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A Brief Study on the Strength Properties of Modified Concrete using Light Expandable Clay Aggregate, Sintered Fly-Ash Aggregate and Tetra Blended Cement along with Pozzolanic & Nano Materials

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Abstract: An attempt is made to study the strength properties of modified M_{20} grade concrete by 100% replacement of natural aggregates with light expandable clay aggregate (LECA) and Sintered fly ash aggregates in equal proportions. It is also proposed to replace 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 such as compressive strength test, flexural strength test, modulus of elasticity, impact value, in-plane shear strength. The results are observed to be quite interesting. ***Keywords: LECA(light weight Expandable Clay Aggregate), Sintered Fly ash Aggregate, Nano TiO_2,Silica fume, slag, Fly ash, compressive strength, split tensile strength, modulus of elasticity, flexure, Impact value, In-plane shear strength.***

I. INTRODUCTION

Concrete is a newer construction material compared to steel and stone. Use of concrete in constructions and buildings may have begun less than a century ago. But in recent past century, very wide and effective research has been seen on improving the properties of concrete with incorporating wide range of supplementary cementing materials such as pozzolanic materials and Nano particles. Recently Nano technology has attracted greater scientific attention mainly due to the usage of Nano particles resulted significantly improved properties from predictable grain-size materials of the same chemical composition. As a consequence, industries can be able to design new and novel products and to re-engineer many existing products that function at unprecedented levels. There are few reports on incorporation of Nano particles in cement-based concrete.

On the one hand the availability of natural aggregate resources in India particularly in Metro Cities has become a matter of concern; on the other hand solutions are being sought for the utilization of increasing quantities of fly ash, released from coal based thermal power plants and such other industrial wastes. The usage of fly ash for production of lightweight aggregate is an appropriate step for the solution of both problems.

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 forming during heating produces a honeycomb structure. LECA has an approximately round or potato shape due to circular movement in the rotary kiln. Some characteristics of LECA are: lightness, thermal insulation by low conductivity coefficient (as low as 0.097 W/mK), soundproofing by high acoustic resistance, moisture impermeable, incompressible under permanent pressure and gravity loads, non–decomposition against severe condition, fire resistant, Ph of nearly 7, freezing and melting resistance, 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.

Use of such lightweight aggregate for production of Structural Lightweight Concrete (SLC) is next appropriate step. The use of light weight concrete permits greater design flexibility and substantial cost savings, reduced dead load, improved cyclic loading, better structural response, longer spans, better fire ratings, thinner sections, smaller size structural members etc., Artificial light Weight

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aggregate is a relatively new material. For the same crushing strength, the density of concrete made with such an aggregate can be as much as 35 percent lower than the normal weight concrete.

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 when compared to the conventional concrete.

II. REVIEW OF LITERATURE

G. Campione, et.al., (2001) [1] studied the mechanical properties of steel fibre reinforced light weight concrete with Pumice stone or expanded clay aggregates and found that there was no significant change in compressive strength for Pumice stone aggregate and increase observed while using expanded clay aggregates tensile strength (using split tensile test) and fracture toughness increased for both Pumice and expanded clay aggregates, with the main advantage of lower structural weight being maintained.

Arvind kumar, et al., (2014)(2) in this experimental investigation used M25 mix design with OPC 43 grade. Natural aggregates were replaced with sintered fly ash aggregates. The compressive strength was attained at 12% replacement of sintered fly ash aggregate in concrete while the minimum strength was attained at 20% replacement.

Prakash Desai, et.al., (1999) (3) arrived at double central notched specimen geometry which fails in predominant Mode-II failure; they also made finite element analysis to arrive at stress intensity factor. Using this DCN geometry lot of experimental investigation using cement paste, mortar, plain concrete have been studied. Details of this geometry are presented as below.

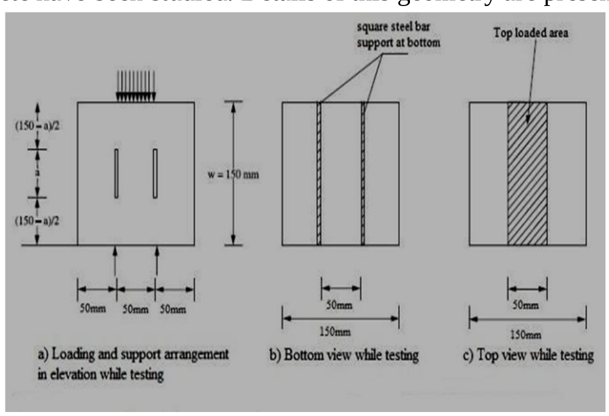

Figure.1. Details of DCN specimen geometry

M. Kosior-Kazberuk, et.al., (2007)(4) showed that the fly ash has a beneficial effect on compressive strength of all cements tested. Although the rate Strength increase of fly ash concrete was slower and sustains for longer periods, the concretes containing fly ash are capable of developing a higher strength than Portland cement concrete as well as the blast furnace cement concrete. After 180 days of storage the concretes containing 20 % of fly ash, related to cement mass, gained a compressive strength about 25 % higher than the concrete without addition, for all types of cement.

