An Experimental Investigation On Sintered Fly Ash Aggregate Concrete Modified With Nano Silicon Dioxide On Two Way Slabs In Flexure

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Abstract: Fly ash is one promising material which can be used as both supplementary cementitious material as well as to produce light weight aggregate. In this introduction mix design is done for M20 grade concrete by IS code method. ACC 53 grade cement is used and natural aggregate is fully replaced with Sintered fly ash aggregate. In this experimental investigation 11% of cement is replaced with three numbers 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 cement. 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, tests have been carried out to find out the flexural strength of modified concrete with and without admixtures.. The concrete made with Nano silicon dioxide gives better results compared to that without silicon dioxide.

Index terms: Sintered fly ash aggregates, admixtures, ACC 53grade, concrete, silicon dioxide, cube strength, flexural strength of slabs and strain energy stored

1. INTRODUCTION: There is a growing need for electricity in India and 70% of power is generated through thermal power plants. The environmental dreads from these plants include air pollution due to particulate emission, water pollution and shortage of land for dumping the fly ash. Further, the poor quality of Indian coal with high ash content worsens the disposal problem. Instead of dumping the fly ash as landfills, it can be widely used as cement replacement material. In the present scenario, construction industry is growing in a very fast manner. The availability of raw materials for the construction industry has become scarce in most parts of the world. The continuous usage of natural resources for the production of the concrete in some locations creates many threatens to the environmental conditions. Much research has been done in this area to find alternative materials to overcome the deficiency of raw materials in the construction industry. In this connection, the present study focused on usage of artificial sintered fly ash aggregates in place of coarse aggregates is a viable alternative.

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 that in the conventional concrete. This can be achieved without sacrificing the strength characteristics; thereby it is possible to produce eco friendly concrete called green concrete. The flow chart of manufacturing process of sintered fly ash aggregates shown below fig 1:

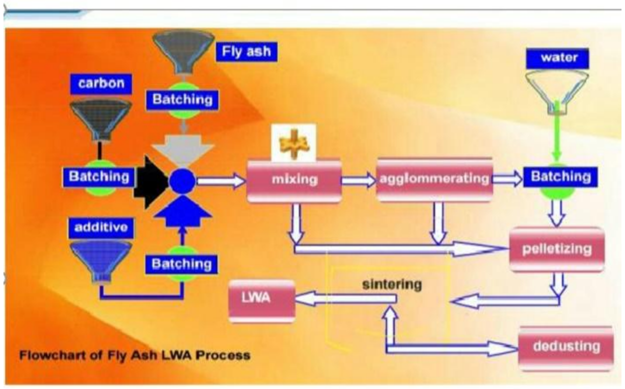


Fig 1: flow chart of sintered fly ash aggregate Manufacturing process

fig 2: sintered fly ash aggregate

2. Review of literature

Luciano senff et al., (1) in their 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) in their paper investigated the durability properties of concrete containing Nano silica at the dosages of 0.3% and 0.9% respectively.

Thorenfeldt, E., (3) 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 &DilipKumar.,(4) reported thatthe maximum compressive strength of 36.25 N/mm^2 is attained at 12% replacement of Sintered fly ash aggregate in concrete while the minimum strength of 26.68 N/mm^2 is attained at 20% replacement,. It is also reported that The maximum flexural strength of 4.95 N/mm^2 is attained at 8% replacement, while the minimum strength of 2.75 N/mm^2 is attained at 20% replacement.

Bauer and Redwood et al.,(5) presented a numerical method based on virtual work approach of yield line theory. The method consists of computing yield load of plate based on the geometry of assumed collapse mechanism defined by means of planes, nodes and lines. This method allows the yield line analysis of plates with a complex shapes, assumed loadings and mechanism and concluded that the computer program to analyse plate structures and also features such as orthotropic and skewness, line loads, point loads, uniformly distributed loads, fans, it also includes procedures for optimization of the yield line mechanisms.

Vechio and Tang., (6) discussed the influence and formation of compressive membrane action in reinforced cement concrete. In this study, two large scale slab specimens were tested under concentrated mid span loads. One slab restrained against lateral expansion at the ends, for the other was free to elongate. The laterally restrained specimen produced high axial compressive force, flexural stiffness and load carrying capacity. A nonlinear analysis procedure was used to model specimen behavior and thus gave accurate predictions of load-deformation response and the ultimate load.

