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Some studies on the Strength Properties of Concrete Modified with Light Expandable Clay Aggregates and Hepta Blended Cement Along with Pozzolanic & Nano materials

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Abstract: One of the disadvantages of conventional concrete is the high self-weight of concrete. Attempts have been made in the past to reduce the self-weight of concrete along with to increase the efficiency of concrete as a structural material. Here an attempt is made to study the strength properties of modified M_{20} grade concrete with 100% replacement of conventional natural aggregates by Light expandable clay aggregates (LECA) along with replacement of cement with three numbers of pozzolanic materials i.e., Silica fume, slag and fly ash in equal proportions along with varying percentages of Nano TiO_2 in spells of 0, 0.5,1 and 1.5% on 11% of pozzolanic materials. After 28 days various tests were carried out on the modified concrete with hepta blended cement i.e., compressive strength test, flexural strength test, modulus of elasticity, impact value, in-plane shear strength through mode-II fracture test. The results are observed to be quite promising.
Keywords: Light Expandable Clay Aggregates, admixtures, Acc 53 grade cement, Titanium dioxide, various tests

I. INTRODUCTION

Light weight concrete using artificial aggregates has become popular in recent years due to the tremendous advantages it offers over the conventional concrete. Modern technology and a better understanding of the concrete have helped much in promotion and use of light weight concrete. A particular type of light weight structural light concrete is the one which is comparatively lighter than the conventional concrete and at the same time strong enough to be used for structural purposes. In some countries the natural dense graded aggregates are either in short supply or available at a considerable distance from industrial cities. In such cases the use of locally produced light weight aggregates in the city area offers more economic solutions. These factors have lead to the development and widespread use of considerable varieties of industrial light weight aggregates of varying quality by trade names such as LECA (Expanded clay), Aglite (expanded shale).etc,

Production of cement involves significant contribution to environmental pollution and approximately 7% of the world's Carbon Dioxide emission is attributable to the production of Portland cement and also consumes natural resources like lime stone etc., and there is a need to economise the use of cement. One of the practical solutions to economise consumption of cement is to replace cement with supplementary cementitious materials like Silica fume, Slag and Fly ash which are also industrial wastes. Production of artificial aggregate using industrial waste also gives an alternate vent for effective disposal which are otherwise causing air pollution due to their fineness.

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. It also helps to improve the pore structure of concrete. Nano materials also reduce porosity as they absorb less water compared to traditional cementitious materials.

II. REVIEW OF LITERATURE

T. Parhizkar, et.al (2011) [1] presented on experimental investigation on the properties of volcanic pumice lightweight aggregates concretes. To this end, two groups of lightweight concretes (lightweight coarse with natural fine aggregates concrete and lightweight coarse and fine aggregates concrete) were built and the physical/mechanical and durability aspects of them were studied. The results of compressive strength, tensile strength and drying shrinkage showed that these lightweight concretes meet the requirements of the structural lightweight concrete.

N. SivalingaRao, et.al (2013) [2] studied on Fibre Reinforced Light Weight Aggregate (Natural Pumice Stone) Concrete. In their study, the mix design was M20 and the test results are as follows: More than the target means strength of M20 concrete is achieved with 20 percent replacement of natural coarse aggregate by pumice aggregate and with 1.5 percent of fibber. Also with 40% pumice and with 0.5% of fibers average target mean strength of M 20 concrete can be achieved.

In the study of Luciano senffet.al, [3] amorphous Nano silica particles were incorporated in cement pastes and mortars and their effect on fresh properties was analysed.

Prakash Desai, et.al [4]arrived at double central notched specimen geometry which fails in predominant Mode-II failure; they also made fin ite element analysis to arrive at stress intensity factor. Using this DCN geometry lot of experimental investigation using cement paste, mortar, and plain concrete was done. Details of this geometry are presented in Plate 2.1.