R.V Balendran, et.al., (2002) (5) studied on "strength and durability performance of High Performance incorporating pozzolanic materials at elevated temperatures". The inclusion of pozzolanic materials like fly ash and silica fume enhances the properties of concrete both in fresh and hardened states. In the case of high performance concrete (HPC), their role in enhancing the workability, strength and durability is extremely significant.

Ali-Nazari, et.al., (2010) (6), added N1, N2, N3 and N4 are the series N blended concrete with 0.5%, 1.0%, 1.5% and 2.0% of Nano-TiO2 particles, respectively per weight of cement in the concrete and fixed w/c ratio of 0.4 was used. It was derived that the workability reduction, increased with the increasing NT (Nano Titanium Dioxide) content and compressive strength of concrete after 28 days was 13.86%, 17.93%, 15.49% and 6.79% increased with the inclusion of 0.5%, 1%, 1.5%, and 2%NT respectively its original strength. The final result of 1% NT contain is the optimum.

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 i.e., Light weight Expandable Clay aggregate, Sintered Fly ash aggregate with tetra blended cement along with Nano materials such as Nano Tio_2, in combination of active pozzolanic material such as Silica fume, Fly Ash and Slag. Hence the present investigation has been under taken.

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A. Objective

Determining of solution for disposal of industrial wastes hazardous to environment as a useful material in the construction industry. By replacing of coarse aggregate in concrete with light weight aggregate to produce light weight concrete.

III. MATERIALS USED

The following materials were used for preparing the concrete mix.

ACC cement of 53 grade

Fine aggregate i.e sand

Coarse aggregate (Light expandable clay aggregate (LECA) and Sintered Fly-ash aggregate.)

Fly ash

Silica fume

Slag

Water

Nano Titanium Dioxide (TiO_2)

Some Typical properties of the materials used are presented in the following table.

S.NO	Name of the material	Properties of materials	
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
		Fineness modulus	2.75
3	Coarse aggregate replaced by LECA & Sintered Fly-ash	Specific gravity of LECA	1.18
		Specific gravity of Sintered Fly-ash aggregate	1.7

A. Cement

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

B. Coarse aggregate

1) *Light weight Expandable Clay aggregate (LECA):* Typical physical characteristics of LECA aggregates procured from Nexus Buildcon Solution Company, Ahmedabad used in this investigation are as follows.

Specific gravity : 1.18

Aggregate Size mm : 10-12mm

Bulk Density : 645kg/m^3

Shape : Round pellets

2) *Sintered fly ash aggregate:* Sintered fly ash aggregate procured from IndiaMart Company, Ahmedabad was used in this investigation. Typical physical characteristics of Sintered fly ash aggregates (As given by the supplier)

Specific gravity : 1.7

Aggregate Size mm : 8-12

Bulk Density : 800 kg/m3

Bulk Porosity : 35-40%

Aggregate Strength : >4.0 MPa

Water Absorption : < 16 %

Shape : Round pellets

C. Water

The local drinking water which was free from acids, impurities and suspended solids etc has been used in this experimental investigation.

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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.

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.

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 dioxide gives favourable results by increasing compressive strength and tensile strength of concrete. An experimental study has been carried out by replacing the cement with Nano Titanium dioxide in the proportion of 0.5%,1% and 1.5% on 11% weight of cement. Nano titanium dioxide was procured from AVANSA technologies, KHANPUR.

Physical Properties of Nano TiO_2 :(As given by the supplier) Purity: 99.9% SSA: 289 m^2/g - large surface area. Colour:White. Bulk Density: 0.12-0.18g/cm^3-

PH: 5.25-7.3

IV. MIX DESIGN OF CONCRETE

M_{20} Mix design has been carried out using ISI methods i.e, IS 10262-2009 and IS 456-2000. The mix proportion obtained was 1:1.58:2.88 with constant water cement ratio 0.5.

A. Mixing, casting and curing

M_{20} mix design has been carried out with the mix proportions of 1: 1.58: 2.88. It means that 1 part of cement, 1.58 parts of fine aggregate and 2.88 parts of coarse aggregate which is nothing but LECA and sintered Fly-ash aggregate and replacing some part 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 with water cement ratio of 0.5. All of these were mixed thoroughly by hand mixing. No super plasticizer was added in concrete. After mixing concrete was placed inside the moulds and were kept in shade. In case of DCN moulds the plates which were used for making notches were removed after 3 hours of casting with carefully. However, the specimens were de moulded after 24 hours of casting and were kept immersed in a clean water tank for curing. After 28 days of curing the specimens were taken out of water and were allowed to dry under shade for few hours. Keeping the volume of concrete constant with saturated and surface dry LECA aggregates and Sintered fly ash aggregates four different mixes which were designated as follows:

Mix	%volume replacement of coarse aggregate		% of admixtures in equal proportion	% of Nano Materials
	LECA	Sintered Fly ash aggregate		
M1	50	50	0	0
M2	50	50	11	0.5
M3	50	50	11	1
M4	50	50	11	1.5

B. Compressive strength of concrete cubes

The test specimens were stored in moist air for 24 hours and after this period the specimens were marked and removed from moulds and kept submerged in clear fresh water until taken out prior to test. The specimens were removed from water after specified curing time and wiped out excess water from the surface. The specimens were placed in the machine in such a manner that the load shall be applied concentrically. Specimens were aligned centrally on the base plate of the machine. The load was applied gradually without shock and continuously at the rate of 140 $kg/cm^2/min$ till the specimen fails. The maximum load was recorded. Compressive strengths of cubes were calculated. The compression strengths of cube are tabulated in table1 and values are graphically presented in figure 1. 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 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 graphically presented in figure 2.

