compressive strength of cubes shall be calculated by dividing load taken by the specimen by the cross sectional area. Values of compressive strength at different percentages of silicon dioxide are given in table 1 below.

4.4.2 Flexural strength: Flexural strength is one measure of the tensile strength of the concrete. It is a measure of an unreinforced concrete beam to resist failure in bending. The flexural strength can be determined by standard test method of third point loading or center point loading. In this study, three beams of size 100*100*500 mm were used to find the flexural strength. The values are presented in table 2.

4.4.3 Modulus of elasticity: The theoretical modulus of elasticity has been calculated using IS code formula.

$E=5000*\sqrt{f_{ck}}$

Where f_{ck}= Characteristic Compressive strength of concrete in N/mm^2

The modulus of elasticity values have been calculated from the empirical formula suggested by Takafumi is

$E=k_1k_2*1.486*10^{-3} * f_{ck}{}^{1/3} *\gamma^{2}$

Where f_{ck} = Compressive strength in N/mm^2, γ = Density in Kg/m^3, K_1= 0.95 (correction factor corresponding to coarse aggregate), K_2= 1.026, (correction factor corresponding to mineral admixtures)

4.4.4 Mode II fracture test

For testing DCN specimens of size 150x150x150mm, notches were introduced at one third portion centrally during casting. The compression test on the DCN cubes was conducted on 3000KN digital compression testing machine. The rate of loading applied is 0.5 KN/sec. Test results shown in table 5 and graphically vide in fig.4.Uniformly distributed load was applied over the central one third part between the notches and square cross section steel supports were provided at bottom along the outer edges of the notches, so that the central portion could get punched/sheared through along the notches on the application of loading.

Table 1: compressive strength

Name of the mix	% Volume replacement of coarse aggregate	% of admixtures in equal proportions	% Nano (SiO_2) on 11% of cement	% of cement	compressive strength in N/mm^2	% increase or decrease of compressive strength
TA0	100	0	0	100	24.8	0
TA1	100	11	0.5	88.945	31.55	27.22
TA2	100	11	1	88.890	25.496	2.806
TA3	100	11	1.5	88.835	25.55	3.024

Table 2 : Flexural strength

Name of the mix	% replacement of coarse aggregate	% of admixtures	% SiO_2 on 11% of cement	% of cement	Flexural strength in N/mm^2	% increase or decrease of flexural strength
TA0	100	0	0	100	3.203	0
TA1	100	11	0.5	88.945	3.66	14.27
TA2	100	11	1	88.890	3.57	11.46
TA3	100	11	1.5	88.835	3.43	7.087

Table 3 : Modulus of elasticity

Name of the mix	% replacement of coarse aggregate	% of admixtures	% SiO_2 on 11% of cement	% of cement	Modulus of elasticity in N/mm^2 $E=5000*\sqrt{fck}$	Modulus of elasticity based on empirical formula $E=k_1k_2*1.486*10^{-3} * f_{ck}{}^{1/3} *\gamma^2$ $K_1=0.95$, $K_2=1.026$	% increase or decrease of modulus of elasticity
TA0	100	0	0	100	2.49	1.82	0
TA1	100	11	0.5	88.945	2.81	1.87	12.85
TA2	100	11	1	88.890	2.52	1.75	1.205
TA3	100	11	1.5	88.835	2.53	1.79	1.606

Table 4: Density

Name of the mix	% Volume replacemen t of coarse aggregate	% of admixtures in equal proportions	% nano (SiO_2) on 11% of cement	% of cement	Density in Kg/cum	Percentage increase or decrease in density
TA0	100	0	0	100	2044	0
TA1	100	11	0.5	88.945	2025	-0.929
TA2	100	11	1	88.890	2027	-0.832
TA3	100	11	1.5	88.835	2048	0.196