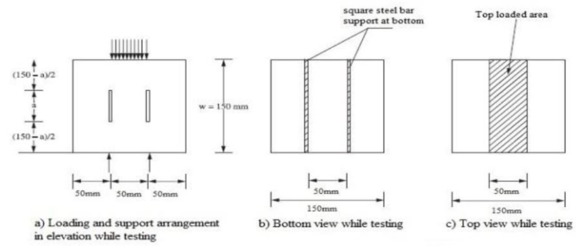

Figure.1. Details of DCN specimen geometry

Swamy R.N& Lambert G.H (1984) [5]studied about the light weight aggregate and proved that the thermal efficiency is very much more to the light weight concrete and the load carrying capacity of the light weight concrete is same as the normal concrete by using some mineral and chemical ad mixtures.

Abdul Rahim and Sandanu. R. Nair [6] investigated the influence of Nano materials with replacement of cement from 2 to 6% by Nano SiO_2, Nano Al_2O_3 and Nano TiO_2 along with replacement of cement by 40% GGBS on M_{60} grade concrete and found that optimum dosage of Nano SiO_2, Nano Al_2O_3 is 3% where as for Nano TiO_2 it is at 4%. Nano material when mixed along with concrete results in less porous and impermeable concrete. The decrease in mechanical properties after the optimum dosage is due to the excess quantity of Nano material present in the concrete than the quantity which is required for combining with liberated lime produced during hydration and therefore the excess silica leaches out leading to the decrease in strength of concrete.

T. Sonia and R. Subhashini [7] investigated mechanical properties of light weight concrete M_{25} mix with partial and 100% replacement of natural aggregate with various percentage such as 20, 40, 60, 80 and 100 along with replacement of cement with ash at various percentage such as 15, 20 and 25% and found that optimum replacement of cement was 15% fly ash and 40% replacement of natural aggregates with LECA.

From the brief literature summary conducted here it appears that much less attention has been paid earlier on the study of concrete modified with artificial aggregate such as LECA aggregate with hepta blended cement along with Nano material such as Nano TiO_2in combination of active pozzolanic material such as Silica fume, Fly Ash and Slag. Hence the present investigation has been under taken.

III. OBJECTIVE

A. Determining solution for disposal of industrial wastes which are which are hazardous to environment as a useful material in the construction industry.

B. By replacing coarse aggregate in concrete with light weight aggregate to produce light weight concrete.

IV. 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 Light expandable clay aggregates (LECA)
4) Fly ash

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5) Silica fume
6) Slag
7) Water
8) Nano Titanium dioxide(Tio2)

A. Cement

ACC 53 grade cement with specific gravity 3.26 was used as binder.

S.No	Name of the material	Properties Of Material	
1	cement	Specific gravity	3.26
		Initial setting time	50 minutes
		Final setting time	460 minutes
		Normal consistency	30%
		Fineness of cement	5%
2	Fine aggregate	Specific gravity	2.54
3	Coarse aggregate (Light Expandable Clay Aggregate)	Specific gravity	1.18

B. Light Expandable clay aggregates

Leca is an acronym term for (Light Expandable Clay Aggregate) which is produced in rotary kiln at about 1200 degree centigrade. The base material is plastic clay which is extensively preheated. Light Expandable Clay Aggregate is procured from Nexcus Buildcon Solution, India.

Specific gravity : 1.18
Aggregate Size mm : 10-12mm
Bulk Density : 645kg/m^3
Shape : Round pellets

C. Water

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

D. Pozzolanic materials

1) Fly ash

The fly ash admixture was procured from Rayalaseema Thermal plant, Muddanur. The test results were shown as below.

Properties of Fly ash Property	Test results
Specific gravity	2.7
Fineness (Retained on 90 micron Sieve)	0%
Bulk density in loosest state	800 kg/m3
Bulk density in densest state	960 kg/m3

2) Silica Fume

The silica fume admixture was procured from Ferro silica unit at Ahmadabad. The test results are shown below.

a) Properties of Silica fume

Property	Test results
Specific gravity	2.1
Fineness (Retained on 90 micron Sieve)	0%
Bulk density in loosest state	420 kg/m^3
Bulk density in compacted state	700 kg/m^3

3) Slag

The source of slag was from Jindhal steel industries, Bellary. The test results are shown below.

