

# **An Experimental Study on Strength Properties of Styrofoam Light Weight Aggregate Concrete Modified with Nano Fe<sub>2</sub>O<sub>3</sub>**

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**ABSTRACT:** Styrofoam or expanded polystyrene or Thermocol is used as packing material in food and manufacturing production equipments to absorb vibration during handling and transportation process. After this process, the Styrofoam which is used to protect the equipment normally is disposed as a waste. It is estimated that it produces large amount of wastes as it is abundantly used in the market. An attempt is made to modify the waste Styrofoam pieces as light weight aggregate. Due to its light weight characteristics, it has potential to serve as aggregates to replace coarse aggregates. Concrete is the most versatile material due to its continuous demand. Many researchers and scientists have developed number of techniques to improve the parameters of concrete i.e.strength&durability. Engineers are continuously pursuing to improve the performance with the help of supplementary cementitious material like blast furnace slag, Flyash, steel slag, silica fume etc. The main objective of this investigation is to study the properties such as compressive strength, in plane shear strength, tensile strengths of lightweight concrete containing Styrofoam. Nano materials such as Iron oxides are also used in this investigation. In this investigation 89% of binding material such as cement which is constant is used. The remaining 11% is replaced with silica fume, slag and GGBS with equal proportions. In addition Nano Fe<sub>2</sub>O<sub>3</sub> is used in the percentages of 0.5, 1.0, 1.5 with respect to 11%. This has resulted the increase in strengths up to 1% addition of Fe<sub>2</sub>O<sub>3</sub> and afterwards they get decreases.

**KEYWORDS:** Nano Fe<sub>2</sub>O<sub>3</sub>, Flexural strength, Mode-II Fracture, compressive strength, impact strength, young modulus

## **I. INTRODUCTION**

The production of concrete requires aggregate as inert filler to provide bulk volume. If this is used continuously it will be left nothing for future generations. Hence there is a necessity for preparing artificial aggregates making use of waste materials available in nature and industrial wastes. The use of cost effective construction materials has accelerated in recent times due to the increase in demand of light weight concrete for mass applications. This necessitates the complete replacement or partial replacement of concrete constituents to bring down the escalating construction costs. In recent times, the addition of artificial aggregates has shown a reasonable cut down in the construction costs and has gained good attention due to its quality on par with conventional aggregates. When structural lightweight concrete is used in construction and maintenance of civil engineering structures, the resultant benefits are reduced overall costs, better heat and

sound insulation properties and better resistance to fire. Despite of its lower compressive strength and lower modulus elasticity, Styrofoam concrete can be potentially used in many kinds of structural elements.

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## II. REVIEW OF LITERATURE

A brief literature review is carried out to find the uses of various types of Thermocol available, their properties, usage and influence of Thermocol on the behavior of concrete members made with different replacements of Thermocol.

As per Ramadan Demirboga, C. Abdulkadir Kan(1). Using artificial aggregate in replacement of natural aggregate in production of concrete has a tendency to increase by the future in order to provide greater sustainability in construction industry. This study investigates the effectiveness of thermal modified waste expanded polystyrene (MEPS) on the workability, density, thermal conductivity and shrinkage of concrete. MEPS aggregate was used as lightweight aggregate in concrete by 25%, 50%, 75%, and 100% in replacement of natural aggregate. The thermal conductivity of samples decreased with increasing of MEPS aggregate and their values were 1.990, 1.518, 1.000, and 0.600 W/mK for 25%, 50%, 75%, and 100% MEPS aggregate in replacement of natural aggregate, respectively. Maximum reduction in the thermal conductivity was observed at the samples that made up of 100% MEPS aggregates and the reduction percentage was around 70%. The average drying shrinkage after 210-day of ambient curing condition was  $2.59 \times 10^{-3}$  for samples of 25% natural aggregate, while it was  $5.08 \times 10^{-3}$  for 100% MEPS aggregate samples.

