iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** IX **Month of publication:** September 2018

DOI:

Flexural Study on Slab Specimens of Modified Concrete using Light Weight Silica Fume Aggregate, Sintered Fly-ash Aggregate and Penta Blended Cement with Pozzolanic and Nano Materials

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Abstract: Aim of this project is to study the flexural properties of the modified M_{20} grade concrete by fully replacing coarse aggregate by Silica fume aggregate and Sintered fly ash aggregate in equal proportions. It is also proposed to replace 11% weight of cement with three numbers of pozzolanic materials like Silica Fume, Slag and Fly Ash along with varying percentages like 0, 0.5, 1 and 1.5% on 11% of weight of cement with two numbers of Nano materials i.e., Nano Silicon Dioxide (SiO_2) and Nano Aluminum Oxide (Al_2O_3) in equal proportions after 28 days of curing. It is also proposed to study variation of corresponding cube compressive strength of modified concrete.

Keywords: Silica Fume aggregates, Sintered fly ash aggregates, ACC 53grade cement, silicon dioxide, aluminum oxide, cube strength, flexural strength of slabs.

I. INTRODUCTION

Concrete is a material with its good strength and long life which has emerged as the predominant construction material for the infrastructure needs of the present situation. Due to the vast usage of concrete in this century, concrete ingredients are in depleting stage. There is an interest mounting up in handling of waste materials as different aggregates and significant research was performed on the use of many different materials as aggregate substitute such as silica fume aggregates and sintered fly ash aggregates which emerge to manufacture light weight concrete. There are many advantages gained from the use of lightweight concrete. These include lighter loads during construction, reduced self-weight in structures, and increased thermal resistance. Lightweight concrete is generally accepted as concrete having a density of about 1800 kg/m^3 or less.

The presence of Nano materials reduces the amount of cement content in concrete when compared to that of conventional concrete. The basic purpose of using Nano materials in concrete is to improve compressive and flexural strengths, it is possible due to the high surface to volume ratio. The Nano material densifies the cement matrix by increasing the C-S-H gel during the pozzolanic reaction of these materials. Also the Nano sized particle fills the voids in interfacial transition zone which is present between the cement and aggregate

II. LITERATURE REVIEW

Wasserman and Bentur [1] had shown that the strength of the concrete could not be accounted for by the strength of the aggregates only and it was suggested that the absorption and pozzolanic activity of the aggregates could have an influence on the strength developed. Alduaij et al. [2] studied lightweight concrete using different unit weight aggregate including lightweightcrushed bricks, lightweight expanded clay and normal weight gravel without the use of natural fine aggregate (no-fines concrete). They obtained a lightweight concrete with 22 MPa cylinder compressive strength and 1520 kg/m3 dry unit weight at 28 days.

Arvind Kumar & DilipKumar.[3], reported that the maximum compressive strength of 36.25 N/mm^2 was attained at 12% replacement of Sintered fly ash aggregate in concrete while the minimum strength of 26.68 N/mm^2 was attained at 20%

replacement. It is also reported that the maximum flexural strength of 4.95 $N/mm^2$was attained at 8% replacement, while the minimum strength of 2.75 N/mm^2 was attained at 20% replacement.

A.H. Shekari and M.S. Razzaghi,[4],reported that Nano particles can improve durability and mechanical properties of high performance concrete. The contribution of NA on improvement of mechanical properties of high performance concrete was more than the other Nano-particles .All of the examined Nano- particles had noticeable influence on improvement of durability parameters.

Nazari, et al [5], reported thatNano-Al2O3 particles blended concrete had significantly higher compressive strength compared to that of the concrete without Nano-Al2O3 particles. It is found that the cement could be advantageously replaced with Nano-Al2O3 particles up to maximum limit of 2.0% with average particle sizes of 15nm. Although the optimal level of Nano-Al2O3 particles content was achieved with 1.0% replacement. Partial replacement of cement by Nano-Al2O3 particles decreased workability of fresh concrete; therefore use of super plasticizer is substantial.

Zhenhua Li & HuafengWang(2014),[6] 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.

III. MATERIALS

The following materials were used for preparing the concrete mix.