a) Properties of Slag

Property	Test results
Specific gravity	2.86
Bulk density in loosest state	600 kg/m^2
Bulk density in compacted state	980 kg/m^3
Fineness (Retained on 90 micron Sieve)	0%

E. Nano Materials

1) Nano Titanium Dioxide (Tio_2)

The interest in use of titanium dioxide in construction materials stemmed initially from its white colour and therefore for its ability to be used in a wide range of products and applications. It is a naturally occurring oxide of titanium. It has a wide range of applications from paint to sunscreen to food colouring. Generally it is sourced from ilmenite, rutile and anatase. The use of Nano titanium oxide gives favorable results by increasing compressive strength and tensile strength of concrete. An experimental study was carried out by replacing the cement with Nano titanium oxide in the proportion of 0.5%,1% and 1.5% on 11% weight of cement. Nano Titanium dioxide is procured from AVANSA technologies, KHANPUR. The results are shown below.

2) Physical Properties of Nano TiO_2:

Purity: 99.9%
SSA: 289 m^2/g
Color: White.
Bulk Density: 0.12-0.18 g/cm^3
PH: 5.25-7.3

V. CASTING OF SPECIMENS

The M20 concrete mix was designed using ISI method which gives a mix proportion of 1:1.58:2.88 with water cement ratio of 0.50. Four different mixes were adopted which are designated as follows.

Name of mix	%volume replacement of coarse aggregate (Light Expandable Clay Aggregate)	%of admixtures in equal proportions	% of Nano (Tio_2)on 11% of cement	% of cement
BN0	100	0	0	100
BN1	100	11	0.5	88.945
BN2	100	11	1	88.890
BN3	100	11	1.5	88.835

To proceed with the experimental program initially steel moulds of size 150x150x150 mm were cleaned brushed with machine oil on all inner faces to facilitate easy removal of specimens afterwards. First fine aggregate and cement along with admixtures silica fu me, slag, fly ash and Nano Titanium dioxide in required percentages were mixed thoroughly and Light Expandable Clay aggregates were added to them. All of these were mixed thoroughly by hand mixing. For each mix three normal 150X150X150mm cube specimens along with 12 No. of DCN specimens were cast with replacement of cement by 11% of its weight by pozzolanic materials (Silica fu me, fly ash and Slag) and the combination of Nano Titanium dioxide in equal proportions with varying percentages (0%, 0.5%, 1%, and 1.5%) on 11% weight of cement. In addition, for each mix three numbers of 500mmX100mmX100mm beams were cast to know the flexural strength. The concrete was poured into the moulds in three layers with each layer being compacted thoroughly with tamping rod 25 times each time to avoid honey combing. Finally, all specimens were kept on the table vibrator after filling up the moulds up to the brim. The vibration was effected for 7 seconds and it was maintained constant for all specimens and all other castings. The steel plates forming notches were removed after 3 hours of casting carefully and neatly finished. After 28 days of curing the specimens were taken out of water and were allowed to dry under shade for few hours.

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VI. TESTING OF SPECIMENS

A. 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 Titanium dioxide are given in table 1 below.

B. Flexural Strength

Flexural strength is one measure of the tensile strength of the concrete. It is a measure of an unreinforced concrete beam to resist failure in bending. The flexural strength test was done by standard test method of two-point loading. In this study, three beams of size 100x100x500 mm were used to find the flexural strength. The flexural strength of beam results are tabulated in table 2 and the values are presented in figure 2.in graphical form.

C. Cylinder Compression Test

In this test the cylindrical specimens were kept vertically so that its axis was vertical between the compressive plates of the 3000KN digital compression testing machine. Narrow strips of the packing material i.e., plywood was placed between the plates and the cylinder to receive compressive stress. The load was applied uniformly until the cylinder fails, by cracks occur on vertical sides takes place. Compressive strength results of cylinders are tabulated in table 3 and values are presented graphically in fig.3

D. Modulus of elasticity

The theoretical modulus of elasticity was calculated using IS code formula.