A .Marcelo Amianti Vagner Roberto Botaro (2)Pointed out that a reduction in porosity, with a consequent reduction in permeability, could be an option for increasing the durability of concrete and preserving its surface characteristics. This research was conducted to identify a new material to be economical, efficient and easily applied, as part of Concrete Impregnated with Polystyrene (CIP), so as to reduce the permeability of pre-cast concrete surfaces, thereby, reducing the rate of degradation and increasing overall durability. Additional aims are: (a) using materials which do not affect the visual aspect of the concrete, so that the system can be used on monuments and other elements that are exposed to inclement weather; and (b) developing a new technology that makes use of recycled polymers. The results were observed to be promising and show a significant reduction in water permeability, reduction in porosity and, consequently, a reduction in the proliferation of fungus on the surface of the concrete treated with expanded polystyrene (EPS).

According to W.C. Tang ,Y. Lo, A. Nadeem (3) Polystyrene aggregate concrete (PAC) is a lightweight concrete with good deformation capacity, but its application is usually limited to non-structural use because of its apparent low strength properties. Their study is an effort to develop a class of structural grade PAC with a wide range of concrete densities between 1400 and 2100 kg/m<sup>3</sup> through partial replacement of coarse aggregate with polystyrene aggregate (PA) in control concrete. Extensive laboratory tests were carried out and the focus of this paper is to characterize the strength and long-term drying shrinkage properties of PAC. The parameters studied include PA content and curing conditions. The results showed that the concrete density, concrete strength and elastic modulus of PAC decrease with increase of PA content in the mix. From the calorimetric test results, the increase in strength acceleration of PAC at early ages is due to the low specific thermal capacity of polystyrene aggregate. Besides, the long-term shrinkage and swelling of PAC are highly dependent on the PA content and the duration of water curing. Owing to the non-absorbent property of polystyrene aggregate, the ratio of reversible shrinkage to drying shrinkage observed for PAC was lower compared to the control concrete

Bing Chena, Juanyu Liub stated that(4). Stated that expanded polystyrene concrete with a density of 800–1800 kg/m<sup>3</sup> and a compressive strength of 10–25 MPa can be made by partially replacing coarse and fine aggregate by EPS beads. Fine silica fume greatly improved the bond between the EPS beads and cement paste and increased the compressive strength of EPS concrete. In addition, adding steel fiber significantly improved the drying shrinkage.

Prakash Desayi, Raghu Prasad B.K, and Bhaskar Desai.V, (7,8,9,10,11 & 12) 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, and plain concrete was carried out.

From the brief literature summary it appears that much less attention has been paid earlier on the study of Styrofoam aggregate concrete modified with Nano material such as Fe<sub>2</sub>O<sub>3</sub> in combination of various pozzolanic materials. Hence the present investigation has been under taken.

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## III. MATERIAL PROPERTIES

The materials used in the present investigation are Ordinary Portland cement of 53 grade having a specific gravity of 3.26 with initial and final setting times of 50 minutes and 460 minutes respectively. Locally available river sand passing through IS 4.75mm sieve with specific gravity 2.4 and fineness modulus 3.58 was used. Styrofoam aggregates with fineness modulus 6.24, Silica fume with specific gravity 2.1, Fly ash with specific gravity 2.7; Slag with specific gravity 2.86, and Nano  $Fe_2O_3$  particles with 15nm was used. Portable water was used for casting all specimens of this investigation.