1) ACC cement of 53grade
2) Fine aggregate i.e., sand
3) Coarse aggregate i.e. Silica fume aggregates and Sintered flyash aggregates
4) Flyash
5) Silicafume
6) Slag
7) Water
8) Nano materials i.e. aluminum oxide, silicon dioxide
9) Steel of HYSD 415grade

A. Cement

Ordinary Portland cement ACC 53 grade was used as binder. Some of the physical properties are presented in Table3.1.1

Table 3.1.1: properties of cement

S.No.	Property	Value
1	Normal consistency	30%
2	Fineness	5%
3	Specific gravity	3.26
4	Initial setting time Final setting time	50 minutes 460 Minutes

B. Fine Aggregate

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

C. Coarse Aggregates

1) *Silica fume aggregates:* Silica fume is a byproduct 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 pozzolana. 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 fig no:3.3.1 and the view of formed silica fume aggregates fig no:3.3.2.

Silica fume was procured from Ferro Silica Unit at Ahmadabad. The physical properties of Silica fume aggregate are shown below Table 3.3.1

Figure 3.3.1: Manufacture process of Silica fume aggregate

Figure 3.3.2: Silica fume aggregate

Table 3.3.1: 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

2) *Sintered fly ash aggregate:* The usual procedure of preparation of Sintered fly ash aggregates is by mixing of flyash with little amount of water and pellets are formed through the technique of agglomeration, pelletizing and then sintered at a temperature of 10000^0C to 12000^0C . These hard pellets can then be used as superior, consistent, lightweight aggregate which is up to 50% lighter than natural aggregate. These aggregates are generally black, brown or red in color depending on its chemical composition. Fig3.3.3 shows the sintered fly ash aggregates used in this study Sintered fly ash aggregates are procured from Litagg Company Ahmedabad was used in this investigation. Some of the physical properties are present in Table 3.3.2

Table 3.3.2: Physical properties of sintered fly ash aggregate (as supplied by the manufacturer)

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%

Figure 3.3.3 Sintered fly ash aggregate

D. Fly ash

The fly ash admixture was procured from Rayalaseema Thermal plant, Muddanur, AP. Some of the physical properties are presented in Table3.4.1

Table 3.4.1: Physical properties of fly-ash

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

E. Silica Fume

The silica fume admixture was procured ferro silica unit at Ahmedabad. Some of the physical properties are presented in Table3.5.1

Table 3.5.1: Physical 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

F. Slag

The source of slag is from Jindhal steel industries, Bellary, Karnataka. Some physical properties are presented in table 3.6.1

Table 3.6.1: Physical properties of Slag

S.NO.	Property	Test results
1	Specific gravity	2.86
2	Bulk density loosest state	600 kg/m^3
3	Bulk density compacted state	980 kg/m^3

G. Water

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

H. Nano Materials

1) *Nano silicon oxide:* Nano silica was procured from AVANSA technologies, KHANPUR. Some of the physical properties are presented in Table 3.8.1.

Table 3.8.1: Physical Properties of Silicon Dioxide (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	(SiO_2) Color	White
5	Bulk Density	<0.10 g/cm^3
6	True Density	2.4 g/cm^3

2) *Nano aluminum oxide:* Nano aluminum oxide was procured from AVANSA technologies, KHANPUR. Some of the physical properties are presented in Table 3.8.2

Table 3.8.2: Physical Properties of Aluminum Oxide (Al_2O_3) (As given by the supplier).

S.NO.	PROPERTY	VALUE
1	Purity	99.5%
2	APS	<20nm
3	SSA	20-80 m^2/g
4	(Al_2O_3) Color	White
5	Bulk Density	0.18g/cm^3
6	True Density	2.9g/cm^3

I. Reinforcement

All the slabs were reinforced with 8 mm diameter,Fe_{415} grade steel reinforcement, placed at 130 mm spacing in both direction at random

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IX, Sep 2018- Available at www.ijraset.com

IV. EXPERIMENTAL PROCEDURE

Table 1: Mix proportions

Mix	%Volume replacement of natural Coarse aggregate with Sintered fly ash & Silica fume aggregates in equal proportions	% of admixtures in equal Proportions (fly ash, silica fume powder, slag)	% of Nano Materials on 11% of Cement	%of cement	Number of cubes cast	Number of RCC slab specimens cast
S-0	100	0	0	100	3	3
S-1	100	11	0	89	3	3
S-2	100	11	0.5	88.945	3	3
S-3	100	11	1	88.890	3	3
S-4	100	11	1.5	88.835	3	3

