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A BRIEF STUDY ON THE STRENGTH PROPERTIES OF CONCRETE MODIFIED WITH SINTERED FLY ASH AGGREGATE AND PENTA BLENDED CEMENT WITH NANO IRON OXIDE

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Abstract: *Effective usage of fly ash in concrete not only extends technical advantage to the properties of concrete but also contributes to the environmental pollution control. Fly ash based light weight aggregate offer potential for large scale utilisation in the construction industry. However lack of technology and absence of market have dissuaded Indian entrepreneurs from producing Sintered fly ash aggregates. An attempt is being made to study the strength properties of modified M_{20} grade concrete by 100% replacement of natural aggregates with Sintered fly ash aggregates. It is also proposed to replace 11% 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 Fe_2O_3 in spells of 0,0.5,1,1.5 and 2% on 11% of pozzolanic materials. The rate of the pozzolanic reaction is proportional to the amount of surface area available for reaction. i.e it is possible to add Nano Fe_2O_3 in order to improve the characteristics of cement mortars. After 28days varies tests were carried out on the modified complete with penta blended cement i.e compressive strength test flexural strength test, modulus of elasticity test, impact test, in plane shear strength through mode-II fracture test with and without admixtures.*

Key words: Sintered fly ash aggregates, admixtures, concrete, iron oxide, various tests.

1. Introduction

The management of coal fly ash produced by thermal power stations is a major problem in many parts of the world. However its generation tends to increase every year. India produces about 120 million tones of fly ash annually. Although some fly ash is used in wide range of applications particularly as a substitute for cement in concrete, large amount of fly ash ie, about 75% of production remain unused and thus required disposal. Due to continuous usage of naturally available aggregates, within short length of time these natural resources get depleted and it will be left nothing for future generations. The use fly ash for production of sintered fly ash light weight aggregate is an appropriate step to minimize the consumption of precious natural resources on one hand and showing an alternate mode for disposal of ever increasing production of fly ash year by year. The fly ash is mixed with limited amount of water and pellets were formed through the technique of agglomeration and pelletizing and then sintered at a temperature of 1000^0C to 1200^0C .The fly ash may contain some unburnt coal which may vary from 2 to 15 percent depending upon the efficiency of burning. The aim is always to make use of the fuel present in the fly ash and to avoid the use of extra fuel materials. The burning of carbon in the pellets and loss of moisture creates a cellular structural bonded together by the fusion of fine ash particles.

The basic purpose of using Nano materials in concrete is to improve the compressive and flexural strength compared to early age. It is possible due to the high surface to volume ratio. It also helps to improve the pore structure of concrete. Nano size materials help to reduce porosity as they absorb less water compare to traditional cementitious materials. The presence of Nano materials reduces the amount of cement content in concrete than the conventional concrete. This can be achieved without compromising much with basic the strength characteristics.

2. Review of literature

V V Arora, et.al. (1) Investigated the suitability of Sintered fly ash aggregate in strength properties with water cement ratios of 0.45 and 0.55. The various Mechanical properties such as Compressive strength, Flexural strength, Split tensile strength, Drying shrinkage, Modulus of Elasticity and Poisson's ratio has been determined.

Abdul Rahim and Sandanu. R.Nair (2) 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.

Thorenfeldt, E (3) reported that Light Weight Aggregate Concrete has a faster hardening factor in the initial setting phase than conventional concrete, normally reaching 80 % of the 28 day strength within 7 days. The strength growth from 28 to 90 days is generally low and decreases with increasing concrete strength level. This is assumed to be a consequence of the strength limiting effect of the light weight aggregate.

Arvind Kumar & Dilip Kumar (4) reported that the maximum compressive strength of 36.25 N/mm^2 is attained at 12% replacement of Sintered fly ash aggregate in concrete while the minimum strength of 26.68 N/mm^2 is attained at 20% replacement,. 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.

Prakash Desai, et.al. V (5,6,7,8,9&10) 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 in Plate 2.1.