### 3.1 PROPERTIES OF THERMOCOAL AGGREGATE:

Styrofoam is a commercial name like Coca-cola. In 1951 German company named BASF successfully restructured chemical bonding of Polystyrene (a synthetic Petroleum product) molecules and developed a substance named stretched Polystyrene and was named as Styrofoam. Nowadays it is manufactured through a simple process. Thermo plastic granules are expanded through application of steam and air, and the expanded granules become much larger in size but remain very light. Styrofoam offers a non-hydroscopic, odorless, closed cell expanded polystyrene containing 98% of its volume with still air and offers excellent insulation properties. Because of its closed cell structure it offers a remarkable resistance to unwanted heat, chill and moisture to penetrate it, and also gives a rigid, structurally strong product to with stand various kinds of loads and vibrations. It is widely used in food packaging and also as protective devices for securing goods and materials from vibration and damage during delivering and transportation process. Especially delivering process is shaped according to the delivering item's shape and after delivering process it is commonly treated as waste and seldom to be recycled as it is not economical.

### 3.2 Styrofoam Aggregates:

The Styrofoam waste was taken from different industries and food packaging units and was broken down into irregular pieces of various sizes by hand. The broken Styrofoam was taken into a tray and was kept in oven at different temperatures as primary trails. It was found that exposure to temperatures of  $180^\circ$  for 10 minutes duration was optimum. Then the Styrofoam was removed and kept in air for some time and then the sample was taken for mixing. Styrofoam aggregate was used as coarse aggregate. For this aggregate the gradation is used as follows. Passing through 20mm and retained on 10mm is 70%. Passing through 10mm and retained on 6mm is 30%. The aggregate has bulk density of  $645-755 \text{ kg/m}^3$ .

## IV. EXPERIMENTAL INVESTIGATION

An experimental study has been conducted on concrete with 100% replacement of conventional natural aggregate by light weight aggregate i.e. Styrofoam aggregates along with partial replacement of cement by 11% of its weight by three number of pozzolanic materials (Silica fume, fly ash and Slag) in equal proportions along with Nano material  $Fe_2O_3$  at varying percentages on 11% of cement (replaced with pozzolanic materials) at 0, 0.5, 1, and 1.5. Concrete of M20 design mix is used in the present investigation. In addition to presenting conventional strength properties such as cube compressive strength, cylinder compressive strength, modulus of elasticity etc., by casting and testing standard cubes and cylinders, Mode-II fracture studies are also conducted and results are presented.

### 4.1 CASTING OF SPECIMENS:

The M20 concrete mix is designed using ISI method which gives a mix proportion of 1:1.49:2.88 with water cement ratio of 0.50. Four different mixes are adopted which are designated as follows:

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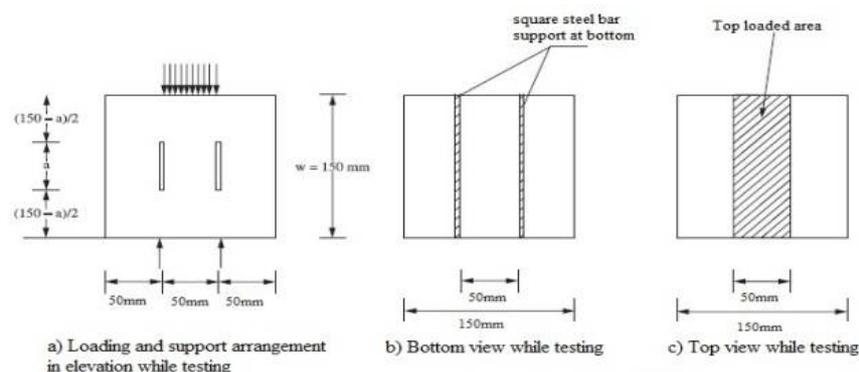
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Name of the MIX	% Volume replacement of Coarse aggregate	% of Admixtures in equal proportions	% of Nano ( $Al_2O_3$ ) on 11% of cement	% of cement
RA <sub>1</sub>	100	0	0	100
RA <sub>2</sub>	100	11	0.5	88.945
RA <sub>3</sub>	100	11	1.0	88.890
RA <sub>4</sub>	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 fume, slag, fly ash and nano-Fe<sub>2</sub>O<sub>3</sub> in required percentages were mixed thoroughly and then Styrofoam aggregates were added with them. All of these were mixed thoroughly by hand mixing. For each mix three plain cubes of 150X150X150mm along with 12 no of DCN specimens with replacement of cement by 11% of its weight by pozzolanic materials (Silica fume, fly ash and Slag) and Nano Ferrous oxide Fe<sub>2</sub>O<sub>3</sub>) with varying percentages (0.5%,1%, and 1.5%) on 11% were cast. Also for each mix three flexure beams of size 500x100x100mm were cast. Besides disc specimen were cast for knowing the impact 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.



