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Flexural Study on Slab specimens of Modified Concrete using Light Expandable Clay Aggregate, Sintered Fly-ash Aggregate and Hexa Blended Cement along with Pozzolanic & Nano Materials

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ABSTRACT:

In the present experimental work, an attempt is made to study Flexural properties of two way slabs with fixed end condition of M_{20} grade concrete by 100% replacement of natural coarse aggregate by two numbers of light weight aggregate i.e., sintered fly ash aggregate and Light Expandable Clay aggregate (LECA) 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 corresponding cube compressive strength of modified concrete.

Key words: Sintered fly ash aggregates, LECA, admixtures, ACC 53grade cement, silicon dioxide, aluminum oxide, cube strength, flexural strength of slabs and strain energy stored

1.INTRODUCTION:

The demand for construction space has been increased many folds with an increase in necessity of human beings. According to recent survey, the population density in world is around 54 persons per sq km, but in India it is around 400 persons per sq km and thus the developing country like India is having land scarcity. Hence vertical growth is preferred to horizontal growth, since more and more people are moving into urban areas which leads to lot of land crunch. This land crunch and load increase demands the use of light weight structural concrete. The light weight structural concrete helps in decreasing the load as the density is reduced substantially from ranges of 2400kg/cubic meter to 1800kg/cubic meter. It is ideal for roof deck repairs, stair pan fill, elevated floor slabs or over lays on existing floor decks. With the increase of construction works, there is an increase in demand of light weight concrete due to its improved strength.

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 waste fly ash which results from burning coal from Thermal plants. This problem is growing especially very severe in India, the world's second largest coal consumer, which produces an estimate of 150 million tons of fly ash per annum and the waste fly ash can be converted into structural light weight aggregate, a product which can be used to replace mined stone aggregate in concrete. However lack of technology and absence of market have dissuaded Indian entrepreneurs from producing sintered fly ash aggregates.

Light expandable clay aggregates or LECA are formed from special plastic clay that is fired in a rotary kiln at 1200^0C. The yielding gases expand the clay by thousands of small bubbles formed during heating which produces a honeycomb structure. It also has good sound insulation, fire resistance and even resists against acidic and alkaline substances,easy movement and transportation, lightweight backfill and finishing, reduction of construction dead load and earthquake lateral load, perfect sweet soil for plants, material for drainage and filtration.

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 at early age; 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 with calcium hydroxide. Also the Nano sized particle fills the voids in interfacial transition zone which is present between the cement and aggregate.

2. LITERATURE REVIEW:

R Anil Kumar et.al.,(2015) (1) Presented experimental investigation on the modified M_{20} grade concrete with 100% replacement of natural aggregate by blending with two numbers of light weight aggregates such as Cinder and Leca in various proportions and found that modified concrete made with 60% Cinder and 40% Leca had an compressive strength of 28.89 N/mm^{2}and tensile strength of 1.67 N/mm^2 and when 20% cement was also replaced by GGBS the compressive strength was increased to 30.68 N/mm^2.

Anju Ramesan, et.al., (2015) (2) investigated the possibility of preparation of plastic aggregates of 20mm size and to study strength properties of modified concrete by replacing natural aggregates by these plastic aggregate and found that optimum percentage replacement of natural aggregate was 30% and found that compressive strength was increased by 9.4% and Split tensile strength by 39%.

Serkan Subasi (2009) (3) investigated the effect of using fly ash in high strength light weight aggregate concrete produced with expanded clay aggregate on physical and mechanical properties of the concrete with cement content of 350, 400 and450Kg/m^3 along with replacement of cement by Fly ash in various proportions of 0, 10, 20 and 30% . It was seen that concretes with 450 Kg/m^{3}cement content and with 10% fly ash replacement had the better results and achieved high strength concrete with a strength of approximately 45 Mpa.

Arvind Kumar & DilipKumar.,(4) 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.

Payam Shafigh and et.al (2011) (5) investigated flexural behavior of reinforced light weight concrete beams made from light weight expanded clay aggregate (LECA) and the experimental results suggest that the ultimate moment of beams made with LECA light weight concrete could be predicted satisfactorily using the equation provided by the ACI code 318 building code.

V. Khonsari and et.al (2010) (6) investigated strength properties of modified concrete by partial replacement of natural aggregate by expanded Perlite by various percentages along with effect of steel and polypropylene fibres. Stress- Strain curves of Perlite concrete were also prepared.