SudarsanaRao et al.,(7) studied the effect of various volume percentages of steel fiber in SIFCON slab specimens subjected to punching shear, deflection, failure load and crack patterns in punching shear. Plain concrete slab and fiber reinforced concrete specimens were used as control specimens. The results showed that SIFCON slabs with 12% fiber volume possess higher performance than the other slab specimens in all respects. The experimental result was compared with IS and ACI codes and the need for separate provisions for SIFCON in punching shear was emphasized. To predict the punching shear capacity of SIFCON slabs a regression model was developed.

SudarsanaRao.,(8) studied the behavior of slurry infiltrated fiber concrete two-way slabs in flexure with three edges fixed and the other edge simply supported with fiber percentage of 8, 10 and 12%. For comparison fiber reinforced concrete and reinforced cement concrete slab specimens were also cast and tested, all slabs specimens are of size 600x600x50 mm. The results showed that the slabs with 12% fiber volume shows excellent performance over FRC and RCC slabspecimens.

Shanmugapriya and Uma., (9) conducted experimentation on high performance concrete with partial replacement of cement by silica fume. The target mean strength of concrete was fixed 60 MPa and percentage of silica fume are used in this investigation are 2.5, 5, 7.5, 10 and 12.5%. The cubes and cylinders of standard size are cast and tested for 28 days and concluded that maximum values of cube compressive strength and split tensile strength were obtained at 7.5% replacement of cement by silica fume

From the brief literature survey 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. Experimental Procedure

The experimental program comprises of casting of 15 numbers of reinforced slab specimens using modified concrete with 100 percent replacement of natural aggregate with sintered fly ash aggregate along with 11% replacement of cement with pozzolanic materials like fly ash, Slag and silica fume in equal proportions along with varying percentages of Nano silicon dioxide (0, 0.5, 1, 1.5) on 11% weight of cement and testing them in a simply supported condition on all four edges. The mix proportions adopted are presented in Table 1. All the slabs are square in shape with size 600 × 600 × 50 mm.

Table 1: Mix proportions:

Mix	% Volume replacement of Coarse aggregate(Sintered fly ash aggregate)	% of admixtures in equal proportions(fly ash, silica fume & slag)	% of Nano Materials on 11% of cement	% of cement	Number of cubes	Number of slab specimens
OSR-0	100	0	0	100	3	3
OSR-1	100	11	0	89	3	3
OSR-2	100	11	0.5	88.945	3	3
OSR-3	100	11	1	88.890	3	3
OSR-4	100	11	1.5	88.835	3	3

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
8. Steel of HYSD 415 grade

4.1 Cement: Ordinary Portland cementACC 53 grade was used as binder. Some physical properties are presented in table 2.1.

Table 2.1: properties of cement:

S.NO.	PROPERTY	NUMERICAL VALUE
1	Normal consistency	30%
2	Fineness	5%
3	Specific gravity	3.26
4	Setting time Initital setting time Final setting time	50 minutes 460 minutes

5.2 Fine Aggregate

Natural sand from Chitravathi River near Bathalapalli with specific gravity of 2.54was used as fine aggregate conforming to zone- II of IS: 383-1970 [7].

5.3 Sintered fly ash aggregate:

Sintered fly ash aggregate procured from LitaggCompany; Ahmedabad was used in this investigation. Some physical properties are presented in table 2.2.

Table 2.2: Typical physical characteristics of Sintered fly ash aggregates

S.NO.	PROPERTY	VALUE
1	Aggregate Size	8-12mm
2	Bulk Density	800 kg/m3
3	Bulk Porosity	35-40%
4	Aggregate Strength	>4.0 MPa
5	Water Absorption	< 16 %
6	Shape	Round pellets
7	Hardness	23.2%
8	Fineness modulus	6.57
9	Specific gravity	1.7
10	Impact	28%

5.4 Water:

The local drinking water which is free from impurities was used in this experimental investigation.

5.5 Fly ash:

The fly ash admixture was procured from Rayalaseema Thermal plant, Muddanur. Some physical properties are presented in table 2.3.

5.6 Silica Fume:

The silica fume admixture was procured ferro silica unit at Ahmedabad. The physical properties are shown below Table 2.3 .

5.7 Slag:

The source of slag from wasJindhal steel industries, Bellary. The physical properties are presented in Table 2.3.