$E=5000*\sqrt{f_{ck}}$ (8) Where,

f_{ck}= Characteristic Compressive strength of concrete in N/ mm^2 The modulus of elasticity values were also calculated from the other empirical formula suggested by Takafumi for light weight concrete.

$E=k_1k_2*1.486*10^{-3}*f_{ck}\,⅓*\gamma^{2}$(9)

Where f_{ck} = Compressive strength in N/mm2, γ = Density in Kg/m^3, K_1 =0.95 (correction factor corresponding to coarse aggregate)' K_2 =1.026, (correct ion factor corresponding to mineral ad mixtures)

E. Mode II fracture test

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

1) In-Plane shear strength: The in plane strength of modified concrete was calculated using the formula

In plane shear strength = P/2*d (d-a) N/mm2Where P= Ultimate load in mode-II shear d= size of the cube= 150mm a= depth of notch

The values of plane shear strength of modified concrete for various a/w ratios in mode-II shear are presented in Table 8 and values are presented graphically in fig.7

Table1: Compressive strength of cubes

Mix	% Volume replacement of coarse aggregate	% of admixtures in equal proportions	% of Nano Nano (TiO_2) on 11% of cement	% of cement	Cube compressive strength in N/mm2	Percentage increase or decrease of compressive strength
BN0	100	0	0	100	24.06	0.0
BN1	100	11	0.5	88.945	24.80	3.1
BN2	100	11	1	88.89	25.23	4.9
BN3	100	11	1.5	88.835	24.03	-0.1

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Table 2: Compressive strength of Cylinders

Mix	% Volume replacement of coarse aggregate	% of admixtures in equal proportions	% of Nano Nano (TiO_2) on 11% of cement	% of cement	Cylinder compressive strength in N/mm2	Percentage increase or decrease of compressive strength
BN0	100	0	0	100	17.429	0.0
BN1	100	11	0.5	88.945	17.957	3.1
BN2	100	11	1	88.89	19.561	12.23
BN3	100	11	1.5	88.835	17.674	1.41

Table 3: Flexural strength of beams

Mix	% Volume replacement of coarse aggregate	% of admixtures in equal proportions	% of Nano Nano (TiO_2) on 11% of cement	% of cement	Flexural strength in N/mm2	Percentage increase or decrease of flexural strength
BN0	100	0	0	100	1.6971	0.00
BN1	100	11	0.5	88.945	1.8237	7.46
BN2	100	11	1	88.89	2.1190	24.86
BN3	100	11	1.5	88.835	1.5706	-7.46

Table 4 Modulus of elasticity

Mix	% Volume replacement of coarse aggregate	% of admixtures in equal proportion	% of Nano (TiO_2) on 11% of cement	% of cement	Modulus of elasticity in N/mm^2		Percentage increase or decrease of modulus of elasticity
					IS code formula	Empirica l formula	
BN0	100	0	0	100	2.453	1.45	0
BN1	100	11	0.5	88.945	2.490	1.49	1.53
BN2	100	11	1	88.89	2.511	1.62	2.40
BN3	100	11	1.5	88.835	2.451	1.47	-0.06

Table 5: Density

Mix	% Volume replacement of coarse aggregate	% of admixtures in equal proportions	% of Nano (TiO_2) on 11% of cement	% of cement	Density in Kg/cum	Percentage increase or decrease in density
BN0	100	0	0	100	1863.7	0
BN1	100	11	0.5	88.945	1878.52	0.80
BN2	100	11	1	88.89	1955.56	4.93
BN3	100	11	1.5	88.835	1875.56	0.64

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Table 6: Ultimate loads in Mode -II fracture test

Name of the mix	%volume replacement of coarse aggregate	%of admixtures in equal proportions	% of Nano Nano (TiO_2) on 11% of cement	a/w=0.3		a/w=0.4		a/w=0.5		a/w=0.6	
				Ultimate Load in KN	%increase or decrease of ultimate load	Ultimate Load in KN	%increase or decrease of ultimate load	Ultimate Load in KN	%increase or decrease of ultimate load	Ultimate Load in KN	%increase or decrease of ultimate load
BN0	100	0	0	90	0	60	0	52	0	35	0
BN1	100	11	0.5	93	2.952	75	23.76	62	19.87	43	20.755
BN2	100	11	1	100	11.070	82	35.91	70	33.97	49	37.736
BN3	100	11	1.5	83	-8.118	61	1.10	56	7.05	40	12.264