G.Campione and et. al. (2001) (7) investigated mechanical properties of steel fibre reinforced light weight concrete manufactured using Pumice stone or expandable clay aggregate and found that the addition fibres increases the brittle behavior of light weight Concrete and also found that Compressive strength of LECA Concrete was increased while no variation was observed for Pumice stone aggregates.

From the brief literature survey conducted here it appears that much less attention has been paid earlier on the study of concrete modified with artificial aggregate i.e., Light weight Expandable Clay aggregate, Sintered Fly ash aggregate with hexa blended cement along with Nano materials such as *Nano* SiO_2, Al_2O_3in combination of active pozzolanic material such as Silica fume, Fly Ash and Slag. Hence the present investigation has been under taken.

3. OBJECTIVES:

Based on the literature review conducted, following are the main objectives of the present work.

- To compare the moment carrying capacity of RCC slabs made by replacing the natural aggregate by Sintered fly ash and LECA aggregates with that of normal conventional concrete.
- Determining of solution for disposal of industrial wastes hazardous to environment as a useful material in the construction industry.

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 and LECA
4. Fly ash
5. Silica fume
6. Slag
7. Water
8. Nano materials i.e. aluminum oxide, silicon dioxide
9. Steel of HYSD 415 grade

4.1Cement: Ordinary Portland cement ACC 53 grade was used as binder. Some of the physical properties are presented in table 1.

Table 1: properties of cement

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

4.2 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].

4.3 Coarse Aggregates:

- **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. Plate 1 shows the sintered fly ash aggregates used in this study.

Sintered fly ash aggregate procured from Litagg Company Ahmedabad was used in this investigation. Some of the physical properties are presented in table 2.

Table 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%

Plate1: sintered fly ash aggregates

- **Light weight Expandable Clay aggregate (LECA):**

It is the special type of aggregate which is formed from special plastic clay by pyroclastic process that is fired in rotary kiln at 1200^0C. The yielding gases expand the clay by thousands of small bubbles forming during heating produces a honeycomb structure. Since it is exposed to high temperature, the organic compounds burn, as a result the pellets expand & form a honeycombed structure. The resulting ceramic pellets are lightweight, porous and have a high crushing resistance. It is environmental friendly, entirely a natural product incorporating same benefits as tile in brick form. LECA is non destructible, noncombustible & impervious to attack by dry-rot, wet-rot & insects. Plate 2 shows the LECA used in this study.

Typical physical characteristics of LECA aggregates procured from Nexus Buildcon Solution Company, Ahmedabad used in this investigation are presented in table 3.

Table 3: Typical physical characteristics of LECA

S.NO.	PROPERTY	VALUE
1	Specific gravity	1.18
2	Aggregate Size mm	10-12mm
3	Bulk Density	645kg/m^3
4	Shape	Round pellets

Plate2: light weight expandable clayaggregate

4.4 Fly ash: The fly ash admixture was procured from Rayalaseema Thermal plant, Muddanur. Some of the physical properties are presented in Table 4.

Table4: Physical properties of fly-ash

S.NO.	PROPERTY	VALUE
1	Specific gravity	2.7
2	Fineness (retained on 90 micronsieve)	0%
3	Bulk density in loosest state	800 kg/m^3
4	Bulk density in densest state	960 kg/m^3

4.5 Silica Fume: The silica fume admixture was procured ferro silica unit at Ahmedabad. Some of the physical properties are presented in Table 5.

Table 5: 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

4.6Slag: The source of slag was from Jindhal steel industries, Bellary. Some of the physical properties are presented in Table 6.

Table 6: 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

4.7 Water: The 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.

4.8 NANO MATERIALS

- **Nano silicon dioxide (SiO_2):**
  Nano silica was procured from AVANSA technologies, KHANPUR. Some of the physical properties are presented in Table 7.

Table 7: Physical Properties of Silicon Dioxide (SiO_2), (As supplied 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

- **Nanoaluminum oxide (Al_2O_3):**

Nano aluminum oxide was procured from AVANSA technologies, KHANPUR. Some of the physical properties are presented in Table 8.

Table 8: Physical Properties of Aluminum Oxide (Al_2O_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

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

5.Experimental Procedure:

The experimental program comprises of casting and testing of 15 numbers of reinforced concrete slabs and 15 numbers of cubes made up of modified concrete by replacing 100 % natural aggregate with sintered fly ash aggregate and LECA in equal proportions along with replacement of cement with 11% of its weight by 3 nof pozzolanic materials i.e. fly ash, slag and silica fume in equal proportions. Varying percentages of two numbers of Nano materials i.e., Nano Silicon dioxide and Nano Aluminum oxide in equal proportions i.e., 0, 0.5, 1, and 1.5on 11% of cement were used in the investigation. The two way slabs were tested with fixed end condition on all its four sides and under udl after 28 days of curing. All the slabs were of square in shape and are of size 600 × 600 × 50 mm. The slabs were white washed for easy identification of crack patterns and placed over the platform for testing. To simulate the fixed supported edge condition, plates were fixed on all the four sides of the slab through nuts and bolts in order to prevent any rotation and any differential settlement. The various mix proportions used are presented in Table 9.