The experimental program comprises of casting and testing of 15 no's of reinforced concrete two way slabs with uniformly distributed load and tested under simply supported end condition on all its four sides. The slab specimens are prepared with modified concrete using 100% cold bonded Silica Fume aggregate and Sintered flyash aggregate in equal proportions 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 and Nano Silicon dioxide in equal proportions 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

V. 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 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 moulds are shown in Fig. 5.1. 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 8 mm steel rods @ 130 mm c/c was kept, at the bottom of mould over 8 mm uses cover blocks. Then the remaining portion of entire mould is filled with freshly prepared concrete. The details of casting are shown in Fig 5.2. Initially dry mixture of cement, pozzolanic materials and Nano materials and sand was spread over the heap of coarse aggregate i.e., mixture of Cold bonded silica fume and sintered flyash aggregates. 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 was 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.

Figure5.1: Slab mould with reinforcement

Figure 5.2: Slab mould filled with concrete

VI. APPLICATION OF LOADING FRAME

The experiment consists of testing of square slabs, simply supported on all edges, under uniformly distributed loading. Load was applied to the top surface of the slabs by a hydraulic pump. From the jack load distributed to an iron plate with balls through I section simulate the uniformly distributed loading conditions as shown in Figure.6.2. The load applied to the slab through a distribution system also called "loading tree" or "load spreaders". This loading system was designed to spread the load to uniform all the points designed to allow for rotation and differential settlement of the supports. The beams were welded through a number of points that have the main purpose of ensuring the general stability of the spreaders and the safety of the persons conducting the testing. The main concern with regards to safety was related to the possibility of sudden slippage at great rotation of the load system in most of the cases between the loading jack and top of the main beam of the spreader. The spreaders were sitting on four 10mm thick steel plates. With this the effect of any irregularities of the slab surface can be eliminated. The loading sequence used was the same for all the samples tested. At the bottom face of slab specimen, a deflectometers with a least count of 0.01mm was placed at center and at all critical sections to record the deflections. The load at the first crack and the corresponding deflection at the bottom center and critical sections of the slab were recorded. The ultimate load and corresponding deflection at the center and critical sections were also observed and recorded for all the slab specimens

Figure 6.1: Arrangement of slab on simply supported condition

Figure 6.2: Testing of slab for flexural strength

VII. TESTING OF SPECIMEN

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 of Nano materials are given in table 3 below
2) *First Crack Load And Ultimate Load Of Slabs In Simply Supported Condition:* The load taken at which first crack formed on the bottom face of slab is called first crack load. The ultimate load was taken when the pointer in the proving ring goes in reverse direction. The values are presented in table 4.
3) *Moment Carrying Capacity Of Slabs At First Crack Load And Ultimate Load Based On Is Code Method:* According to IS code method of designing the moment carrying capacity calculated using the following formula

$$M=W*\alpha_x*L^2_x$$

Where M= Bending moment

For simply supported condition

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

The values are presented in table 4.

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 and equilibrium method

Moment carrying capacity for simply supported condition

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

Where

W= collapse load

L= Total length of slab

The values are presented in Table 4.

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

Table 3: Cube Compressive Strength

Mix proportions	Cube compressive strength in N/mm^2	Percentage increase of compressive strength w.r.t to S-0
S-0	28.76	0
S-1	30.20	5.00
S-2	34.60	20.03
S-3	36.11	22.07
S-4	31.16	8.34

Table 4: Moment carrying capacity of Simply Supported Slabs and strain energy stored in slabs.

Mix	At First Crack			At Ultimate Failure				
	Load (KN)	Moments (KN-m)		Load (KN)	Moments(KN-m)			Strain energy stored (KN-mm)
		by IS method	by Yield line theory		IS method	Yield line theory	% increase moments w.r.t yield line theory	
S-0	14.25	1.16	1.05	79.25	6.48	5.38	20.44	186.55
S-1	15.73	1.28	1.07	81.38	6.66	5.52	20.80	194.73
S-2	18.86	1.54	1.28	96.35	7.88	6.54	20.48	215.44
S-3	22.61	1.84	1.53	117.61	9.62	7.98	20.55	240.85
S-4	16.67	1.36	1.13	83.86	6.86	5.69	20.56	202.61