Table 5: Ultimate loads in Mode-II fracture test

Name of the mix	% replacement of coarse aggregate	% admixtures	% silicon dioxide	a/w=0.3		a/w=0.4		a/w=0.5		a/w=0.6	
				Ultimate load in KN	% increase or decrease of ultimate load	Ultimate load in KN	% increase or decrease of ultimate load	Ultimate load in KN	% increase or decrease of ultimate load	Ultimate load in KN	% increase or decrease of ultimate load
TA0	100	0	0	121	0	106.7	0	88.7	0	62.3	0
TA1	100	11	0.5	145	19.834	115	7.778	98	10.485	66.67	7.01
TA2	100	11	1	119.7	-1.074	95	-10.96	88.3	-0.451	55.67	-10.64
TA3	100	11	1.5	110	-9.09	93	-12.84	81.67	-7.925	55	-11.72

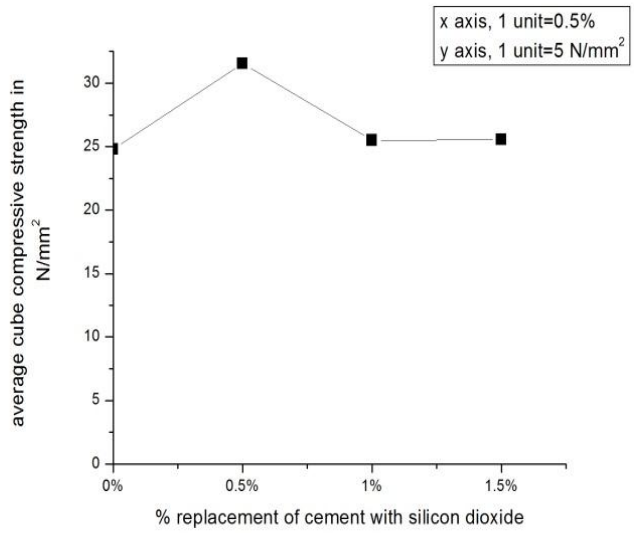

Fig 1: Compressive strength of cubes

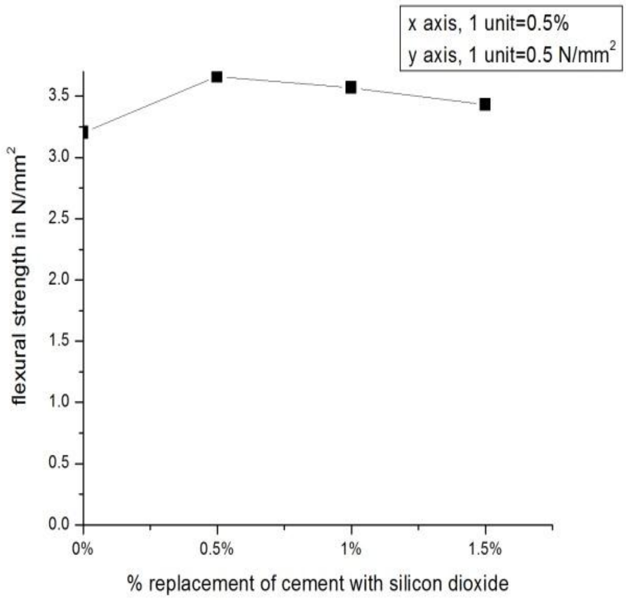

Fig 2: Flexural strength

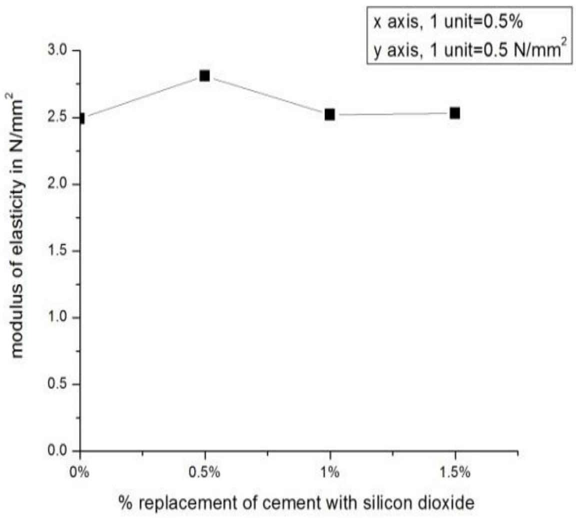

Fig 3: Modulus of elasticity

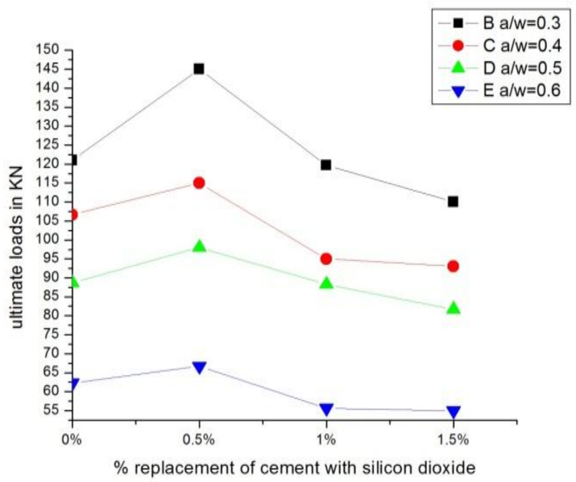

Fig 4: superimposed loads for different a/w ratios

5. Discussion of test results

5.1 Influence of silicon dioxide on cube compressive strength

In the present study natural aggregate has been fully replaced with Sintered fly ash aggregates. The variation of compressive strength verses varying percentage replacement at 0, 0.5, 1 and 1.5% on 11% of cement with Nano SiO_2 in addition with constant 11% of three numbers of pozzolanic materials i.e., Silica fume, Slag and Fly ash in equal proportions at 28 days are shown in figures 1. From the above figures it may be observed that with the addition of silicon dioxide the cube compressive strength increases with addition of 0.5% and with more addition of Nano SiO_2 the strength is decreased. The cube compressive strength for 1% and 1.5% addition of SiO_2 are almost equal. The results are tabulated in table 1.