C. Cylinder Compression Test

In this test the cylindrical specimens were kept vertically so that its axis is 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. Compressive strength results of cylinders are tabulated in table 3 and values are graphically presented in fig.3.

D. Cylinder Split tensile Test

In this test the cylindrical specimens were kept horizontally so that its axis is parallel to 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

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cylinder to receive compressive stress. The load was applied uniformly until the cylinder fails, by cracks occurred on top and bottom. Split tensile strength results of cylinder are tabulated in table 4 and values are graphically presented in fig 4.

E. Ratio of cylinder and cube compressive strength:

For normal concrete the ratio of cylinder to cube compressive strength is about 0.8 where as in this experimental investigation the ratio is found to be about 0.85.The difference in the ratio is due to the higher compressive strength of cylinder and cube of modified concrete along with pozzolanic materials compared to the compressive strength of cube and cylinder of normal concrete. The ratio of cylinder and cube compressive strength values show that the values decreases with the addition of Nano TiO_2.The results of ratio of cylinder to cube compressive strength are tabulated in table 5 and values are graphically presented in fig 5.

F. Modulus of elasticity:

The theoretical modulus of elasticity was calculated using IS code formula (**7**).

$$E=5000*\sqrt{f_{ck}}$$

Where,

f_{ck}= Characteristic Compressive strength of concrete in N/ mm^2 . The modulus of elasticity values were calculated from the other empirical formula suggested by Takafumi (8) for light weight concrete.

$$E=k_1k_2*1.486*10^{-3}*f_{ck}{}^{1/3}*\gamma^2.$$

Where f_{ck} = Compressive strength in N/mm^2, 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). The Modulus of Elasticity, a value based on Empirical formula and IS code are presented in Table 6 & Table 7 respectively and values are graphically represented in fig.6.

G. 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 was 0.5 KN/sec. uniformly distributed load was applied over the central one third parts 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. Test results are shown in table 8 and presented graphically in fig.8.

H. 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/mm^2

Where 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 9 and values are shown graphically in Figure 9.

VI. DISCUSSION OF TEST RESULTS

In the present study natural aggregate has been fully replaced with Sintered fly ash aggregates and LECA in equal proportions along with replacement of some part of cement by three numbers of pozzolanic materials i.e., Silica fume, slag and fly ash in equal proportions and varying percentages of Nano TiO_2 in spells of 0, 0.5, 1 and 1.5% on 11% of pozzolanic materials.

A. Influence of Nano TiO_2 on cube compressive strength

The variation of compressive strength verses varying percentage replacement at 0, 0.5, 1 and 1.5% on 11% of cement with Nano TiO_2, at 28 days is shown in figure 2. From the above figures it may be observed that with the addition of Nano TiO_2 the cube compressive strength increases up to 1% addition and with more addition of Nano materials beyond 1% the strength is decreased.

B. Influence of NanoTiO_2on flexural strength of beam specimens

From the table 2 and figure 3 it may be observed that the flexural strength of beams is increased continuously up to 1% addition of Nano materials and afterwards it is decreased. Hence 1% addition of Nano TiO_2 is observed to be optimum.

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C. Influence of NanoTiO$_2$ on modulus of elasticity

The modulus of elasticity results with various percentages of NanoTiO$_2$ in equal proportions are presented in table 6 for 28 days based on empirical formula methods and based on the IS code as mentioned in table 7. From the results it is observed that modulus of elasticity has been increased continuously up to 1% of NanoTiO$_2$. With more addition of NanoTiO$_2$ the values of modulus of elasticity are decreased. It is also observed that the modulus of elasticity values calculated from IS code are higher when compared with those calculated from empirical formula.

D. Influence of NanoTiO$_2$ 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 NanoTiO$_2$ in equal proportions were tested with load in Mode-II (in plane shear). The variations of in plane shear strength and percentage increase or decrease in in-plane shear strength verses percentage replacement of cement with NanoTiO$_2$in equal proportions are presented in table 9 which are presented for different a/w ratios after 28 days. The graphical variation is presented in Figure 9.From this it is observed that the in-plane shear strength increases up to 1% addition of Nano TiO$_2$ and on further increasing the nano material the in-plane shear strength decreases.

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

In case of cubes, the initial cracks were developed at top and propagated to the bottom with the increase in load and they were widened along the edges of cubes. In case of cylinders, the initial cracks were developed at top or bottom side with the increase in load the cracks are widened at central height. In the flexural beams all 12 beams were 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 propagated are observed and new cracks have developed along the span. Final failure occurs in the middle portion. The failure of the DCN specimen is such that the crack patterns obtained for DCN specimen geometry are 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 formation 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.