3 numbers of cube specimens 150x150x150 mm were also cast for the corresponding proportions of cement concrete to find out the compressive strength simultaneously.

Table 9 : Mix proportions.

Mix	%Volume replacement of natural Coarse aggregate with Sintered fly ash & LECA in equal proportions	%of admixtures in equal proportions	%of Nano Materials on 11% of cement	%of cement	Number of cubes cast	Number of rcc slab specimens cast
PBK-0	100	0	0	100	3	3
PBK-1	100	11	0	89	3	3
PBK-2	100	11	0.5	88.945	3	3
PBK-3	100	11	1	88.890	3	3
PBK-4	100	11	1.5	88.835	3	3

6. Casting of specimens:

The M_{20} concrete mix design was used, which gives a mix proportion of 1:1.49:2.88 with water cement ratio of 0.50. Five different mixes were used as designated in table no.9. Steel moulds were used to cast the slab specimens of required size. Two L-shaped frames with a depth of 50 mm which 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 from slab specimens. The moulds are shown as in Plate 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 concrete. In case of hand mix dry mixture of cement, pozzolanic and Nano materials were weighed exactly as per their proportions and are mixed thoroughly along with sand and the mixture was spread over the heap of blended light weight aggregates. Hand mixing was done after adding required quantity of water to achieve uniform mix and to prevent any 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 water ponds. After removing the slab specimens from the curing pond, they were allowed to dry under shade for a while and then white washing was done on both sides, for 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.

Plate 3: slab mould with reinforcement

Plate 4: slab mould filled with concrete

7. Structural Loading Frame and Platform:

The steel 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 is stiff enough to support the loading without significant deformations. The loads acting vertically from the top, is in the same way as its own weight and dead loads are acting. Detailing and structural design for steel members and .connections were done according to the Indian Standards IS- 800:1984.

8. Application of load and loading sequence:

The experiment consists of testing of square slabs, supported on all its four sides with fixed end supports, under uniformly distributed loading. The slab specimen was placed over a clear opening of 470mm x 470mm. Plates were fixed on all the four sides of the slab through nuts and bolts in order to prevent any rotation and any differential settlements. Load was applied to the top surface of the slabs by a hydraulic pump through 25 tons recalibrated proving ring at regular intervals .This point load was transmitted to the entire slab specimen through a series of I-sections placed on a flat plate welded with a series of iron balls to transfer the load as uniformly distributed load

This plate was placed over the slab specimen in inverted position with iron balls touching the surface as shown in Plate 5, Plate:6 , Plate:7. At the bottom face of slab specimen, a deflectometers with a least count of 0.01mm were placed at centre and 2nos each along the two 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.

Plate 5: Slab Testing Machine with Fixed Plates

Plate 6: Slab Testing Machine

Plate 7: Testing arrangement of slabs for Flexure strength

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9. Testing of specimens:

9.1 Compressive strength of cubes: Compressive strength of cubes is calculated by dividing load taken by the specimen by the cross sectional area. Values of compressive strength at different percentages of Nano silicon dioxide and Aluminum oxide are given vide table 10 below.

9.2 First crack load and ultimate load of slabs in fixed supported condition: The load which is recorded under the occurrence of first crack on the bottom face of slab is called as first crack load. The total number of proving ring readings obtained till the deflectometer deflects in reverse direction reducing its value is called as ultimate load of slab. Cracks propagate from bottom to top face of the slab. The values are presented in table 11.

9.3 Moment carrying capacity of slabs at first crack load and ultimate load based on IS code(8) method: According to IS code method of design the moment carrying capacity of a slab calculated using the following formula

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

Where M= Bending moment.

W=ultimate load carrying of slab.

For restrained supported condition $\boldsymbol{\alpha_x}$**=0.056**(moment coefficient from IS code:456:2000)

$\mathbf{L_x}$**=**Effective length of slab

The values are presented in table 11.

9.4 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 is calculated by following formulas derived from combined process of Virtual work done method and equilibrium method

Moment carrying capacity for supported condition

$$M_y=\frac{WL\,2}{48}$$

Where W= collapse load

L= Total length of slab

The values are presented in table 11.