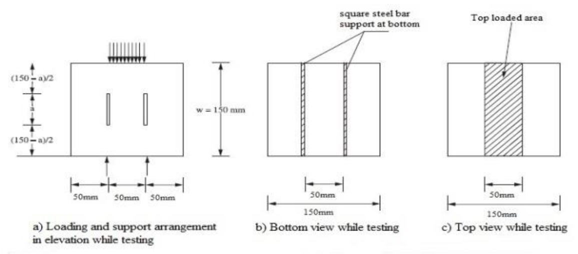

Fig:1 Details of DCN specimen geometry

From the brief literature summary conducted here it appears that much less attention has been paid earlier on the study of sintered fly ash aggregate concrete modified with Nano material such as ironoxide. Hence the present investigation has been under taken.

3. Objective

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

By replacing of conventional coarse aggregate in concrete to produce light weight concrete.

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. Artificial Coarse aggregate i.e sintered fly ash aggregates
4. Fly ash
5. Silica fume
6. Slag
7. Water

4.1 Cement & fine aggregate:

ACC 53 grade cement and locally available sand were used which have following properties.

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	2.4

Sintered fly ash aggregates: This may be the normal coarse aggregate sintered aggregate sintered fly ash aggregate is procured from Litagg Company, Ahmedabad is used in this investigation.

Typical physical characteristics of sintered fly ash aggregates are as follows.

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

Specific gravity : 1.777

4.3 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 used here are designated as follows they have.

Name of the MIX	% Volume replacement of Coarse aggregate (sintered fly ash aggregate)	% of cement replacement by admixtures in equal proportions	% of Nano (FE_2O_3) on 11% of cement	% of cement
NA0	100	0	0	100
NA1	100	11	0.5	88.945
NA2	100	11	1.0	88.890
NA3	100	11	1.5	88.835
NA4	100	11	2	88.780

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 iron oxide in required percentages were mixed thoroughly and then Sintered fly ash aggregates were added with them. All of these were mixed thoroughly by hand mixing. For each mix & 12 nos of DCN 150X150X150mm specimens for four a/w ratios with replacement of cement by 11% of its weight by
three numbers of pozzolanic materials (Silica fume, fly ash and Slag) and Nano iron oxide with varying percentages (0%, 0.5%, 1%, and 1.5%) on 11% weight of cement and along with 3 no's of plain cubes, 3no's of plain beams of size 500mmX100mmX100mm were cast. 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.

4.4Testing of specimens

4.4.1 Compressive strength of cubes: Compressive strength of cubes was calculated by dividing load taken by the specimen by the cross sectional area. Values of compressive strength at different percentages of Nano iron oxide are given in table 1 below.

4.4.2 Flexural strength: Flexural strength is one measure of the tensile strength of the concrete. It is a measure of strength to resist failure in bending. The flexural strength can be determined by standard test method of two point loading or center point loading. In this study, three beams of size 100*100*500 mm were used to find the flexural strength in two point loading. The values are presented in table 2.

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

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

Where f_{ck}= Characteristic Compressive strength of concrete in N/mm^2

4.4.4 Mode II fracture test

For testing DCN specimens of size 150x150x150mm, notches were introduced at one third portion centrally during casting. The compression 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 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.(fig:1)

5. Discussion of test results

5.1 Influence of iron oxide on cube compressive strength

In the present study natural aggregate was fully replaced with sintered fly ash aggregates. The variation of compressive strength verses percentage replacement of cement with iron oxide addition at 28 days is shown in figures 2. From the above figures it may be observed that with the addition of Nano Fe_2O_3 the cube compressive strength increases continuously for 0.5%, 1% & 1.5% and with more addition of Nano Fe_2O_3 the strength is decreased. Here 1.5% is observed to be of optimum. The results are tabulated in table 1.

5.2 Influence of Nano Fe_2O_3 on flexural strength of beam specimens

The results are tabulated in table 2 and graphically presented in fig 3 .In the present study natural aggregate was fully replaced with sintered fly ash aggregates. From the results it is seen that the flexural strength of beams is increased continuously from 0.5% to 1.5% addition of Nano Fe_2O_3 and beyond 1.5% it is observed to be decreased. The percentage variation is less than the compressive strength.

5.3 Influence of Nano Fe_2O_3 on modulus of elasticity

The modulus of elasticity results with various percentages of Nano Fe_2O_3 are presented in table 3 for 28 days based on IS code as (11) mentioned above. From the results it is observed that modulus of elasticity has been increased continuously from 0.5% to 1.5% addition of nanomaterial and the percentage variation is less than the compressive strength. Beyond 1.5% addition it is decreased.