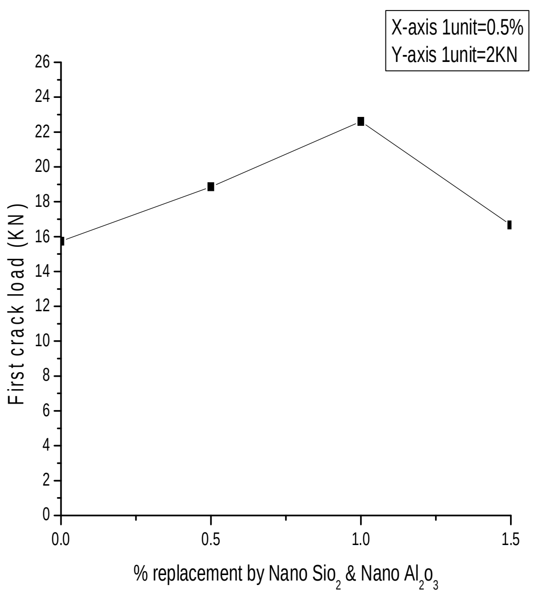

Fig7.1: First crack load Vs % replacement by NanoSio$_2$ & NanoAl$_2$o$_3$

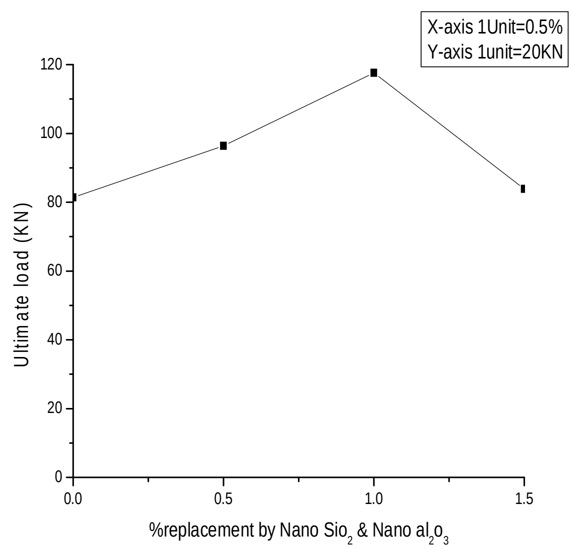

Fig7.2: ultimate load Vs %replacement by NanoSio$_2$ & Nano Al$_2$o$_3$

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IX, Sep 2018- Available at www.ijraset.com