Table 2.3: Physical properties of fly ash, silica fume and Slag

S.NO	Property	Numerical value		
		Fly ash	Silica fume	Slag
1	Specific gravity	2.7	2.1	2.86
2	Bulk density in loosest state	800 kg/m^3	420 kg/m^3	600 kg/m^2
3	Bulk density in compacted state	960 kg/m^3	700 kg/m^3	980 kg/m^3

5.8 NANO MATERIALS

5.8.1 Nano silica or silicon dioxide (SiO_2):

Nano silica was procured from AVANSA technologies, KHANPUR. The physical properties are presented in table 2.4.

Table 2.4: Physical Properties of Silicon Oxide Nanopowder (SiO_2) (As given by the supplier)

S.NO.	PROPERTY	VALUE
1	Purity	98+%
2	APS	60-80nm
3	SSA	160-600m^2/g
4	(SiO2) Color	White
5	Bulk Density	<0.10 g/cm^3
6	True Density	2.4 g/cm^3

Table 2.5: Certificate of Analysis (Given by the supplier)

SiO2	Ti	Ca	Na	Fe
>98%	<220 ppm	<130ppm	<80ppm	<40ppm

***5.9*Reinforcement:**

All the slabs was reinforced with 10 mm diameter Fe 415 grade steel rods, placed at 130 mm spacing in both directions.

6.1 Casting of specimens:

The M20 concrete mix was designed using ISI method which gives a mix proportion of 1:1.49:2.88 with water cement ratio of 0.50. Five different mixes were adopted as shown in table 1.Steel moulds were used to cast the slab specimens of required size. Two L-shaped frames with a depth of 50 mm were connected to a flat plate at the bottom using nuts and bolts. Cross-stiffeners were provided to the flat plate at the bottom to prevent any possible deflection while casting the specimens. The gaps were effectively sealed by using thin card-boards and wax to prevent any leakage of cement-sand slurry in slab specimens. The steel cage in the mould is shown in Fig. 3. Initially, the steel mould was coated with waste oil so that the slab specimens can be removed easily from the moulds. Then the mat of 10 mm steel rods @ 130 mm c/c was kept, at the bottom of mould over 10 mm cover blocks. Then the remaining portion of entire mould was filled with freshly prepared sintered fly ash concrete. A view of cast specimen is presented in Fig 4. Initially dry mixture of cement, pozzolanic materials, silicon dioxide and sand was spread over the heap of coarse aggregate. Hand mixing was done after adding required quantity of water to achieve uniform mix and to prevent the segregation or balling of aggregates and cement slurry. All the specimens were given table vibration. The test specimens were de-moulded after 24 hours and were cured for 28 days in curing water ponds. After removing the slab specimens from the curing pond, they were allowed to dry under shade for some time and then they were white washed on both sides, to achieve clear visibility of cracks during testing.

Fig 3: slab mould with reinforcement

fig 4: slab mould filled with concrete

6.2 Structural Loading Frame and Platform

The set-up available at Structural Engineering laboratory was used to test square slab specimens of size 600X600mm. The loading platform consists of four welded steel beams of ISLB 150 in square shape with clear opening of 470X470mm and it is supported on four columns of ISLB 150 placed at four corners. The loading platform and loading frame is stiff enough to support the loading without significant deformations. The loads acts vertically from the top, the same way as own weight acting. Detailing and structural design for steel members and .connections are done according to the Indian Standards IS- 800:1984. (See Fig 5)

6.2.1 Application of load and loading sequence

The experiment of testing square slabs, under simply supported condition on all four edges, with uniformly distributed loading load involved application of load on the top surface of the load through precalibarated proving ring and hydraulic jack. The load was distributed to an iron plate with 50mm diameter iron balls welded closely and placed above the surface of RCC slab specimen to simulate uniformly distributed loading conditions through I sections placed above the plate. The load applied to the slab through a distribution system also called "loading tree" or "load spreaders"is as shown in fig.6. At the bottom face of slab specimen, a deflecto meters with a least count of 0.01mm were placed at center and at all critical sections to record the deflections. The load at the first crack and the corresponding deflection at the center and at critical sections along the diagonals of the slab were recorded. The ultimate load and corresponding deflection at the center and at critical sections were also observed and recorded for all the slab specimens. (See Fig 6)

Fig 5:slab specimen placed on loading platform in simply supported condition

Fig 6: Testing arrangement of slabs for Flexure strength

7. Testing of specimens

7.1 Compressive strength of cubes:

Compressive strength of cubes was calculated by dividing load taken by the specimen by the cross sectional area. Values of compressive strength at different percentages ofnano silicon dioxide are given in table 3 below.