Table 7:Ratio of cylinder strength to cube strength

Name of the mix	% Volume replacement of Coarse aggregate(Light Expandable Clay Aggregate)	% of admixtures in equal proportions	% of Nano Nano (TiO_2) on 11% of cement	% of cement	Cylinder strength	Cube strength	Ratio of cylinder to cube strength
BN0	100	0	0	100	17.429	24.06	0.724
BN1	100	11	0.5	88.95	17.957	24.80	0.724
BN2	100	11	1	88.89	19.561	25.23	0.775
BN3	100	11	1.5	88.84	17.674	24.03	0.735

Table 8: In plane shear stress and percentage increase or decrease of in plane shear

Name of the mix	%volume replacement of coarse aggregate	%of admixtures in equal proportions	% of Nano Nano (TiO_2) on 11% of cement	a/w=0.3		a/w=0.4		a/w=0.5		a/w=0.6	
				In plane shear strength In N/mm^2	%increase or decrease of in plane shear stress	In plane shear strength In N/mm^2	%increase or decrease of in plan e shear stress	In plane shear strength In N/mm^2	%increase or decrease o in plan e shear stress	In plane shear strength In N/mm^2	%increase or decrease o in plan e shear stress
BN0	100	0	0	2.857	0	2.235	0	2.311	0	1.963	0
BN1	100	11	0.5	2.952	3.333	2.765	23.76	2.770	19.87	2.370	20.755
BN2	100	11	1	3.175	11.11	3.037	35.91	3.096	33.97	2.704	37.736
BN3	100	11	1.5	2.635	-7.778	2.259	1.10	2.474	7.05	2.204	12.264

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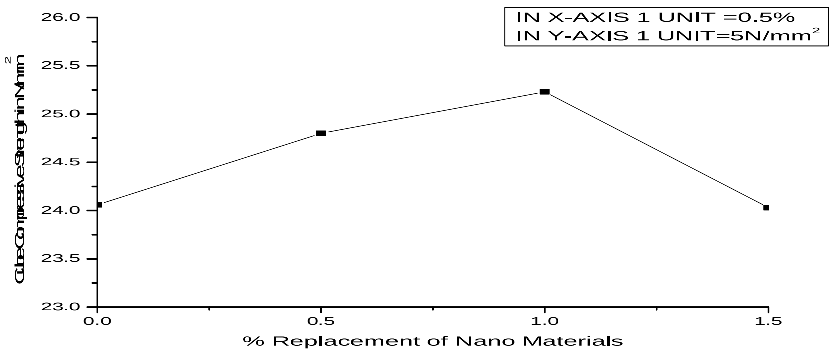