**Fig 1. Details of DCN test specimen geometry**

## V. TESTING OF SPECIMENS

The cube specimen was kept vertically on other faces of loading concrete between the compressive plates of the 3000KN automatic compression testing machine with 0.5KN/sec rate of loading. The load was applied uniformly until the specimens fail, and ultimate loads were recorded. The test results of cube are furnished in table 1. The results of modulus of elasticity are furnished in table no 3. Flexural strength test was carried out on prismatic beam specimens of size 500mm\*100mm\*100mm. The beam specimen was tested using Two Point loading system. The test results were presented in table.2. For testing DCN specimens of size 150x150x150mm, notches were introduced at one third portion centrally as shown Fig.1 in during casting. The shear 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.4. and table.5

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and graphically vide in fig.5. Uniformly distributed load was applied over the central one third part between the notches and square cross section steel supports 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.

### 5.1 DISCUSSION OF CRACK PATTERN AND TEST RESULTS:

In case of cubes under compression test initial cracks are developed at top and propagated to bottom with increase in load and then the cracks were widened at failure along the edge of the cube and more predominantly along the top side of casting. In the flexural test beams have been 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.

DCN specimen and the failure of the DCN specimen are presented in and crack patterns obtained for DCN specimen geometry for the four notch depths. During testing, for most of the specimen's 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. Simultaneously the cracks formed at the bottom of one or both the notches and propagated downwards at visible inclination. In some cases cracks branched into either side at the two edges of the supporting square bar at the bottom or at the edge of the loaded length at top or at both places.

#### 5.1.1 INFLUENCE ON COMPRESSIVE STRENGTH

The cube compressive strength of concrete with 100% Styrofoam aggregates with 0% admixtures and Nano Iron-Oxide is 11.97 N/mm<sup>2</sup>. With replacement of 11% cement with three numbers of pozzolanic materials in equal proportion along with varying percentage of Nano Iron-Oxide content on 11% of cement in the spells of 0.5%, the cube compressive strength is found to be optimum at 1% Nano Iron- Oxide. When it is increased to 1.5%, there is decrease in the cube compressive strength of concrete as shown in fig.1 and table.1.

#### 5.1.2 INFLUENCE ON FLEXURAL STRENGTH:

Flexural strength results are presented in Table.2. and graphically in Fig.2. It is observed that there is increase in strength up to 1% of Nano Iron-Oxide addition with constant 11% admixtures and there after decrease in the flexural strength is observed. This behaviour is more or less same as the compressive strength.

#### 5.1.3 INFLUENCES ON MODULUS OF ELASTICITY:

Moduli of elasticity results calculated based on empirical formula(11) IS code[ 456-2000] are presented vide table.3. and graphically vide Fig.4.. Its trend of variation is same as that of compressive strength

#### 5.1.4 INFLUENCE ON IN-PLANE SHEAR STRENGTH:

The variations of ultimate loads and the percentage increase or decrease in ultimate loads versus various percentage of Nano Iron-Oxide are presented vide Fig.5 These are presented for different a/w ratios (i.e., 0.3, 0.4, 0.5, 0.6). From these diagrams 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 up to 1% of NanoIron--Oxide and there after slightly decreased for all a/w ratios.

#### 5.1.5 INFLUENCE ON DENSITY:

The variations of cube density for various percentage of Nano iron- oxide are presented in Fig.6. From the diagram it is observed that density is found to be optimum at 1% nano Iron oxide.