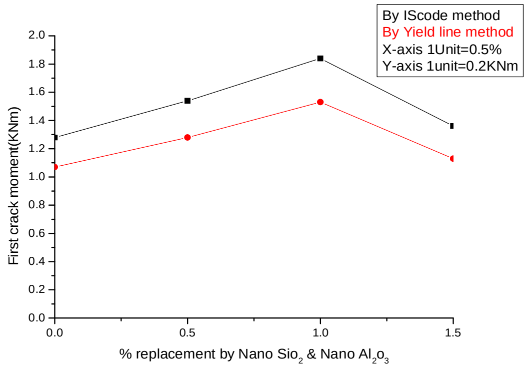

Fig7.3: Comparison of First crack moments as per IS Code and Yield Line theory

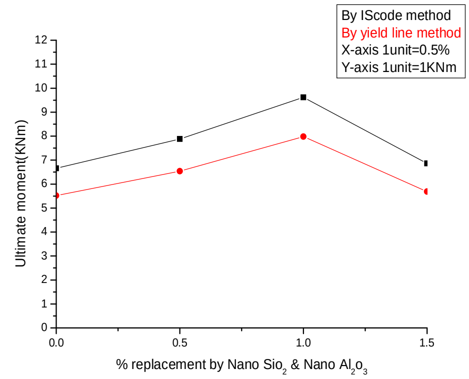

Fig7.4: Comparison of ultimate moments as per IS code & Yield Line theory

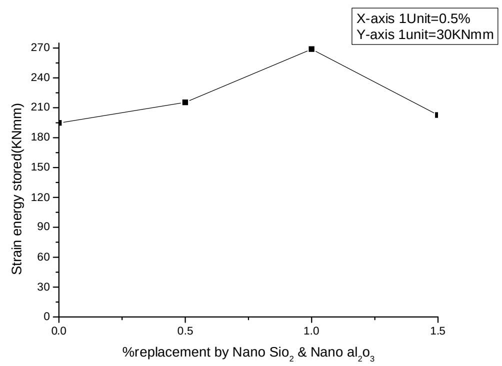

Fig 7.5: Strain energy stored Vs %replacement by Nano Sio_2 & Nano Al_2o_3

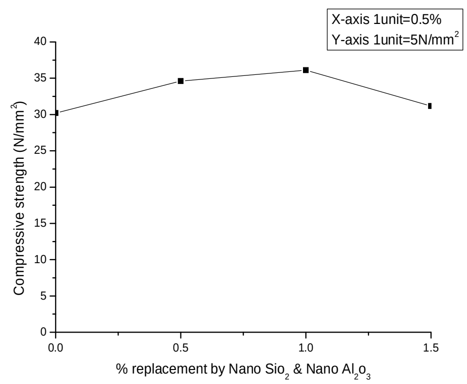

Fig 7.6: Compressive strength of cubes Vs % replacement by Nano Sio_2 & Nano Al_2o_3

VIII. DISCUSSION OF TEST RESULTS

1) *Influence Of Nano Sio_2, Al_2o_3 On First Crack And Ultimate Load In Two Way Slabs With Simply Supported End Condition:* In the present study natural aggregate has been fully replaced with Sintered fly ash aggregate and silica fume aggregate. The variation of first crack load and Ultimate load versus varying percentage addition of Nano $SiO_2$and Al_2O_3 in equal proportions at 0%, 0.5%, 1% and 1.5% on 11% of cement along with pozzolanic materials at 28 days are presented graphically vide fig 7.1 and fig 7.2. From the figures it may be observed that with addition of silicon dioxide & aluminum oxide, the first crack and ultimate loads are increased up to 1% and with more addition of Nano materials of SiO_2, and Al_2O_3 both these loads have been decreased. Hence 1% addition of nano materials is found to be optimum. The results are tabulated in table 4
2) *Influence of Nano SiO_2,Al_2O_3 on Moment carrying capacity of slabs at first crack load and Ultimate load in two way slabs with simply supported end condition based on IS code and Yield line theory:* In the present study natural aggregate is fully replaced with Sintered fly ash aggregate and silica fume aggregate in equal proportions. The moment carrying capacity of slabs is increased continuously up to 1% addition of Nano materials of SiO_2, and Al_2O_3 and afterwards it is decreased. Hence 1% addition of nano materials is found to be optimum. The results are tabulated vide table 4 and graphical representation is given vide fig7.3and fig7.4. Also the moment carrying capacity calculated using IS code method is found to be higher than that of using yield line theory approach.
3) *Influence Of Nano Sio_2, Al_2o_3 On Strain Energy Stored In Slabs:* In the present study natural aggregate is fully replaced with Sintered fly ash aggregate and silica fume aggregate in equal proportions. The moment carrying capacity of slabs is increased continuously up to 1% addition of Nano materials and there after the strain energy is decreased. Hence 1% addition of nano materials is found to be optimum. The results are tabulated vide table no 11 and represented graphically vide fig 7.5

4) *Influence Of Nano Sio$_2$, Al2o3 On Cube Compressive Strength:* In the present study natural aggregate has been fully replaced with Sintered fly ash aggregates, silica fume aggregate in equal proportions. The variation of compressive strength versus varying percentage addition of Nano SiO_2 and Al_2O_3 in equal proportions at 0%, 0.5%, 1% and 1.5% on 11% of cement along with replacement of cement with constant 11% of its weight with three numbers of pozzolanic materials i.e., Silica fume, Slag and Fly ash in equal proportions is presented in fig 7.6. From the above figures it may be observed that with the addition of silicon dioxide& aluminum oxide the cube compressive strength increases with addition up to 1% and with more addition of Nano SiO_2& Al_2O_3 the strength is decreased. Hence 1% addition of nano materials is found to be optimum. The results are tabulated vide table no 3 and represented graphically vide fig 7.6

IX. CONCLUSIONS

A. The target mean strength of M_{20}grade 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% replacement of natural aggregate by 50% Sintered fly ash aggregates & 50% Silica fume aggregates is 28.76 N/mm^2.
B. With the replacement of cement by 11% of three numbers of Pozzolanic materials i.e., Silica fume, fly ash and slag in equal proportions and 1% on 11% weight of cement by two numbers of Nano materials i.e., Nano SiO_2 and Nano Al_2O_3 in equal proportions the cube compressive strength rises to 36.11 N/mm^2 from 28.76 N/mm^2. The cube compressive strength is found to be optimum at 1% of nano materials added in this investigation.
C. Moment carrying capacity of slabs calculated at first crack load and ultimate loads, as per Yield line theory method is less when compared with those calculated using IS code method.
D. Moment carrying capacity of slabs is found to be optimum at 1.0% replacement by Nano silicon oxide and Nano aluminum oxide.
E. The strain energy stored in slabs is found to be optimum at 1.0% replacement of Nano silicon dioxide & Nano aluminum oxide i.e., 240.85KN-mm.
F. The light weight concrete prepared by combination of Sintered fly ash aggregates and Silica fume aggregates is no way inferior to M_{20} grade concrete with reduction in density of concrete with reduced consumption of cement by 11%.

