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Flexural Study Thruogh Slab Specimens with Fully Replacement of Natural Coarse Aggregate by Cold Bonded Silica Fume Aggregate with Nano Aluminium Oxide

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1. ABSTRACT: Solid waste management is becoming an integral part of civilization. With rapid industrialization disposal of waste generated from industries is becoming a problem. Effective utilization of these materials will become a boon for the construction industry. It also mitigates the environmental issues. It is proposed to manufacture cold bonded silica fume aggregates with little amount of cement having density around 1200 kg/m^3 which will also serve as light weight aggregate.
In the last decade Nanotechnology has been gathering spectacular amount of attention in the field of building materials. The incorporation of Nano sized particles in a small amount to the building materials can influence their properties significantly and it can contribute to the creation of novel and sustainable structures. The strength of concrete can be increased in various ways. Some kind of additives or some innovative materials can be added to increase the strength of concrete.
A mix design is done for M_{20} grade concrete by IS code method. ACC 53 grade cement is used and natural aggregate is fully replaced with cold bonded silica fume aggregates. It is also proposed to replace cement by 11% of its weight with three numbers of pozzolanic materials like silica fume, slag and fly ash in equal proportions along with varying percentages of Nano aluminum oxide at 0, 0.5, 1 and 1.5 on 11% of cement. Aluminum oxide possesses more pozzolanic action. Because of pozzolanic action, aluminum oxide reacts with free lime during hydration and produces more C-S-H gel. The main aim of this project is to find moment carrying capacity of two way slabs with modified concrete with fixed end condition on all its four sides under UDL along with corresponding cube compressive strength. The concrete made with aluminum oxide gives better results compared to that without aluminum oxide.

***Key Words*:** Silica fume aggregates, admixtures, ACC 53grade, Nano aluminum oxide, cube strength, flexural strength of slabs and strain energy stored

2. INTRODUCTION:

Solid, so normally accepted in structures, spans and in various different structures, is taken for granted as massive and profound development material. Not necessarily so! A broad range of lightweight cement concretes is being manufactured nowadays. Initially, Romans prepared lightweight concrete by utilizing natural aggregates from volcanic stones. After the advancement of Portland cement in the early 1800s, however, it took the discovery and improvement of manufactured lightweight aggregates in the early 1900s to convey structural lightweight concrete to full maturity. The primary aim of lightweight concrete is to lessen the dead weight of structure to be utilized as a part of a structure which then allows an architect to diminish the measure of structural components (sections/beams) and size of foundation as well. Lightweight material has high potential to decrease the seismic mass of the structure and along these lines diminish the level of seismic powers acting on a structure.

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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 eco friendly concrete called green concrete.

3. LITERATURE REVIEW: Much research has been carried out for the improvement of strength and various parameters of concrete using Nano materials. These are enumerated as follows;

A.H.Shekaria (2010) (1) studied about the mechanical properties and durability of concrete using Nano materials such as titanium, ferrous oxide, zirconium, and alumina. Results showed that **Nano alumina** is most effective Nano particle.

Ali Nazari & Shadi Riahi(2011) (2) studied regarding the mechanical and physical properties of concrete, incorporating Nano Silica and Nano alumina in concrete and curing in different media. Results indicate that Nano alumina improves mechanical and physical properties of concrete. Abrasion resistance and compressive strength of concrete were found out. Results of study showed that abrasion resistance is more for the specimen which contains silica Nano particles in both water curing and saturated limewater curing.

Amal R. Jayapalan & Bo Yeon Lee(2013) (3) studied about the influence of Nano and micro materials on early age properties of cementitious material. Results indicated that, as the size of fillers is changed, shrinkage and pore structure of concrete can be changed.

PayamHosseini & RezaHosseinpourpia(2006) (4) made investigation on interaction between different Nano materials (Nano clay, Nano alumina, Nano silica
and Nano calcium carbonate) and amino saline in cement mortar.