9.5 Strain energy stored in slabs: The energy absorption is defined as the area under the load-deflection curve. The values are determined from test results, and are listed in Table 11.

Table 10: Cube Compressive Strength

Mix proportions	Cube compressive strength in N/mm^2	Percentage increase of compressive strength w.r.t to PBK-0
PBK-0	29.28	0
PBK-1	31.17	3.96
PBK-2	34.34	17.28
PBK-3	38.029	29.89
PBK-4	32.90	12.36

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Table 11: Moment carrying capacity and Strain energy stored in slabs with fixed end condition on all its four sides

Mix	%Volume Replacement of coarse Aggregate with Sintered Fly ash Aggregate	First crack load(KN)	First crack moment as per IS code (KN-m)	Ultimate load (KN)	Ultimate Moment as per IS code (KN-m)	Ultimate Moment as per Yield line theory (KN-m)	Strain energy stored in slab (KN-mm)
PBK-0	100	23.85	1.82	101.35	7.77	0.80	142.86
PBK-1	100	26.97	2.06	104.47	8.01	0.91	184.00
PBK-2	100	35.75	2.74	116.97	8.97	1.21	208.21
PBK-3	100	46.35	3.55	129.47	9.92	1.57	254.50
PBK-4	100	38.22	2.93	121.35	9..30	1.29	212.79

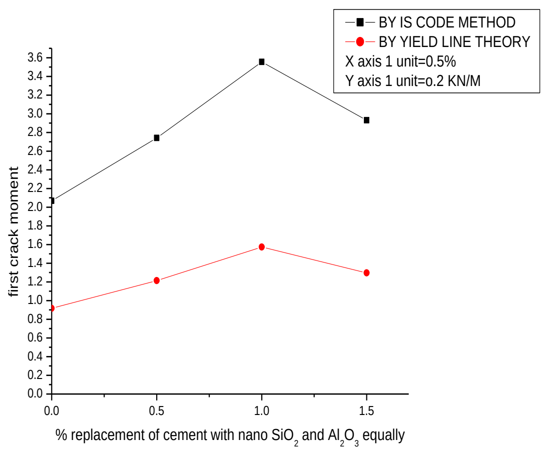

Fig11.1:Variation of first crack Moments Versus percentage replacement of SiO_2, and Al_2O_3 .

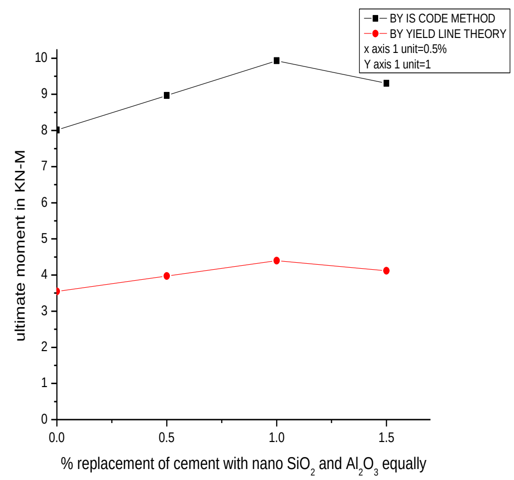

Fig11.2:Variation of ultimate load Moments versus percentage replacement of SiO_2, and Al_2O_3 .

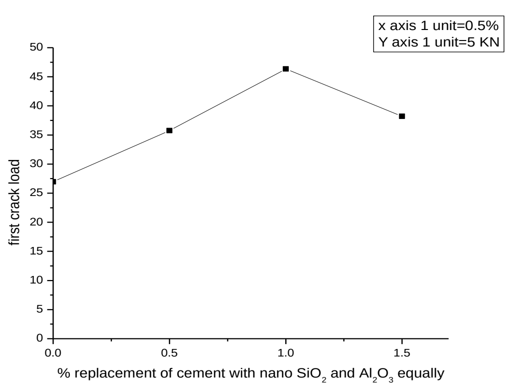

Fig 11.3: Variation of First crack Load Versus percentage replacement of SiO_2, and Al_2O_3 .

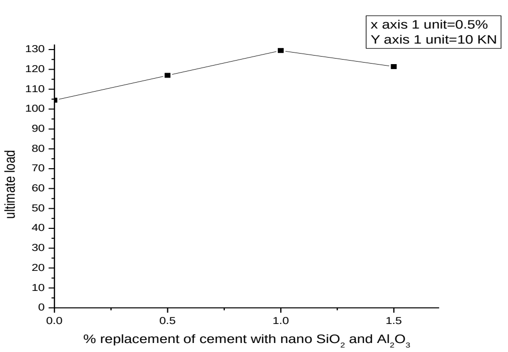

Fig 11.4: Variation of ultimate crack Load Versus percentage replacement of SiO_2, and Al_2O_3 .