Table 1: Compressive strength of Cubes:

Mix	%volume Replacement of coarse Aggregate		% of admixtures in equal proportions	% of Nano material(Tio2) on 11% of cement	% of cement	Cube compressive strength in N/mm^2	Percentage increase or decrease of compressive strength
	Light Weight Expandable Clay Aggregate	Sintered Fly-ash Aggregate					
M1	50	50	0	0	100.00	26.47	0.0
M2	50	50	11	0.5	88.945	29.99	13.3
M3	50	50	11	1	88.89	32.16	21.5
M4	50	50	11	1.5	88.835	30.22	14.2

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Table 2: Flexural Strength of Beams:

Mix	% Volume replacement of coarse aggregate		% of admixtures in equal proportions	% of Nano material(Tio2) on 11% of cement	% of cement	Percentage of cement replacement by Nano material	Flexural strength in N/mm^2	Percentage increase or decrease of flexural strength
	LECA	Sintered Fly-ash Aggregate						
M1	50	50	0	0	100	0%	2.1994	0.00
M2	50	50	11	0.5	88.945	0.5%	2.3260	5.75
M3	50	50	11	1	88.89	1%	3.0009	36.44
M4	50	50	11	1.5	88.835	1.5%	2.7478	24.93

Table 3: Compressive strength of cylinders:

Mix	% Volume replacement of Coarse aggregate(Light Expandable clay aggregate)		% of admixtures in equal proportions	% of Nano Material on 11% of cement	% of cement	Cylinder compressive strength in N/mm^2	Percentage increase or decrease of compressive strength
	Light Weight Expandable Clay Aggregate	Sintered Fly-ash Aggregate					
M1	50	50	0	0	100	22.76	0.00
M2	50	50	11	0.5	88.945	25.19	10.68
M3	50	50	11	1	88.89	26.7	17.31
M4	50	50	11	1.5	88.835	24.78	8.88

Table 4: Split Tensile Strength of Cylinders:

Mix	% Volume replacement of Coarse aggregate(Light Expandable clay aggregate)		% of admixtures in equal proportions	% of Nano Material on 11% of cement	% of cement	Cylinder split tensile strength in N/mm^2	Percentage increase or decrease of split tensile strength
	Light Weight Expandable Clay Aggregate	Sintered Fly-ash Aggregate					
M1	50	50	0	0	100	1.96	0.00
M2	50	50	11	0.5	88.945	2.31	17.85
M3	50	50	11	1	88.89	2.50	27.55
M4	50	50	11	1.5	88.835	2.40	22.44

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Table 5: Ratio of cylinder to cube compressive strength:

Mix	% Volume replacement of Coarse aggregate		% of admixtures in equal proportions	% of Nano Material on 11% of cement	% of cement	Cylinder strength (28 Days)	Cube strength (28 Days)	Ratio of cylinder strength to cube strength	Percentage increase or decrease of ratio
	LECA	Sintered Fylash Aggregate							
M1	50	50	0	0	100	22.76	26.47	0.86	0.00
M2	50	50	11	0.5	88.95	25.19	29.99	0.84	-2.28
M3	50	50	11	1	88.89	26.7	32.16	0.83	-3.44
M4	50	50	11	1.5	88.84	24.78	30.22	0.82	-4.63

Table 6: Modulus of Elasticity by Empirical Formula:

Name of the Mix	% Volume replacement of Coarse Aggregate		% of Nano material replacing 11% of cement	F_{ck} in N/mm^2	Density in kg/m^3	Young's Modulus by Empirical Formula*10^4 $E=k_1k_2*1.486*10^{-3} f_{ck}^{1/3} \gamma^2$ $K_1=0.95$, $K_2=1.026000$ in *10^4 in N/mm^2	% of increase or decrease of modulus of elasticity
	LECA	SINTERED FLY-ASH					
M1	50	50	0	26.47	1869.63	1.51	0.000
M2	50	50	0.5	29.99	1914.07	1.65	9.252
M3	50	50	1	32.16	2014.81	1.87	23.917
M4	50	50	1.5	30.22	1878.52	1.59	5.508

Table 7: Modulus of Elasticity by IS Code Formula:

Mix	% Volume replacement of coarse aggregate		% of admixtures in equal proportions	% of Nano material (Tio2) on 11% of cement	% of cement	Modulus of elasticity*10^4 in N/mm^2 $5000f_{ck}^{0.5}$	Percentage increase or decrease of modulus of elasticity
	LECA	Sintered Fly-ash					
M1	50	50	0	0	100	2.573	0
M2	50	50	11	0.5	88.945	2.738	6.42
M3	50	50	11	1	88.89	2.836	10.22
M4	50	50	11	1.5	88.835	2.749	6.84

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Table 8: Ultimate Loads in Mode II Fracture Test:

Name of the mix	% Replacement of Coarse aggregate		% of admixtures in equal proportions	% of Nano Materials	a/w=0.3		a/w=0.4		a/w=0.5		a/w=0.6	
	Leca	Sintered Fly-ash			Ult imate loadin KN	% increase Or decreasE of ultimate load	Ult imate load in KN	% increase or decrease of ultimate load	Ultimate load in KN	% increase or decrease of ultimate load	Ult imate load in KN	% increase Or Decrease Of ultimate Load
M1	50	50	0	0	108	0	100	0	88	0	68	0
M2	50	50	11	0.5	118	8.61	105	4.98	93	5.3	70	2.45
M3	50	50	11	1	125	15.07	112	11.93	102	15.53	75	9.8
M4	50	50	11	1.5	110	1.846	95	-5.32	81	-8.33	66	-3.43