Zhenhua Li & HuafengWang(2014) (5) studied about effect of containing different amount of Nano alumina. Cylindrical specimens were cast to study compressive strength and elastic modulus of cement composite. Elastic modulus was increased by 143%, with the addition of 5% Nano alumina after 28 days of curing and compressive strength was increased by 30 %, with the addition of 7% Nano alumina after 7 days of curing. Thus Nano alumina has significant effect on both elastic modulus and compressive strength.
From the brief literature review conducted here it appears that much less attention has been paid earlier on the study of flexural properties of modified concrete with partial to 100% replacement of natural aggregates with Cold bonded Silica Fume aggregate along with the usage of nano materials. Hence the present investigation has been under taken.

4. Objective

- Determining solution for disposal of industrial wastes hazardous to environment as a useful material in the Construction industry and save the natural resources
- By replacing of coarse aggregate with silica fume aggregate in concrete to produce light weight concrete.

5. Experimental Procedure

The experimental program comprises of casting and testing of 15 no’s of reinforced concrete two way slabs with uniformly distributed load and with fixed end condition on all its four sides. The slab specimens are prepared with modified concrete using 100% cold bonded Silica Fume aggregate in place of natural aggregate. It is also attempted to replace cement by 11% its weight with 3 no’s of pozzolanic materials i.e. fly ash, slag and silica fume in equal proportions along with varying percentages (0,0.5,1,1.5) of Nano aluminum oxide on 11% of cement. The mix proportions of the various mixes are presented in Table 1. All the slabs are square in shape and are of size 600 × 600 × 50 mm. The slabs are white washed for easy identification of crack patterns and placed over the platform for testing.

Table 1: Mix proportions:

MIX	%Volume replacement of Coarse aggregate by Silica fume 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
JA	100	0	0	100.00	3	3
JB	100	11	0	89.00	3	3
JC	100	11	0.5	88.945	3	3
JD	100	11	1	88.890	3	3
JE	100	11	1.5	88.835	3	3

6. MATERIALS

6. 1.Materials used:

The following materials are used for preparing the concrete mix.

1. ACC cement of 53 grade
2. Fly ash
3. Silica fume
4. Slag
5. Nano Al_2O_3
6. Fine aggregate i.e sand
7. Coarse aggregate i.e Silica fume aggregates
8. Water
9. Steel of HYSD 415 grade

6.2 Cement: Ordinary Portland cement ACC 53 grade is 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 Initial setting time Final setting time	50 minutes 460 minutes

6.3 Fly ash:

The fly ash admixture is produced from Rayalaseema Thermal plant, Muddanur. Some physical properties are presented in table 2.2

Table 2.2: Physical properties of fly-ash

S.No	Property	Value
1	Specific gravity	2.7
2	Fineness (retained on 90 micronsieve)	0%
3	Bulk density loosest state	800 kg/m^3
4	Bulk density compacted state	960 kg/m^3

6.4 Silica Fume:

The silica fume admixture is produced from ferro silica unit at Ahmadabad. Some physical properties are presented in table 2.3.

Table 2.3: Properties of Silica fume

S.No	Property	Test results
1	Specific gravity	2.1
2	Fineness (retained on 90 micron sieve)	0%
3	Bulk density loosest state	420 kg/m^3
4	Bulk density compacted state	700 kg/m^3

6.5 Slag:

The source of slag is from Jindhal steel industries, Bellary. Some physical properties are presented in table 2.4

Table 2.4: Physical properties of Slag

S.NO.	Property	Test results
1	Specific gravity	2.86
2	Fineness (retained on 90 micron sieve)	0%
3	Bulk density loosest state	600 kg/m^3
4	Bulk density compacted state	980 kg/m^3

6.6: Nano aluminum oxide (Al_2O_3):

Nano aluminum oxide is produced from AVANSA technologies, KANPUR. Some physical properties are presented in table 2.5

Table 2.5: Physical Properties of Aluminum Oxide Nanopowder (Al2O$_3$) (Given by the supplier)

S.NO.	PROPERTY	VALUE
1	Purity	99.5%
2	APS	<20nm
3	SSA	20-80 m^2/g
4	(SiO2) Color	White
5	Bulk Density	0.18g/cm^3
6	True Density	2.9g/cm^3

6.7 Fine Aggregate

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

6.8 Silica fume aggregate:

Silica fume is a by product in the form of smoke that results from electric furnaces of industries producing Silicon metal or ferrosilicon alloys. Silicon and ferrosilicon alloys are produced in electric furnaces and the raw materials are quartz, coal and wood chips. Before the mid 1970's nearly all silica fume was discharged into atmosphere. After environmental concerns necessitated collection and land filling became economically justified to use Silica Fume in various applications. Because of chemical and physical properties it is a very reactive pozzolan. Silica fume consists primarily of amorphous (non-crystalline) Nano Aluminum Oxide(Al_2O_3).