7.2 First crack load and ultimate load of slabs in simply supported condition:

The load recorded at the first crack formed at the bottom face of slab is called first crack load. The first crack load, ultimate load and the corresponding deflections were also recorded. The values are presented in table 4.

7.3 Moment carrying capacity of slabs at first crack load and ultimate load based on IS: 456-2000 code method:

Following the IS code method of calculating the moment carrying capacity of a slab was done using the following formula

$$\mathbf{M=W*\alpha_x*L^2_x}$$

Where M= Bending moment

L_x=Effective length of slab

W= Load at first crack/ultimate load

For simply supported condition

α_x=0.062(moment coefficient from IS code: 456:2000)

L_x=Effective length of slab

W=ultimate load carrying of slab

. The values so calculated are presented in table 4.

7.4 Moment carrying capacity of slabs at first crack load and ultimate load based on Yield line theory:

According to yield line theory the moment carrying capacity of slabs was calculated by following formulas derived from combine process of Virtual work done and equilibrium method.

Moment carrying capacity for simply supported condition is given by,

$$M_y=\frac{WL2}{24}$$

Where

W= collapse load

L= Total length of slab

. The values so calculated are presented in table 4.

7.5 Strain energy stored of slabs:

The energy absorption is defined as the area under the load-deflection curve. The values were determined from test results, and are listed in Table 4

8. Discussion of test results

8.1 Influence of Nano SiO_2 on cube compressive strength

In the present study natural aggregate has been fully replaced with Sintered fly ash aggregates. The variation of 28 days compressive strength verses varying percentage replacements of 0, 0.5, 1 and 1.5% on 11% of cement with Nano SiO2 in addition with constant 11% of three numbers of pozzolanic materials i.e., Silica fume, Slag and Fly ash in equal proportions is shown in fig 7.1. From the above figure it may be observed that with the addition of silicon dioxide the cube compressive strength increases upto0.5% of Nano SiO_2 and with more addition of Nano SiO2 the strength is decreased. The results are tabulated in table 3.

8.2First crack load:

In the present study natural aggregate has been fully replaced with Sintered fly ash aggregates. The variation of first crack load in flexure verses varying percentage replacement at 0, 0.5, 1 and 1.5% on 11% of cement with Nano SiO2 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 is shown in fig 7.2. From the figure it may be observed that with the addition of silicon dioxide the first crack load increases upto0.5% of Nano SiO_2 and with more addition of Nano SiO2 the strength is decreased. The results are tabulated in table 4.

1.3 Moment carrying capacity of slabs at first crack load based on IS code:

In the present study natural aggregate is fully replaced with Sintered fly ash aggregates. The moment carrying capacity of slabs is increased continuously up to 0.5% addition of silicon dioxide and afterwards it is decreased. The results and tabulated in table 4 and presented graphically in fig 7.3.

1.4 Moment carrying capacity of slabs at first crack load based on Yield line theory:

In the present study natural aggregate is fully replaced with Sintered fly ash aggregates. The moment carrying capacity of slabs is increased continuously up to 0.5% addition of silicon dioxide and afterwards it is decreased. The results and tabulated in table 4 and presented graphically in fig 7.3.

8.5Ultimate load:

In the present study natural aggregate has been fully replaced with Sintered fly ash aggregates. The variation of ultimate load averses varying percentage replacement at 0, 0.5, 1 and 1.5% on 11% of cement with Nano SiO2 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 is shown in fig 7.4. From the figures it may be observed that with the addition of silicon dioxide the ultimate load increases upto 0.5% addition of Nano SiO2 and with more addition of Nano SiO2 the strength is decreased. The results are tabulated in table 4 and presented graphically in fig 7.4

.8.5 Moment carrying capacity of slabs at ultimate load based on IS code:

In the present study natural aggregate is fully replaced with Sintered fly ash aggregates. The moment carrying capacity of slabs is increased continuously up to 0.5% addition of silicon dioxide and afterwards it is decreased. The results and tabulated in table 4 and are graphically shown in fig 7.5.

8.6 Moment carrying capacity of slabs at ultimate load based on yield line theory:

In the present study natural aggregate is fully replaced with Sintered fly ash aggregates. The moment carrying capacity of slabs is increased continuously up to 0.5% addition of silicon dioxide and afterwards it is decreased. The results and tabulated in table 4 and graphically shown in fig 7.5.