#### 5.1.6 INFLUENCE ON IMPACT BLOWS:

The variations no of impact blows for various percentage of Nano iron- oxide are presented in Fig.3 and in table.6. From the diagram it is observed that the number of impact blows increases upto to 1% addition of nano material and there after decrease, which is similar to the variation of others strength.

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**TABLE.1.CUBE COMPRESSIVE STRENGTH RESULTS**

S.NO	Name of the MIX	% Volume replacement of Coarse aggregate	% of Admixtures in equal proportions	% of Nano (Fe <sub>2</sub> O <sub>3</sub> ) on 11% of cement	% of cement	Cube compressive strength N/mm <sup>2</sup>	increase or decrease in compressive strength
						28 days	28 days
1	LA <sub>1</sub>	100	0	0	100	11.97	0
2	LA <sub>2</sub>	100	11	0.5	88.945	12.28	2.58
3	LA <sub>3</sub>	100	11	1.0	88.890	12.74	6.4
4	LA <sub>4</sub>	100	11	1.5	88.835	11.77	1.61

**TABLE.2.FLEXURAL STRENGTH RESULTS**

S.NO	Name of the MIX	% Volume replacement of Coarse aggregate	% of Admixtures in equal proportions	% of Nano (Fe <sub>2</sub> O <sub>3</sub> ) on 11% of cement	% of cement	Flexural strength in N/mm <sup>2</sup>	increase or decrease in Flexural strength in %
						28 days	28 days
1	LA <sub>1</sub>	100	0	0	100	1.075	0
2	LA <sub>2</sub>	100	11	0.5	88.945	1.343	24.63
3	LA <sub>3</sub>	100	11	1.0	88.890	1.343	24.63
4	LA <sub>4</sub>	100	11	1.5	88.835	1.075	0

**TABLE3.YOUNG'S MODULUS**

S.NO	Name of the MIX	% Volume replacement of Coarse aggregate	% of Admixtures in equal proportions	% of Nano (Fe <sub>2</sub> O <sub>3</sub> ) on 11% of cement	% of cement	Youngs Modulus E=5000√fck in *10 <sup>4</sup> N/mm <sup>2</sup>	increase or decrease in Youngs modulus in %
						28 days	28 days
1	LA <sub>1</sub>	100	0	0	100	1.73	0
2	LA <sub>2</sub>	100	11	0.5	88.945	1.75	1.1
3	LA <sub>3</sub>	100	11	1.0	88.890	1.78	1.7
4	LA <sub>4</sub>	100	11	1.5	88.835	1.72	0.57

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**TABLE 4: ULTIMATE LOAD IN MODE-II FOR DCN SPECIMENS WITH a/w RATIOS = 0.30, 0.40**

Name of the MIX	% Volume replacement of Coarse aggregate	% of Admixtures in equal proportions	% of Nano (Fe <sub>2</sub> O <sub>3</sub> ) on 11% of cement	% of cement	a/w=0.3		a/w=0.4	
					Ultimate load in KN	% increase or decrease in ultimate load	Ultimate load in KN	% increase or decrease in ultimate load
LA <sub>1</sub>	100	0	0	100	53	0	48	0
LA <sub>2</sub>	100	11	0.5	88.945	56	5.6	50	4.1
LA <sub>3</sub>	100	11	1.0	88.890	58	9.4	52	8.33
LA <sub>4</sub>	100	11	1.5	88.835	52	1.8	51	6.25