The individual particles are extremely small, approximately 1/100th the size of an average cement particle. Because of its fine particles, large surface area, and the high Al_2O_3 content, silica fume is a very reactive pozzolanic material. An attempt is made to produce cold bonded Silica fume pellets to use as light weight aggregate.

One of the common techniques while producing the light weight aggregate is by agglomeration technique. In agglomeration technique the pellets are formed by agitation granulation and compaction. The agitation method does not take any external force rather than the rotational force. With the increasing dosage of water in the binder the cohesive force of the particles increases. Here attempts have been made to form pellets of Silica Fume with various proportions of lime and cement mixed with water. Pelletization of Silica Fume is done by using a rotating drum with fixed blades with adjusting inclination. The percentage of binder content is taken by weight of silica fume. The percentage proportion adopted for formation of pellets is 47:47:6 i.e., silica fume: lime: cement. The drum used for pelletization of silica fume aggregates is shown vide fig no: 1 and the view of formed silica fume aggregates vide fig no: 2.

Silica fume is procured from Ferro Silica Unit at Ahmadabad. The physical properties of Silica fume aggregate are shown below vide table 2.6

Table 2.6: Typical physical characteristics of Silica fume aggregates

S.NO.	PROPERTY	VALUE
1	Bulk Density	854 Kg/ m3
2	Water Absorption	20%
3	Shape	Round
4	Specific Gravity	2.18
5	FINENESS modulus	5.80

6.9 Water:

The water used for casting and curing of concrete specimens should be free from acids, impurities and suspended solids etc and if the above materials are present in water would affect the strength and durability of concrete. The local drinking water which is free from such impurities has been used in this experimental investigation.

Fig 1: Manufacture process of silica fume aggregate

Fig 2: Silica fume aggregate

7. REINFORCEMENT:

All the slabs are reinforced with 10 mm diameter with Fe_{415} grade steel reinforcement, placed at 130 mm spacing in both directions

7.1 Casting of specimens:

The M_{20} concrete mix is designed using IS code which gives a mix proportion of 1:1.49:2.88 with water cement ratio of 0.50. Four different mixes are used, which are designated as in table no.1. Steel moulds are 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 moulds are 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 uses cover blocks. Then the remaining portion of entire mould is filled with freshly prepared silica fume concrete. The details of casting are shown in Fig 4. In case of hand mix, mixture of cement, pozzolanic materials and Nano aluminum oxide 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. For all the specimens table vibration was adopted. 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 a while and then they were coated with white paint on both sides, to achieve clear visibility of cracks during testing. The loading position on the top and the dial gauge position at the bottom of the slab were marked with black paint.

Fig 3: Slab mould with reinforcement

Fig 4: Slab mould filled with concrete

7.2 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 frame was designed with beam and column elements. The loading platform consists of four welded steel beams of ISLB 150 in square shape and it is supported on four columns of ISLB 150 placed at four corners. The loading platform and loading frame was stiff enough to support the loading without significant deformations. The loads acts vertically down wards on the slab specimens from the top, in the same way as its own weight and dead loads is acting. Detailing and structural design for steel members and connections were done according to the Indian Standards IS- 800:1984. (See Fig 5:)