5.4 Discussion on the effect of Nano Fe_2O_3 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 iron oxide 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 Fe_2O_3 are presented in table 5which are presented for different a/w ratios after 28 days .The graphical variation are presented in fig:5. From these diagrams it is observed that with the increase in the a/w ratio there is decrease in ultimate load and also there is increase in ultimate loads up to 1.5% of Nano Fe_2O_3 and thereafter decreased for all a/w ratios.

5.5 Influence of Nano Fe_2O_3 on density

Density of modified concrete with sintered fly ash aggregates with Nano Fe_2O_3 is decreased when compared to that for natural aggregate concrete**.** The density results are presented in table 4. From the results it is observed that density of modified concrete has been increased continuously from 0.5% to 1.5% and the behavior is more or less same as that for compressive strength.

5.6 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 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

Table1: Compressive strength of cubes

Mix	% Volume replacement of coarse aggregate (sintered fly ash aggregate)	% of admixtures in equal proportions	% Nano Fe_2O_3 on 11% of cement	% of cement	Cube compressive strength in N/mm^2	Percentage increase or decrease of compressive strength
NA0	100	0	0	100	24.80	0
NA1	100	11	0.5	88.945	30.38	22.5
NA2	100	11	1	88.890	34.20	37.90
NA3	100	11	1.5	88.835	37.06	49.43
NA4	100	11	2	88.780	33.14	35.25

Table2: Flexural strength of beams

Mix	% Volume replacement of coarse aggregate (sintered fly ash aggregate)	% of admixtures in equal proportions	% Nano Fe_2O_3 on 11% of cement	% of cement	Flexural strength in N/mm^2	Percentage increase or decrease of flexural strength
NA0	100	0	0	100	3.20	0
NA1	100	11	0.5	88.945	3.38	5.526
NA2	100	11	1	88.890	3.52	9.896
NA3	100	11	1.5	88.835	3.80	18.638
NA4	100	11	2	88.780	3.45	8.562

Table3: Modulus of elasticity

Mix	% Volume replacement of coarse aggregate (sintered fly ash aggregate)	% of admixtures in equal proportions	% Nano Fe_2O_3 on 11% of cement	% of cement	Modulus of elasticity in N/mm^2	Percentage increase or decrease of modulus of elasticity
NA0	100	0	0	100	2.49	0
NA1	100	11	0.5	88.945	2.75	10.441
NA2	100	11	1	88.890	2.92	17.269
NA3	100	11	1.5	88.835	3.04	22.08
NA4	100	11	2	88.780	2.85	15.43

Table 4: Density

Mix	% Volume replacement of coarse aggregate (sintered fly ash 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
NA0	100	0	0	100	2044	0
NA1	100	11	0.5	88.945	2057	0.63
NA2	100	11	1	88.890	2071	1.32
NA3	100	11	1.5	88.835	2097	2.59
NA4	100	11	2	88.78	2042	-0.09

Table 5: Ultimate loads in Mode-II fracture test

Name of the mix	% of replacement of coarse aggregate (sintered fly ash aggregate)	% of admixtures	% of nano iron oxide	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
NA0	100	0	0	119	0	106	0	84	0	62.3	0
NA1	100	11	0.5	120.12	1.93	109	1.886	86.21	2.63	64.53	3.04
NA2	100	11	1	121.91	1.6	111.12	4.83	87.59	4.27	66.34	4.87
NA3	100	11	1.5	122.12	1.7	114.43	7.95	88.67	7.04	69.81	12.05
NA4	100	11	2	120.43	1.4	108	3.12	85.12	3.20	63.19	2.42