**TABLE5: ULTIMATE LOAD IN MODE-II FOR DCN SPECIMENS WITH a/w RATIOS = 0.50, 0.6**

Name of the MIX	% Volume replacement of Coarse aggregate	% of Admixtures in equal proportions	% of Nano (Fe <sub>2</sub> O <sub>3</sub> ) on 11% of cement	% of cement	a/w=0.5		a/w=0.6	
					Ultimate load in KN	% increase or decrease in ultimate load	Ultimate load in KN	% increase or decrease in ultimate load
LA <sub>1</sub>	100	0	0	100	41	0	35	0
LA <sub>2</sub>	100	11	0.5	88.94	44	7.31	43	22.87
LA <sub>3</sub>	100	11	1.0	88.89	48	17.01	45	28.75
LA <sub>4</sub>	100	11	1.5	88.83	43	14.283	40	14.25

**TABLE 6: IMPACT STRENGTH**

Name of the MIX	% Volume replacement of Coarse aggregate	% of Admixtures in equal proportions	% of Nano (Fe <sub>2</sub> O <sub>3</sub> ) on 11% of cement	% of cement	IMPACT STRENGTH	
					NO OF BLOWS	% increase or decrease in blows
LA <sub>1</sub>	100	0	0	100	93	0
LA <sub>2</sub>	100	11	0.5	88.945	103	10.25
LA <sub>3</sub>	100	11	1.0	88.890	107	15
LA <sub>4</sub>	100	11	1.5	88.835	105	2.91

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**TABLE 7: DENSITY AND PERCENTAGE INCREASE OR DECREASE IN DENSITY**

Mix	% Volume replacement of coarse aggregate	% of admixtures in equal proportions	% nano ( $Fe_2O_3$ ) on 11% of cement	% of cement	Density in Kg/cum	Percentage increase or decrease in density
LA0	100	0	0	100	1540	0
LA1	100	11	0.5	88.945	1556	1.03
LA2	100	11	1	88.890	1600	3.896
LA3	100	11	1.5	88.835	1572	2.079

The following figures are presented in this thesis.



Thermocol aggregates before oven



Impact test



Thermocol concrete mixing



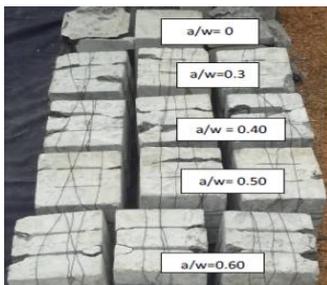
Thermocol aggregates preparation in oven

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DCN specimen cracking after 28 days

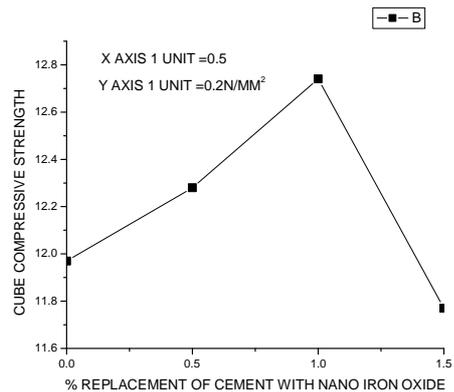


Fig.1 Compressive strength of cube



Flexure test after 28days curing

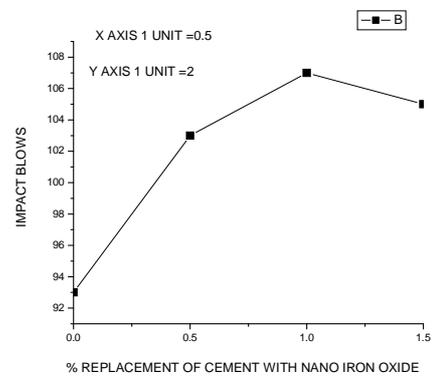
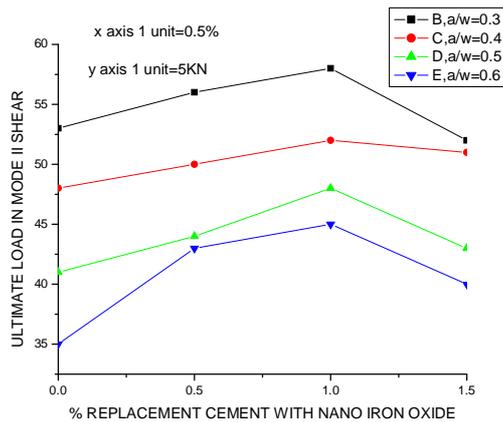
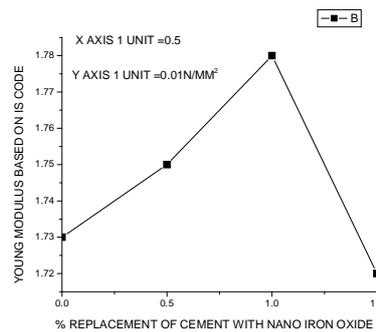