7.3 Application of load and loading sequence:

The experiment of testing of square slabs, under fixed end condition on all its four edges with uniformly distributed loading involved by application of load on the top surface of the slabs through pre-calibrated proving ring and hydraulic jack. From the jack load was distributed to an iron plate with 50mm dia iron balls welded closely and placed in inverted position facing the iron balls over the slab specimen to simulate the uniformly distributed loading conditions through a series of I- sections placed over the iron plate. The load applied to the slab through a distribution system also called “loading tree” or “load spreaders” is as shown vide fig.6. This loading system was designed to spread the load uniformly to all the points designed. The slab specimens were placed over the clear span of 470mm and plates were fixed with nuts and bolts in order to prevent any rotation and differential settlement as shown vide fig no: 5 The loading sequence used is the same for all the samples tested. At the bottom face of slab specimen, a deflectometer with a least count of 0.01mm was placed at centre and two no’s each along diagonals to record the deflections. The load at the first crack and the corresponding deflection at the bottom centre and critical sections of the slab were recorded. The ultimate load and corresponding deflection at the centre and critical sections were also observed and recorded for all the slab specimens. (See Fig 6)

Fig 5: Slab Testing Machine with Fixed Plates

Fig 6: Slab Testing Machine

8. Testing of specimens

8.1 Compressive strength of cubes: The specimens were removed from water after 28 days of curing and excess water is wiped out from the surface and dried under shade and white washing was done so that cracks are properly visible. The specimens were placed in the machine in such a manner that the load shall be applied concentrically. The load was applied gradually without shock and continuously till the specimen fails. 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 of Nano Al_2O_3 are given vide table 4.

8.2 First crack load and ultimate load of slabs in fixed supported condition: The load taken at which first crack formed on the bottom face of slab is called first crack load. The ultimate load is taken at which maximum size of crack propagate from bottom to top face of the slab and also there is sudden reversal of proving ring reading .The values are presented in table 5.

8.3 Moment carrying capacity of slabs at first crack load and ultimate load based on IS code method: According to IS code (6) method of design the moment carrying capacity calculated using the following formula

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

Where M= Bending moment
For restrained supported condition
α_x**=0.056**(moment coefficient from IS code: 456:2000)
L_x=Effective length of slab
W=ultimate load carrying of slab
. The values are presented in table 5.

8.4 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 calculated by following formulas derived from combine process of Virtual work done method and equilibrium method
Moment carrying capacity for fixed supported condition is

$$M=\frac{WL2}{48}$$

Where W= collapse load
L= Total length of slab
. The values are presented in table 5.

8.5 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 5

Table 4: compressive strength

Mix	Compressive strength in N/mm^2	% increase in strength in comparison with modified concrete (zero replacement of cement)
JA	27.08	0
JB	28.13	3.88
JC	30.04	9.90
JD	34.22	26.40
JE	27.5	1.55

Table 5: moment carrying capacity and strain energy stored of slabs:

Mix	At First Crack			At Ultimate			
	Load (KN)	Moments(KN-m)		Load (KN)	Moments(KN-m)		Strain energy stored (KN-mm)
		IS method	Yield line theory		IS method	Yield line theory	
JA	16.355	1.25	0.555	78.855	7.19	2.677	112.14
JB	20.095	1.54	0.6822	90.103	6.9	3.05	163.6
JC	21.346	1.63	0.72	118.228	9.06	4.01	179.4
JD	25.096	1.92	0.84	135.103	10.36	4.5	199.506
JE	18.853	1.44	0.64	84.478	6.47	2.86	116.03

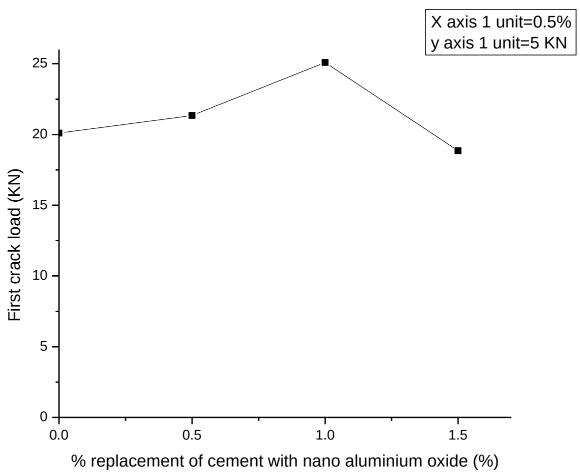

Fig 7.1: Variation of First crack load versus percentage replacement of cement with Nano Aluminium oxide