Figure.2. Compressive strength of cubes

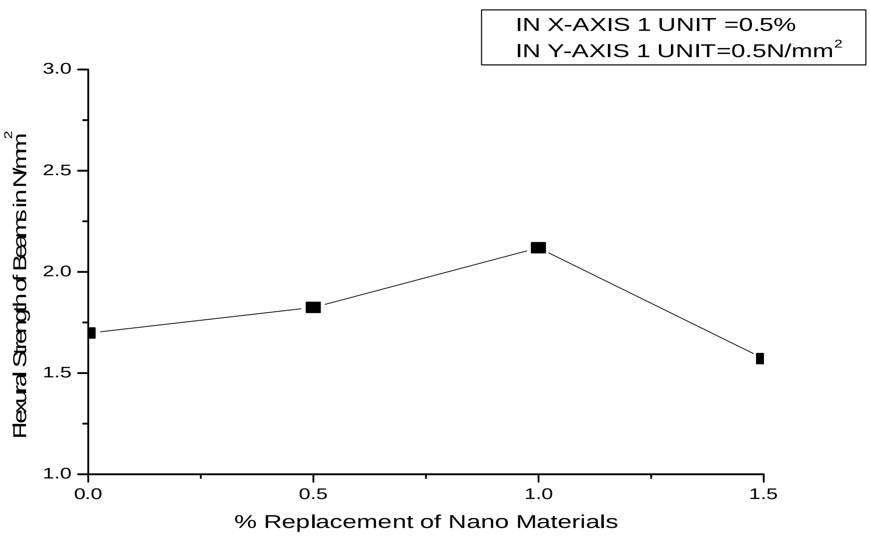

Figure.3.flexural strength

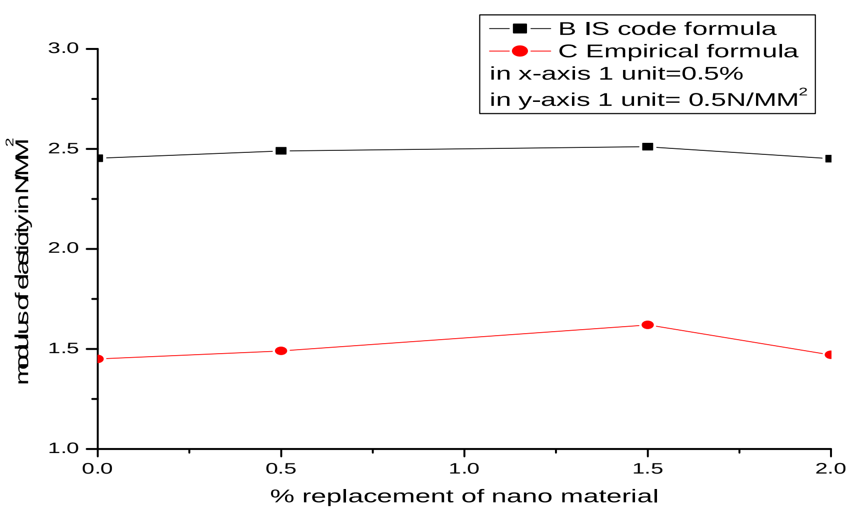

Figure.4. Modulus of elasticity

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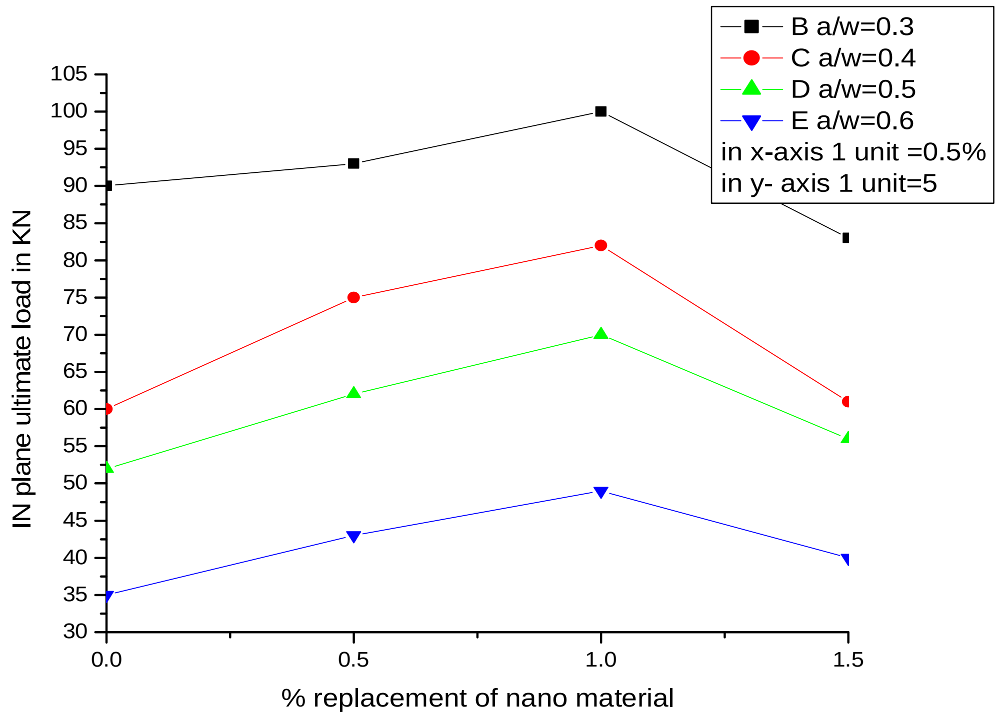