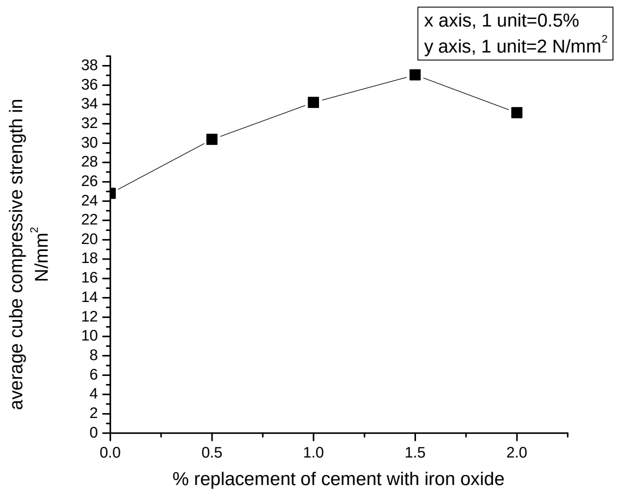

Fig 2: Compressive strength of cubes

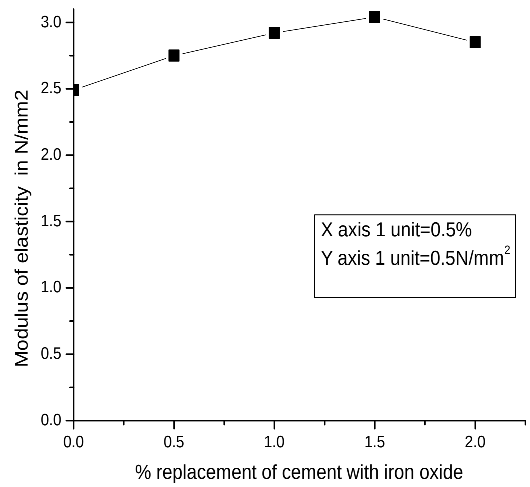

Fig 4: Modulus of elasticity

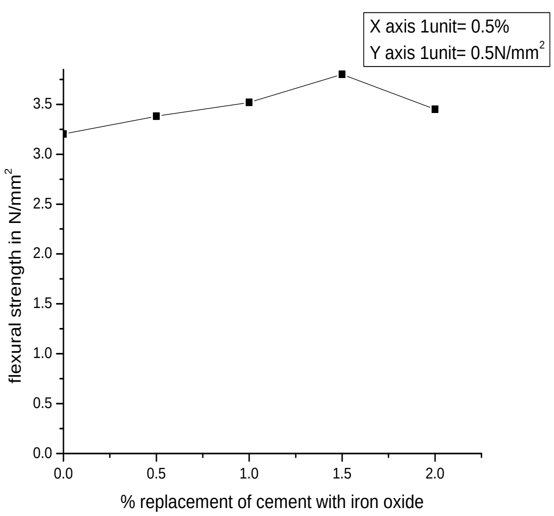

Fig 3: flexural strength

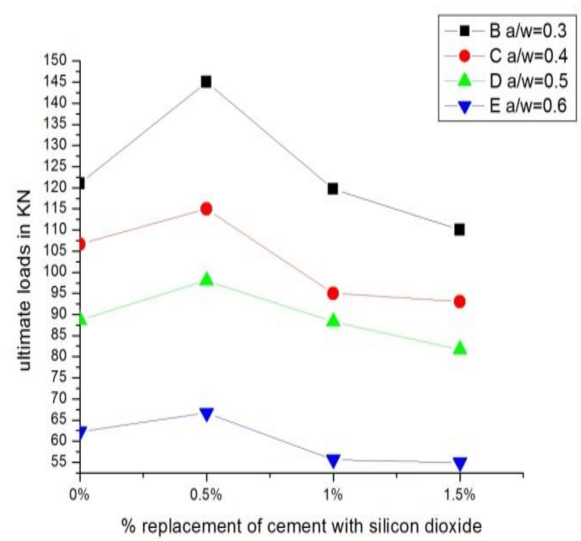

Fig 5: superimposed loads in mode-II for different a/w ratios

6. Conclusions

- 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% Sintered fly ash aggregate is 24.80 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 1.5% of Nano Fe_2O_3 the cube compressive strength of modified concrete rises to 37.06 N/mm^2 which is much higher than target mean strength of M_{20} concrete. In the present study 1.5% of nano ironoxide is optimum

- With 1.5% of Nano Fe_2O_3 and constant 11% pozzolanic materials replacing the cement there is increase in flexural strength and Young's modulus and with further increase of Nano Fe_2O_3 content there is decrease in both the values.

- It is observed that with the increase in the a/w ratio there is decrease in ultimate loads in mode-II. There is increase in ultimate loads upto 1.5% of Nano Fe_2O_3 and with further increase in Nano Fe_2O_3 content there is decrease in ultimate loads for all a/w ratios.

- The light weight concrete prepared by 100% Sintered fly ash aggregate as coarse aggregate is no way inferior to the natural aggregate and also consumption of cement can be reduced by about 11%.

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