5.2 Influence of silicon dioxide on flexural strength of beam specimens

In the present study natural aggregate is fully replaced with Sintered fly ash aggregates. The flexural strength of beams is increased continuously up to 0.5% addition of silicon dioxide and afterwards it is decreased. The results and tabulated in table 2 and shown in figures 2.

5.3 Influence of Nano silicon dioxide on modulus of elasticity

The modulus of elasticity results with various percentages of SiO_2 are presented in table 3 for 28 days based on IS code methods and the empirical formula as mentioned above. From the results it is observed that modulus of elasticity has been increased continuously up to 0.5% SiO_2 addition and afterwards it is decreased. It is also observed that the modulus of elasticity values calculated from IS codes are higher compared to empirical formula.

5.4 Discussion on the effect of SiO_2 on in plane shear strength

All the DCN specimens with different a/w ratios i.e 0.3, 0.4, 0.5 and 0.6 and with different percentages of SiO_2 were tested with load in Mode-II (in plane shear). The variations of ultimate loads and percentage increase or decrease in ultimate loads verses percentage replacement of cement with Nano SiO_2 are presented in table 5which are presented for different a/w ratios after 28 days.

5.5 Influence of silicon dioxide on density

Density of modified concrete with Sintered fly ash aggregates with Nano SiO_2 is decreased to 15% compared to natural aggregate concrete.