Table 9: In-plane Shear strength:

Name of the mix	% Replacement of Coarse aggregate		% of admixtures In Equal proportions	% of Nano Materials	a/w=0.3		a/w=0.4		a/w=0.5		a/w=0.6	
	Leca	Sintered Fly-ash			In-plane shear strength N/sq.mm	% increase Or Decrease of In-plane shear strength	In-plane shear strength in N/sq.mm	% increase or decrease of In-plane shear strength	In-plane shear strength N/Sq.mm	% increase or decrease of In-plane shear strength	In-plane shear strength N/Sq.mm	% increase Or Decrease Of In-pla ne shear strength
M1	50	50	0	0	3.429	0	3.716	0	3.911	0	3.778	0
M2	50	50	11	0.5	3.746	9.259	3.901	4.98	4.119	5.303	3.87	2.45
M3	50	50	11	1	3.968	15.74	4.136	11.29	4.519	15.53	4.148	9.8
M4	50	50	11	1.5	3.492	1.852	3.519	-5.316	3.585	-8.33	3.648	-3.431

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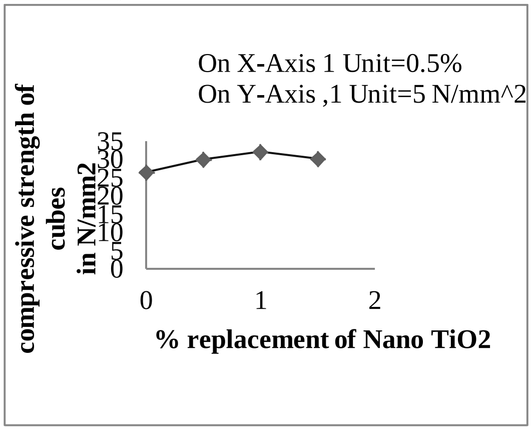