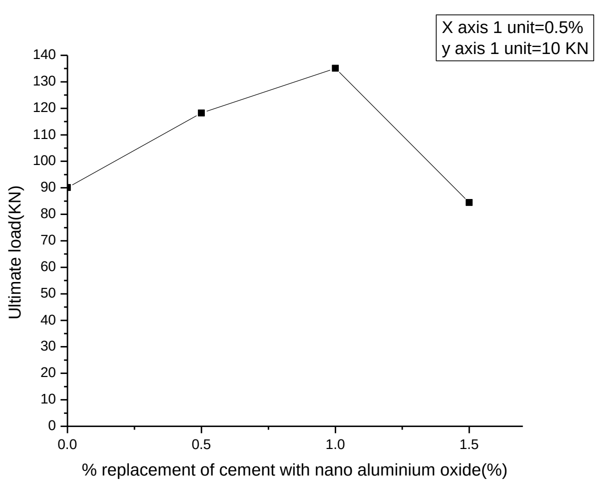

Fig7.2: Variation of Ultimate crack load versus percentage replacement of cement with Nano Aluminium oxide

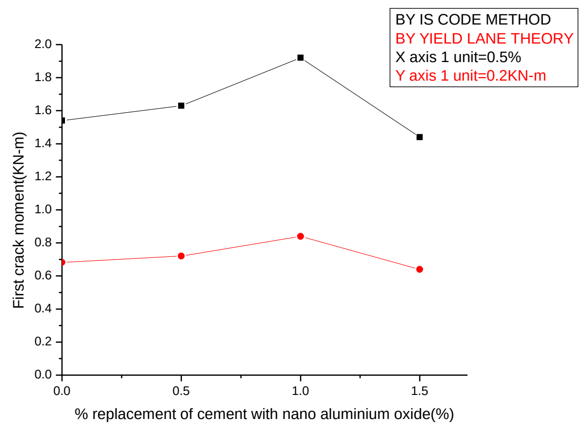

Fig 7.3: Super imposed variation of ultimate moment versus percentage replacement of cement with nano aluminium oxide

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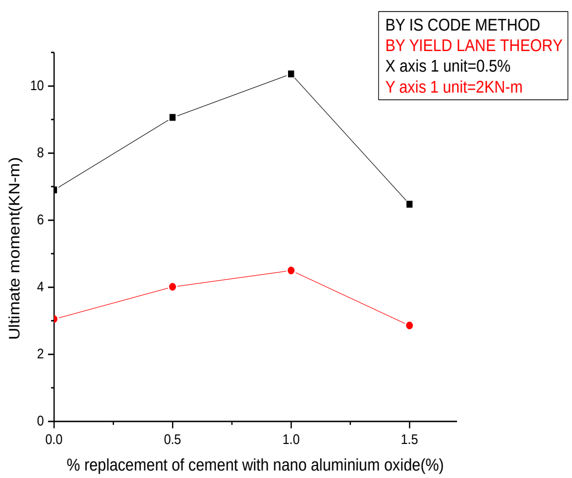

Fig 7.4: Super imposed variation of first crack moments versus percentage replacement of cement with nano aluminium oxide

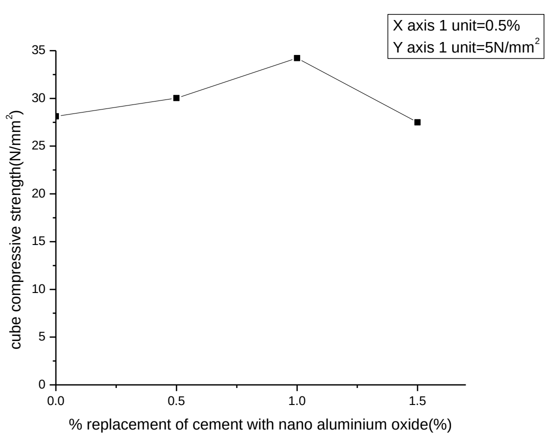

Fig:7.5: Variation of cube Compressive Strength Versus Percentage replacement of cement with nano aluminium oxide