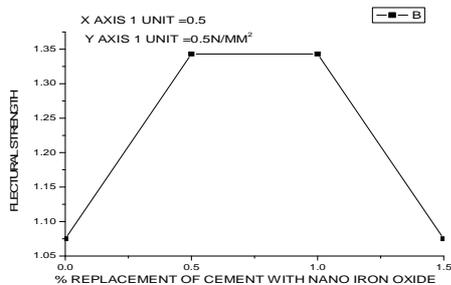
Fig.3 Impact strength



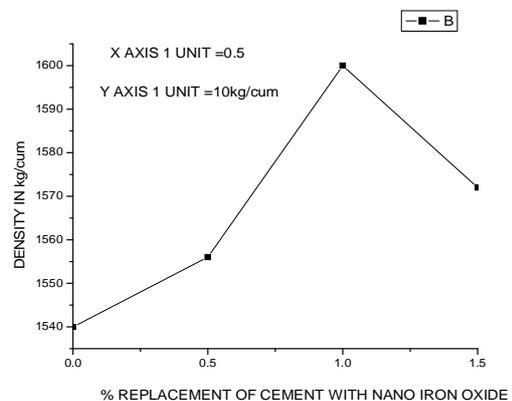
**Fig.5 Super imposed of ultimate load a/w ratio**



**Fig.4 Young's modulus based on IS CODE formula**



**Fig.2 Flexural strength**



**Fig.6. Density variation curve**

## VI. CONCLUSIONS

From the limited experimental study of the following conclusions are seem to be valid:

1. The target mean strength of  $M_{20}$  concrete is  $26.60 \text{ N/mm}^2$ . From the experimental study it is observed that the 28 days cube compressive strength of modified concrete with 100% Styrofoam aggregate is  $11.97 \text{ N/mm}^2$ . With the replacement of cement by 11% with three numbers of pozzolanic materials i.e., silica fume, slag, flyash are in equal proportioning along with nano  $\text{Fe}_2\text{O}_3$  in the spells of 0.5%, the cube compressive strength of modified concrete rises to  $12.74 \text{ N/mm}^2$  at 1%, which is found to be optimum.
2. With the increase in percentage of Nano  $\text{Fe}_2\text{O}_3$  up to 1% and with constant 11% pozzolanic materials replacing the cement, there is an increase in flexural strength and Young's modulus and with further increase in Nano  $\text{Fe}_2\text{O}_3$  content, there is decrease in both values.

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3. For all a/w ratios, it is observed that with the increase in the a/w ratio there is decrease in ultimate load in plane shear. There is an increase in plane shear ultimate loads up to 1% of Nano Iron-Oxide addition and there after slightly get decreased with further addition of nano material .
4. With the increase in percentage of Nano Fe<sub>2</sub>O<sub>3</sub> up to 1% and with constant 11% pozzolanic materials addition replacing the cement, there is increase in impact blows and afterwards decreases beyond 1%.
5. With the increase in percentage of Nano Fe<sub>2</sub>O<sub>3</sub> up to 1% and with constant 11% pozzolanic materials replacing the cement, there is an increase in density and afterwards it decreases.

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