5.6 Discussion of crack patterns in cubes, cylinders, beams and DCN specimens:

In case of cubes, the initial cracks are developed at top and propagated to the bottom with the increase in load and they are widened along the edges of cubes. In case of cylinders, the initial cracks are developed at top or bottom side with the increase in load the cracks are widened at central height. In the flexural beams all 9 beams have failed in flexural mode. As the load increases the flexural cracks initiates in the pure bending zone and the first cracks appears almost in the mid span. As the load increases, existing cracks propagated are observed and new cracks have developed along the span. Final failure occurs in the middle portion. The failure of the DCN specimen is such that the crack patterns obtained for DCN specimen geometry are mostly along the notch depths. During testing, for most of the specimen initial hair line cracks started at the top of one or both the notches, and as the load was increased further, the cracks widened and propagated at an inclination and sometimes to the middle of the top loaded zone. In a few cases, initial cracks started at the bottom of the one or both notches. As the load was increased propagation of these cracks at an inclination was observed along with the formation of cracks at top of the notches. These cracks finally propagated toward the middle of the top loaded zone leading to failure of the specimen. In some cases cracks formed either side at two edges of the supporting load bearing plate at the bottom or at the loaded length at top side. For most of the specimens with a/w = 0.3, 0.4, 0.5, 0.6, as the load was applied formation of initial hair line cracks at the top of one or both the notches was observed. With the increase of load propagation of these cracks in more or less vertical direction along with the formation of new cracks at the bottom of one or both the notches was observed.

6. Conclusions

- The target mean strength of M_{20} concrete is 26.60 N/mm^2.From the experimental study it is observed that the 28 days cube compressive strength of modified concrete with 100% Sintered fly ash aggregate is 24.80 N/mm^2 and with replacement of cement by 11% with three numbers of pozzolanic materials i.e., Silica fume, Slag and Fly ash in equal proportions and 0.5% of Nano silicon dioxide the cube compressive strength of modified concrete rises to 31.55 N/mm^2 which is much higher than target mean strength of M_{20} concrete.
- With the 0.5% percentage of Nano SiO_2 and with constant 11% pozzolanic materials replacing the cement there is increase in flexural strength and Young's modulus and further increase in Nano Silicon dioxide content there is decrease in both values.
- From the analysis of test results it is concluded that young's modulus calculated from IS code is higher compared to empirical formula.
- It is observed that with the increase in the a/w ratio there is decrease in ultimate load and there is increase in ultimate loads with 0.5% of Nano SiO_2 and further increase in Nano SiO_2content there is decrease in ultimate loads for all a/w ratios.
- The light weight concrete prepared by 100% Sintered fly ash aggregate as coarse aggregate is no way inferior to the natural aggregate and also consumption of cement can be reduced by about 11%.

References

1) Luciano Senff et al., Effect of Nano-silica on rheology and fresh properties of cement pastes and mortars Construction and Building Materials 23 (2009) 2487–2491
2) Hongjian Du et al.,Durability performances of concrete with Nano-silica Construction and Building Materials 73 (2014) 705–712

3) A.M. Said et al.,Properties of concrete incorporating Nano-silica Construction and Building Materials 36 (2012) 838–844
4) Prakash Desayi, B.K.Raghu Prasad and V.Bhaskar Desai, “Mode – II fracture of cementitious materials- part – I : Studies on specimens of some new geometries”, Journal of Structural Engineering, Vol.26, No.1, April 1999, pp.11-18.
5) Thorenfeldt, E., Design Criteria of Light weight Aggregate Concrete. CEB/FIP International Symposium on Structural Light weight Aggregate Concrete, Sandefjord, Norway, pp. 720- 732, 1995.
6) Arvind Kumar , DilipKumar Use of Sintered Fly Ash Aggregates as Coarse Aggregate in concrete,SSRG International Journal of Civil Engineering (SSRG-IJCE)– volume1issue4 September2014
7) Takafumi Noguchi, et.al (2009) “ A Practical Equation for Elastic Modulus of Concrete”. ACI structural journal/Sept-Oct 2009, technical paper title no. 106-SXX.
8) I.S.Code 456-2000 “Code of practice for plain and reinforced concrete” Bureau of Indian Standards, New Delhi.