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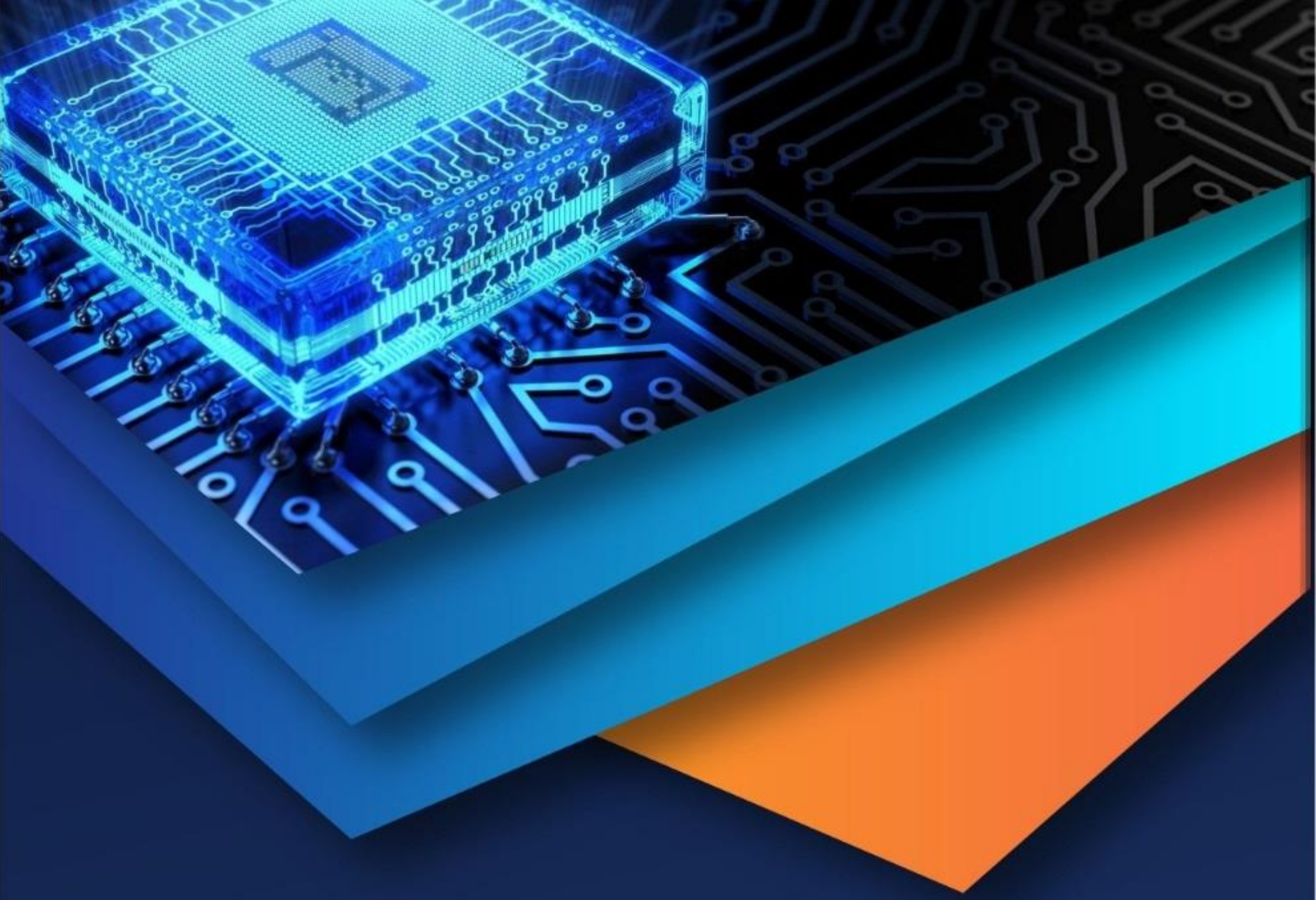

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