Figure 2: Compressive Strength of Cube

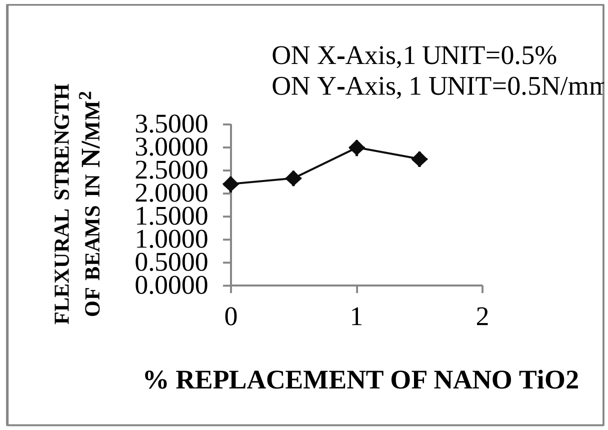

Figure 3: Flexural Strength of beams

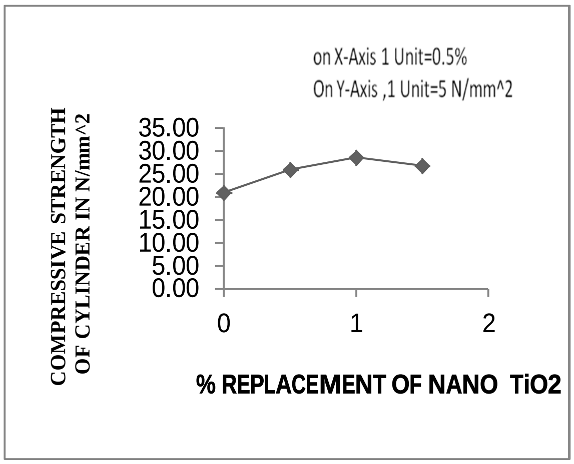

Figure 4: Compressive strength of cylinders

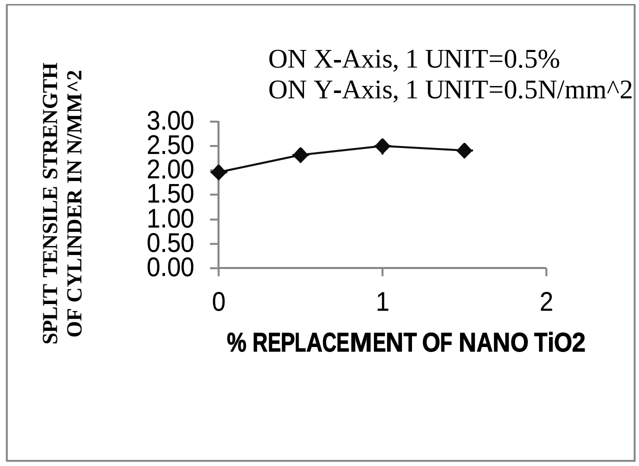

Figure 5: Split tensile Strength of cylinders

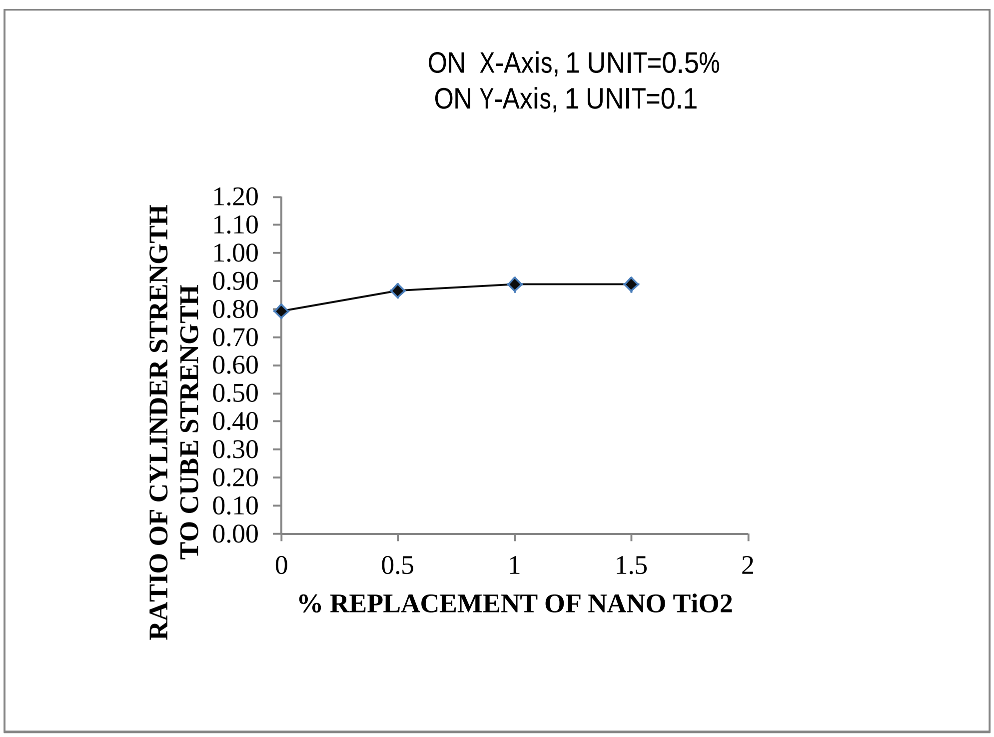

Figure 6: Ratio of cylinder to cube compressive strength

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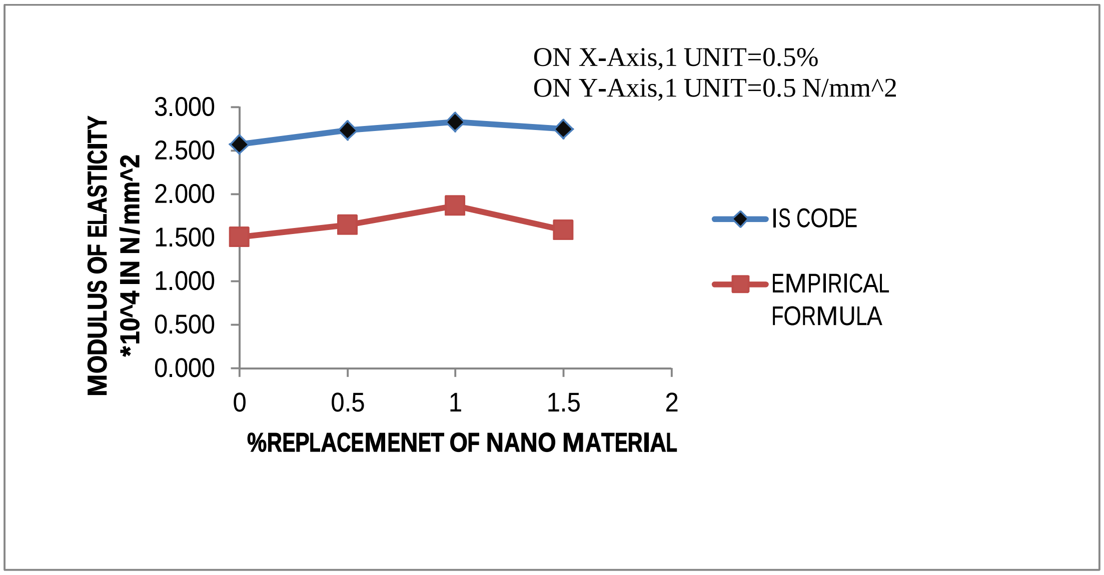