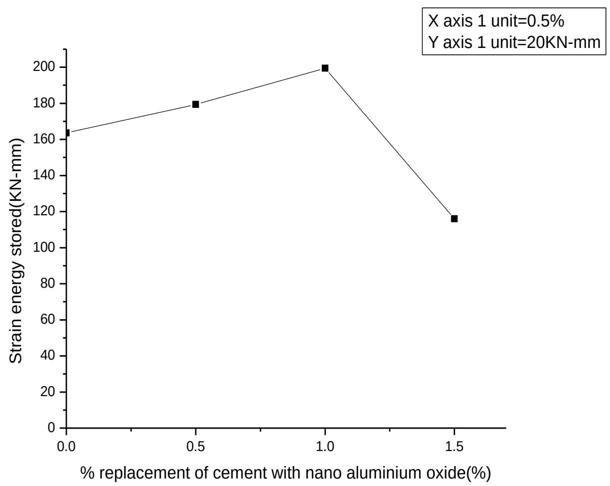

Fig:7.6: Variation of strain energy stored versus percentage replacement of cement with nano aluminium oxide

9.Discussion of test results:

9.1 First crack and Ultimate crack load:

The variation of first crack load and Ultimate load of two way slabs of modified concrete verses varying percentage replacement of Nano Al_2O_3 at 0, 0.5, 1 and 1.5% are shown graphically vide fig 7.1 and 7.2 and vide table no: 5. From them it is found that both loads are increasing up to 1% addition of Nano Al_2O_3 and there after the values are decreased.

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

In the present study natural aggregate is fully replaced with Silica fume aggregates. The moment carrying capacity of slabs is increased continuously up to 1% addition of Nano Al_2O_3 and afterwards it is decreased. The results are tabulated in table 5 and graphical representation is presented vide fig 7.3 and 7.4.

9.3 Influence of Nano Al_2O_3 on cube compressive strength:

In the present study, natural aggregate has been fully replaced with Cold bonded Silica fume aggregates. The variation of compressive strength verses varying percentage replacements of Nano Al_2O_3 at 0, 0.5, 1 and 1.5% of modified concrete are shown vide fig 7.5 and vide table no: 4. From the above figures it may be observed that with the addition of aluminum oxide the cube compressive strength increases up to addition of 1% and with more addition of Nano Al_2O_3 the strength is decreased.

9.4 Influence of Nano Al_2O_3 on strain energy stored in slabs:

In the present study natural aggregate is fully replaced with Silica fume aggregates. The strain energy stored in slabs is increased continuously up to 1% addition of Nano aluminium oxide and afterwards it is decreased. The results are tabulated in table 5 and shown in fig 7.6.

10. Conclusions:

- The cube compressive strength of modified concrete with 100% replacement of natural aggregate by cold bonded Silica fume aggregate is 27.08 N/mm^2 which is more than the target mean strength of M_{20} concrete i.e., 26.60 N/mm^2.
- It is observed that the cube compressive strength of modified concrete with replacement of cement by 11% of its weight by three numbers of pozzolanic materials is increased to 28.13 N/mm^2 i.e., an increase of 3.88% over that of concrete without any replacement of cement.

- There is continuous increase in cube compressive strength with addition of Nano Al_2O_3 in percentage variations of 0.5, 1 on 11% of cement in addition to three numbers of pozzolanic materials and the strength is 34.22 N/mm^2 with 1% i.e., an increase of 26.40% and with more addition of Nano Al_2O_3 the strength is decreased to 27.50 N/mm^2

  - It is observed that with 1% of Nano Al_2O_3 and with constant 11% pozzolanic materials replacing the cement there is increase in first crack load, ultimate load, moment carrying capacity and strain energy stored in slabs and with further increase in Nano Al_2O_3 content there is decrease in all above values.
  - From the analysis of test results it is concluded that moment carrying capacity of slabs calculated from IS code is higher when compared with that calculated using Yield line theory.
  - The light weight concrete prepared by 100% Silica fume aggregate as coarse aggregate is no way inferior to the natural aggregate concrete and also consumption of cement can be reduced by about 11%.

11. References:

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