Figure.5. super imposed loads for different a/w ratios

Ratio of cylinder strength to cube strength

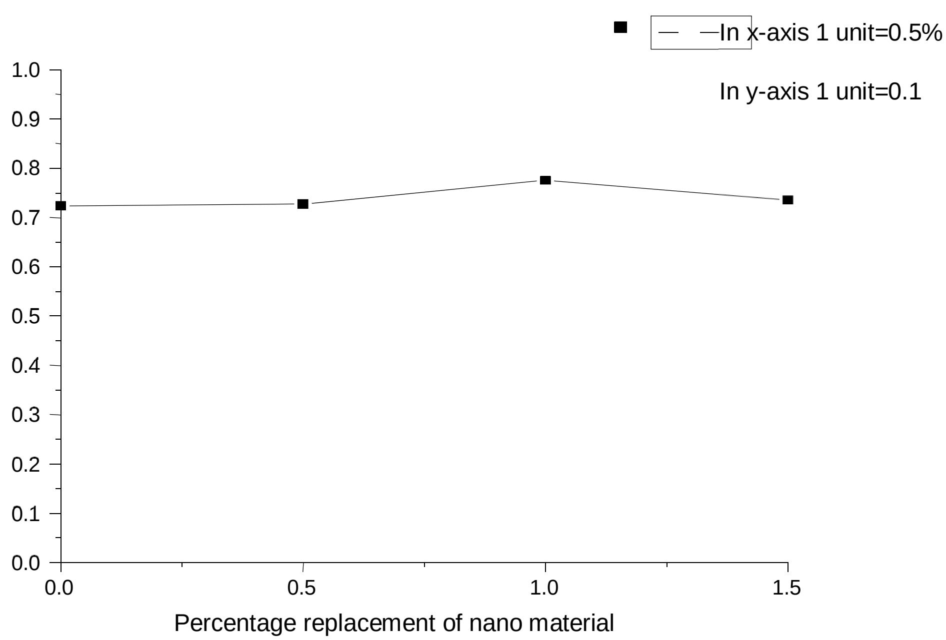

Figure.6. Ratio of cylinder strength to cube strength

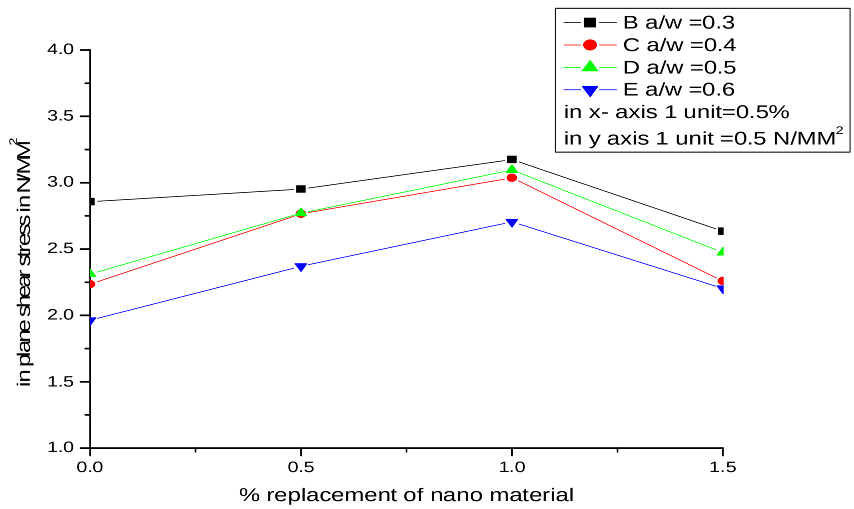

Figure.7.Super imposed variation of In plane shear strength for different a/w ratios