8.7 Influence of Nano SiO_2 on strain energy stored in slabs:

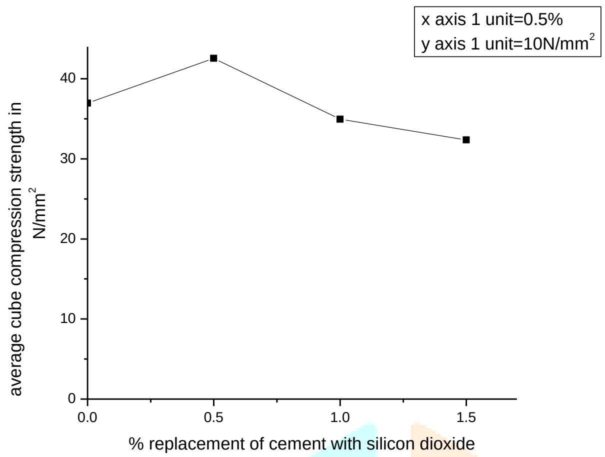
In the present study natural aggregate is fully replaced with Sintered fly ash aggregates. The strain energy stored in slabs is increased continuously up to 0.5% addition of nano Silicon dioxide and afterwards it is decreased. The results and tabulated in table 4 and are graphically shown in fig 7.6.

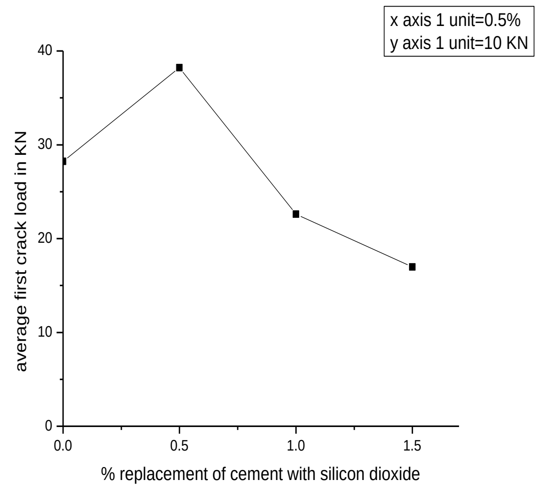
Table 3: compressive strength

Mix proportions	Cube compressive strength in N/mm^2	Percentage increase of compressive strength w.r.t to OSR-0
OSR-0	28.84	0
OSR-1	36.97	28.19
OSR-2	42.56	39.12
OSR-3	34.95	21.19
OSR-4	32.36	12.2

Table 4: moment carrying capacity and strain energy stored of slabs:

Mix	At first crack			At ultimate				
	Load (KN)	Moment carrying capacity (KN-m)		Load (KN)	Moment carrying capacity(KN-m)			Strain Energy absorption (kN-mm)
		Based on IS code	Based on Yield line theory		Based on IS code	Based on Yield line theory	% of Increase moment w.r.t yield line theory	
OSR-0	15.11	1.28	1.789	81.98	6.96	5.56	25.18	110.37
OSR-1	28.23	2.4	1.93	120.11	10.19	8.16	24.88	194.12
OSR-2	38.22	3.25	2.59	155.71	13.22	10.57	25.07	269.87
OSR-3	22.605	1.92	1.54	101.36	8.61	6.88	25.14	144.03
OSR-4	16.98	1.44	1.12	84.48	7.17	5.77	24.26	112.48



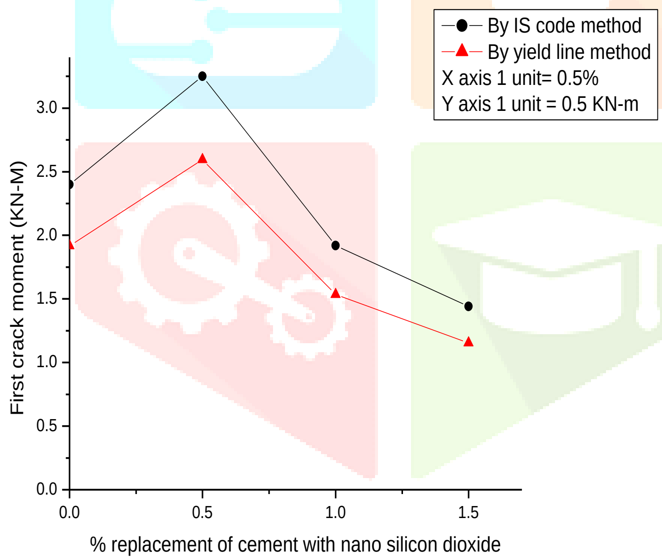


Nano SiO_2

fig 7.1:

Cube compression strength VS %replacement of cement with Nano SiO_2

Fig 7.2: first crack load VS % replacement of cement with Nano SiO_2



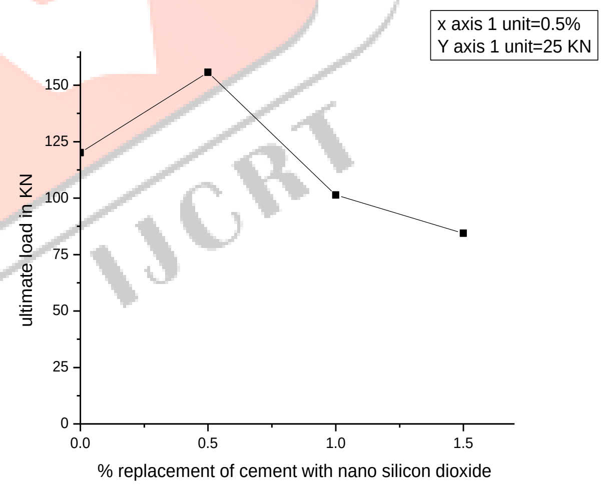


fig 7.3: Super imposed variation of moment at first

Fig 7.4: Ultimate load VS % replacement of

crack moment VS % replacement with Nano SiO_2

Cement with Nano SiO_2 capacity at ultimate with Nano SiO_2

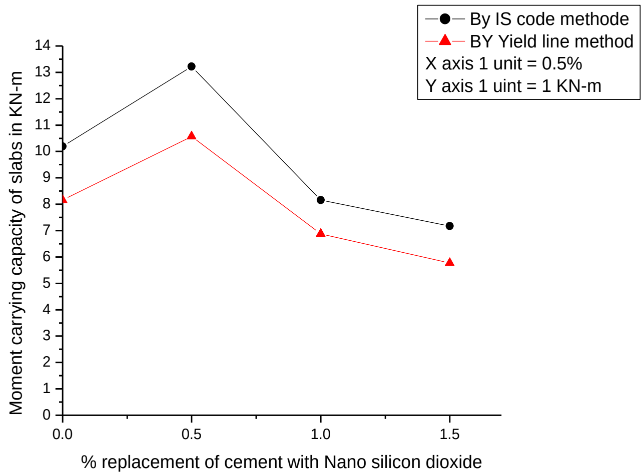


fig 7.5: Super imposed variation of moment carrying load VS % replacement of cement with Nano SiO_2

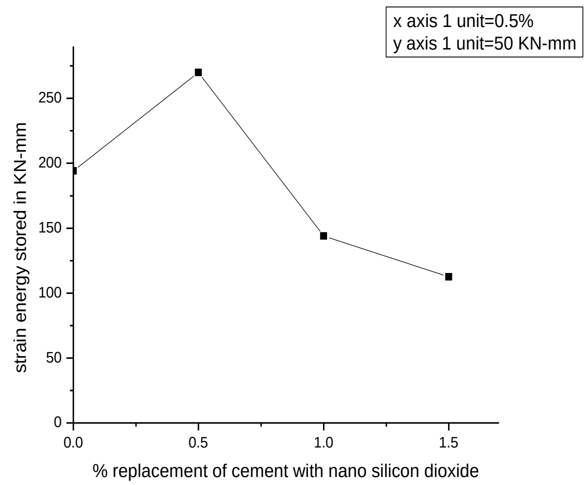


Fig 7.6: Strain energy stored in slabs VS % replacement of cement with Nano SiO_2

9. Conclusion:

- The target mean strength of M_{20} concrete is 26.60 N/mm2.From the experimental study it is observed that the 28 days cube compressive strength of modified concrete with 100% Sintered fly ash aggregate is
- 28.80 N/mm2 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 42.56 N/mm2 which is much higher than target mean strength of M_{20} concrete.
- With the 0.5% percentage of Nano SiO2 and with constant 11% pozzolanic materials replacing the cement there is an optimum increase in first crack load, ultimate load, moment carrying capacity and strain energy stored on slabs and with further increase in Nano Silicon dioxide content there is decrease in all values.
- From the analysis of test results it is concluded that moment carrying capacity of slabs calculated from IS code method is higher compared to that calculated using Yield line theory.
- 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%.

10. References

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