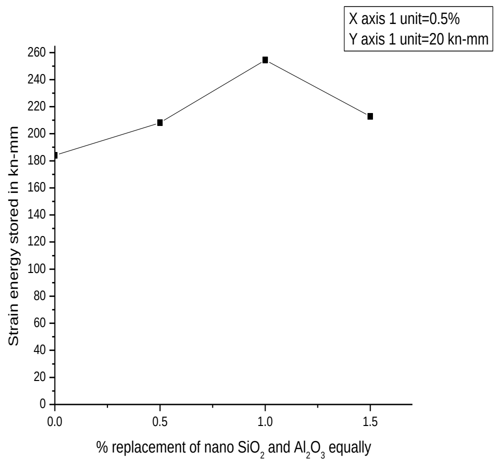

Fig11.5: Variation of Strain energy Versus percentage replacement of SiO_2, and Al_2O_3 .

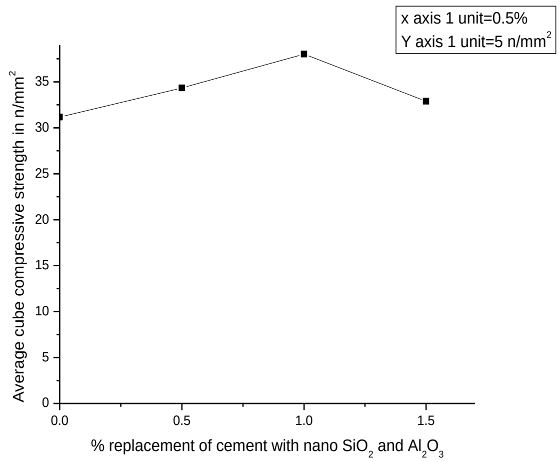

Fig11.6: Variation of Compressive strength Versus percentage replacement of SiO_2, and Al_2O_3 .

10. Discussion of test results

10.1 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 fixed 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 LECA 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. The results are tabulated vide table 11 and graphical representation is given vide fig 11.1 and fig 11.2.Also the moment carrying capacity calculated using IS code method is found to be higher than that of using yield line theory approach.

10.2 Influence of Nano SiO_2, Al_2O_3 on First crack and Ultimate load in two way slabs with fixed end condition: In the present study natural aggregate has been fully replaced with Sintered fly ash aggregate and LECA. 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 11.3 and fig 11.4. From the figures it may be observed that with addition of silicon dioxide & aluminum oxide, the first crack and ultimate load is increased up to 1% and with more addition of Nano materials of SiO_2, and Al_2O_3there after both these loads are decreased. The results are tabulated in table 11.

10.3 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 LECA in equal proportion. The moment carrying capacity of slabs is increased continuously up to 1% addition of Nano materials and there after the strain energy is decreased. The results are tabulated vide table no 11 and graphically vide fig 11.5.

10.4 Influence of Nano SiO_2,Al_2O_3 on cube compressive strength: In the present study natural aggregate has been fully replaced with Sintered fly ash aggregates, LECA in equal proportions. The variation of compressive strength versus varying percentage addition of Nano SiO_2 and Al_2O_3at 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 11.6. 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. The results are tabulated in table 10.

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11. CONCLUSIONS:

The following conclusions are drawn based on the experimental results.

1) 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 50% Sintered fly ash aggregate and 50% LECA in equal proportions is 29.28 N/mm^2 and with replacement of cement by 11% of its weight with three numbers of pozzolanic materials i.e., Silica fume, Slag and Fly ash in equal proportions and with addition of 1% of Nano SiO_2 & Al_2O_3on 11% of weight of pozzolanic materials, the cube compressive strength of modified concrete rises to 38.029 N/mm^2. With more addition of Nano materials of SiO_2 &,Al_2O_3 materials i.e., 1.5% the strength is decreased.

2)The moment carrying capacity of slabs is found to be optimum with 1% addition of nano materials.

3) From the analysis of test results it is concluded that moment carrying capacity of slabs calculated from IS code is higher compared to Yield line theory.

4) Blended light weight aggregates with Sintered fly ash aggregate and LECA in can be viewed as better replacement for normal aggregates and thus the demand of natural aggregates can be reduced to an appreciable extent.

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