Figure 7: Modulus of Elasticity based on IS code and Empirical formula

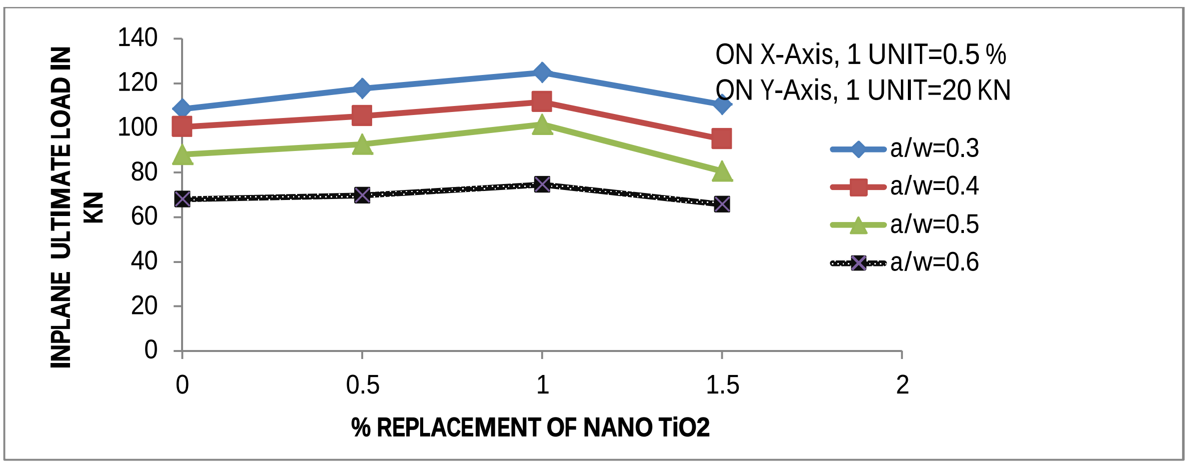

Figure 8: Ultimate loads for different a/w ratios

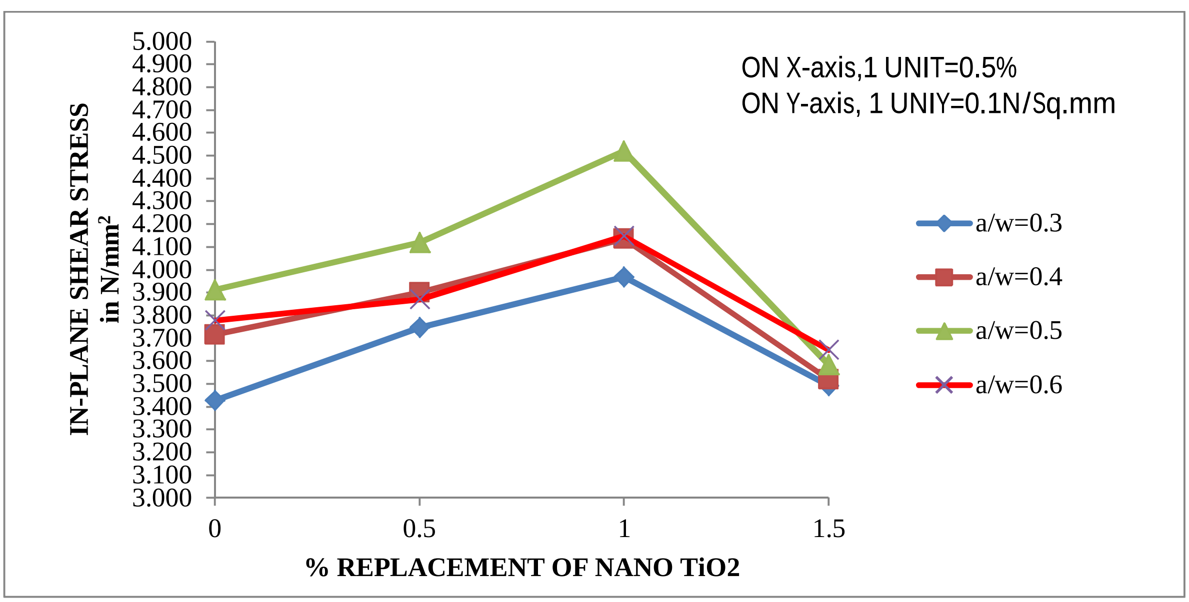

Figure 9: Super Imposed variations of In-palne shear strength for different a/w ratios

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VII. CONCLUSIONS

A. The following conclusions are drawn Based on the Experimental Results.

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 26.47 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 NanoTiO_2 on 11% of weight of pozzolanic materials the cube compressive strength of modified concrete rises to 32.16 N/mm^2 which is higher than the target mean strength of M_{20} concrete. With more addition of Nano materials i.e., 1.5% the strength is decreased.

All the beams have been failed in the flexural zone and as such the flexural cracks have been propagated from the bottom side to top with crushing of concrete at the top surface. It is observed that the 28 days flexural strength of modified concrete with 50% LECA aggregate and 50% sintered fly ash aggregate is 2.1914 N/mm^2 and with replacement of cement with pozzolanic materials with constant proportion of 11% and 1% of NanoTiO_2 the flexural strength of modified concrete rises to 3 N/mm^2 with an increase of 36.44%. With addition of more NanoTiO_2, the strength is decreased.

It is observed that the 28 days cylinder compressive strength of modified concrete with 50% LECA and sintered 50% fly ash aggregate is 22.76 N/mm^2 and split tensile strength of concrete is observed as 1.96 N/mm^2. 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 Materials i.e, TiO_2 in equal proportion the cylinder compressive strength of modified concrete rises to 26.7 N/mm^{2}and split tensile

Strength rises to 2.5 N/mm^2. With addition of more NanoTiO_2 the strength is decreased.