VII. DISCUSSION OF TEST RESULTS

A. *Influence of Titanium dioxide on cube compressive strength*

In the present study natural aggregate has been fully replaced with and Light expandable Clay aggregates. The variation of compressive strength verses varying percentage replacement at 0,0.5, 1 and 1.5% on11% of cement with NanoTiO_2 along with constant 11% o f three numbers of pozzolanic materials i.e ., Silica fume, Slag and Fly ash in equal proportions . It may be observed that with the addition of Titanium dioxide the cube compressive strength increases up to 1% addition of Nano materials and beyond 1% the strength is observed to decrease. Graphically, shown in fig2.

B. *Influence of Titanium dioxide on flexural strength of beam specimens*

In the present study natural aggregate is fully replaced with Light Expandable Clay aggregates. The flexural strength results are tabulated in table 3 and graphically shown in figure3. The flexural strength of beams is increased continuously up to 1% addition of Nano materials and afterwards it is decreased.

C. *Influence of Titanium dioxide on modulus of elasticity*

The modulus of elasticity results with various percentages of Nano materials are presented in table 4 for 28 days based on IS code empirical formula and the other empirical formula as suggested in the literature. From the results it is observed that modulus of elasticity has been increased continuously up to 1% Nano materials addition and afterwards it is decreased. It is also observed that the modulus of elasticity values calculated from IS codes are slightly higher when compared with those calculated by the other empirical formula. The graphical variation is presented in fig.4

D. *Discussion on the effect of Titanium dioxide on in plane shear strength*

All the DCN specimens with different a/w ratios i.e 0.3, 0.4, 0.5 and 0.6 and with different percentages of Nano materials were tested with load in Mode-II (in plane shear). The variations of ultimate loads and percentage increase or decrease in ultimate loads verses percentage replacement of cement with Nano materials are presented in table 6which are presented for different a/w ratios after 28 days of curing. The values are increased up to 1% of Nano material and beyond 1% the value are decrease as shown in fig .5

E. *Influence of Titanium dioxide on density*

Density of modified concrete with Light Expandable Clay Aggregate with Nano materials is decreased when compared with that for normal concrete

F. *Discussion of crack patterns in cubes, cylinders, beams and DCN specimens*

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

VIII. CONCLUSIONS

A. The target mean strength of M_{20} concrete is 26.60 N/ mm^2.From the experimental study it is observed that the 28 days cube compressive strength of modified concrete with 100% Light Expandable Clay aggregate is 24.06 N/ mm^2 and with replacement of cement by 11% with three numbers of pozzolanic materials i.e., Silica fume, Slag and Fly ash in equal proportions and 1% of Nano Titanium dioxide the cube compressive strength of modified concrete rises to 25.23 N/ mm^2 which is slightly nearer to the target mean strength of M_{20} concrete.

B. With the 1% percentage of Nano materials and with constant 11% pozzolanic materials replacing the cement, there is increase in flexural strength and Young's modulus and with further increase in Nano Titanium dioxide content beyond 1%, there is a decrease in both values.

C. From the analysis of test results it is concluded that young's modulus calculated from IS code formula is higher when compared to that calculated from other empirical formula.

D. It is observed that with the increase in the a/w ratio there is decrease in ultimate load and there is increase in ultimate loads with 1% of Nano materials and with further increase in Nano materials content beyond1% there isa decrease in ultimate loads for all a/w ratios.

E. The light weight concrete prepared by 100% Light expandable Clay Aggregate as coarse aggregate is in no way inferior to the natural aggregate and also consumption of cement can be reduced by about 11%.

F. As per the test results the ratio of cylinder strength to cube strength increases up to 1%. After that it decreases.

G. From the analysis of test results it is observed that in plane shear stress for a/w different ratios 0.3, 0.4, 0.5, 0.6 values increases up to 1% of Nano material addition and afterwards after it decreases.

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