It is observed that the Modulus of Elasticity by Empirical formula of modified concrete with 50% LECA and 50% sintered fly ash aggregates is $1.51*10^4$ N/mm^2 and with replacement of cement with pozzolanic materials with constant proportion of 11% and 1% of NanoTiO_2 the modulus of Elasticity of modified concrete rises to $1.87*10^4$ N/mm^2 with an increase of 23.9%. With addition of more NanoTiO_2, the strength is decreased. It is observed that the Modulus of Elasticity by IS code formula of modified concrete with 50% LECA and 50% sintered fly ash aggregates is $2.573*10^4$ N/mm^2 and with replacement of cement with pozzolanic materials with constant proportion of 11% and 1% of NanoTiO_2 the modulus of Elasticity of modified concrete rises to $2.836*10^4$ N/mm^2 with an increase of 10.22%. With addition of more NanoTiO_2, the strength is decreased. It is also observed that the results obtained by empirical formula are lesser than those values calculated based on IS code.

Density of LECA and sintered fly ash aggregate concrete with NanoTiO_2 is nearly 22.09% less than that for conventional concrete.

6.It is observed that ultimate loads in Mode-II fracture are found to decrease continuously with the increasing the $\frac{a}{w}$ ratio and there is increase in ultimate loads up to 1% of NanoTiO_2 with constant proportions of pozzolanic materials and thereafter slightly get decreased for all a/w ratios.

7. It is observed that the ultimate in-plane strength increases as a/w ratio increases. The addition of pozzolanic materials and NanoTiO_2 content has significantly enhanced the in-plane shear strength. During the test it is clearly observed that the cracks have developed more or less all along the notches. As in other cases the in planes shear strength increases with increasing the content of Nano TiO_2 up to 1%.

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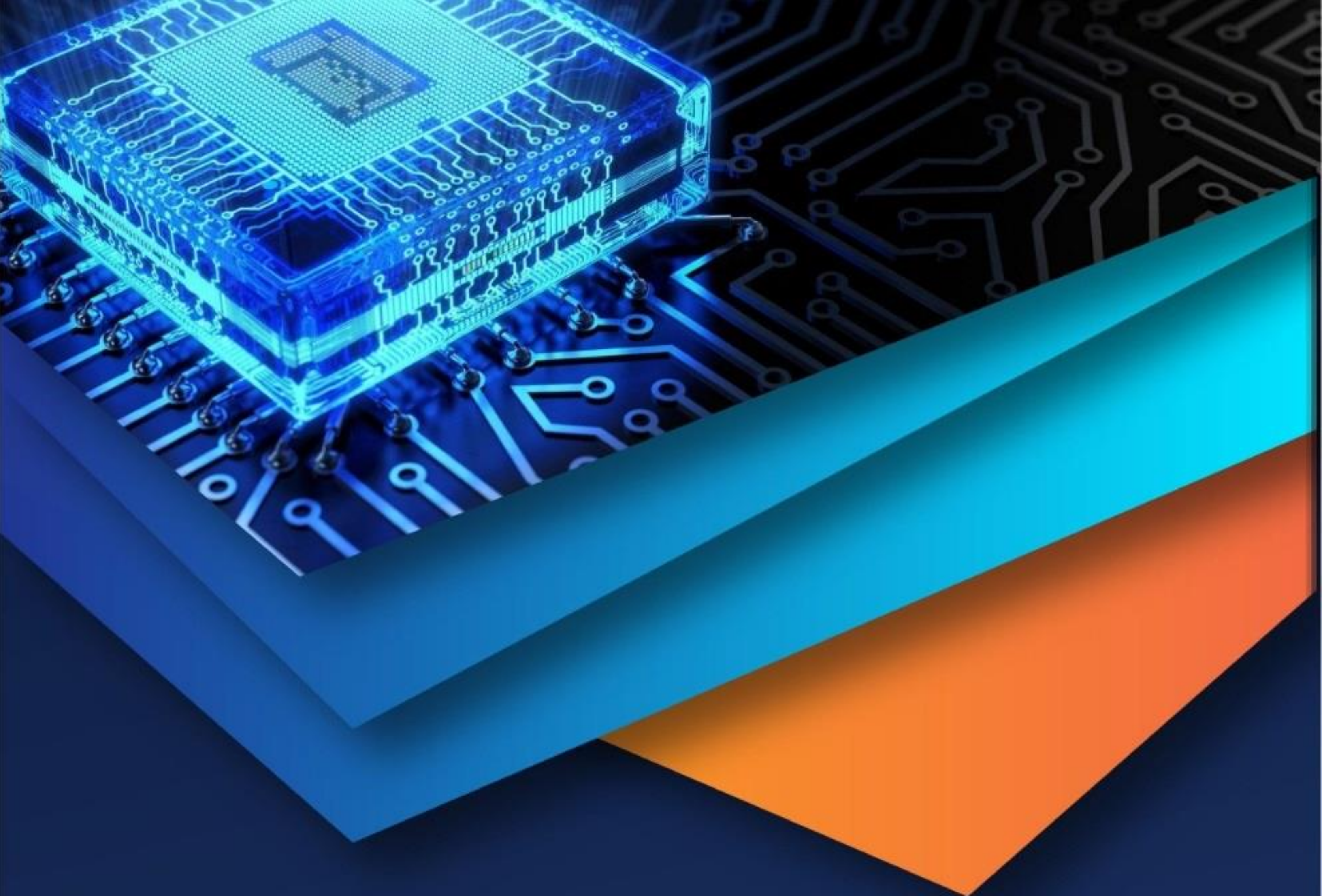

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