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An Experimental Investigation of Strength and Thermal Analysis on Mortar with Micro and Nano Flyash

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ABSTRACT

This works aims to study the effect of partial substitution of ordinary Portland cement (OPC) by micro flyash and Nano flyash on the mechanical properties of mortar is investigated. The mechanical properties and thermal analysis of mortar were studied with the combination of micro flyash and nano flyash. A total number of 102 mortar cubes were cast in 70.6mm x 70.6mm, were crushed including the trail experiment. It was calculated with the particular water cement ratio of 0.38. The phase composition of the hydration products was investigated using X-ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscope (SEM), and Energy-Dispersive X-ray Spectroscopy (EDX) were taken to study the morphological and mineralogical composition of the material. The compressive strength of concrete generally increases with increase in the fineness so as to obtain a reduction in porosity. The addition of small closely spaced and uniformly dispersed materials to mortar would substantially improve its mechanical and fire-resistant properties. To increase the fineness of flyash it is converted to nano particles by using ball mill apparatus. Nano flyash acts as a filler agent and it improves the pore structure. From the results, at 600˚C flyash and nano flyash combination resist the heat and reduction in mass were observed.

Keywords : Flyash, Nano Flyash, Compressive Strength, and Elevated Temperature.

I. INTRODUCTION

Fly ash is a by-product of thermal power station in Tutucorin. The utilization of fly ash in concrete as a raw material for cement production and as a partial replacement of cementing concrete is well established [4]. Consumption of fly ash in manufacture of concrete is more environmentally friendly [5]. Fly ash would reduce the exploitation of natural resources. This gives considerable savings in consumption of cement. One of the major constituent materials in concrete is cement and its production and energy demand is well established [35]. The contribution of cement industry to the CO_2 emissions is about 5% of the global CO_2 [12]. The cement sustainability initiative progress report shows that combustion acquires 40% whilst calcinations acquires 60% of the total CO_2 emissions from cement manufacturing process [12]. The worldwide cement industry contributes around 1.65 billion tons of the greenhouse gas emissions annually [15]. During manufacture 1 ton of cement produce 1 ton of CO_2 are produced. CO_2 is most harmful greenhouse gas about 0.66 to 0.82kg for every kilogram of its manufacture that may lead to global warming which in turn affects the environment [7]. Due to production of Portland cement, it is estimated that by the year 2020 the CO_2 emissions will rise by about

50% from current levels [15]. Therefore, to preserve the global environment from the impact of cement production, it is now believed which new binders are indispensable to replace Portland cement [15]. In this regard, the flyash is one of the revolutionary developments related to novel materials resulting in low cost environmentally friendly [15]. SiO_2 and Al_2O_3 in the flyash react with calcium hydroxide formed as a result of hydration of Portland cement and start a pozzolanic reaction. For this main reason flyash can be used instead of Portland cement. The contribution of cement industry to CO_2 emissions about 5% of the global CO_2 emissions [12]. It is an important need to product the environment from pollution by finding a suitable binder that can act as an excellent alternative in the place of cement to make a sustainable development in the construction industry [7]. Flyash is usually described as the finely divided residue that result from the combustion of ground or powdered coal that is transported by flue gases from the combustion zone to particle removal system. Flyash from bituminous and anthracite coals is referred. ASTM class F flyash or low calcium flyash [8]. It is attracted more attention due to its availability in large quantities and its ability. It is an alumina and silica-rich waste material [11]. It is a mineral admixture which enhances flowability in the fresh state of concrete and its widely recommended as a partial replacement of cement. In order to reduce the usage of ordinary Portland cement in concrete recent environmental awareness in construction industries promote the use of supplementary cementitious materials such as flyash, granulated blast furnace slag (GGBS), rice husk ash (RHA), silica fume and meta kaolin(MK) [23]. Hence in this study in order to make flyash as energy efficient material the specimen is subjected to curing condition at muffle furnace. Compressive strength, split tensile strength, thermal test such as compressive strength are studied [7]. Literature indicated that man y researchers have investigated the effect of flyash in concrete consisting of partial replacement of cement by flyash. The present investigation is designed to evaluate the mechanical properties .

II. MATERIALS

A. Cement

Ordinary Portland Cement (OPC) was used in the concrete mix. It has a specific gravity of 3.12, percentage of water required for obtaining cement paste of standard consistency as 28% and initial and final setting time of 30 minutes and 120 minutes respectively.

B. Fine aggregate

Good quality natural river sand, belonging to Zone II (according to IS 383 - 1978), It has a specific gravity of 2.65 and fineness modulus of 3.14

C. Flyash

Fly ash is generated as a combustion by product of coal. It is used as a fuel in thermal industries. The specific gravity of fly ash is 2.33.

D. Super Plasticizer

CONPLAST SP430 (NE) was high range water reducing admixture for increasing the workability. It is a brown liquid containing no chloride content and complies with IS 9103 – 1999. The maximum dosage of super plasticizer in high strength concrete is 2% by the total weight of cement content.

CHARACTERIZATION

A. SEM

A scanning electron microscope (SEM) scans a focused electron beam over a surface to create an image. The electrons in the beam interact with the sample, producing various signals that can be used to obtain information about the surface topography and composition. After the SEM result flyash sample is confirmed that the sample is below 10^{-9} in size.

B. FTIR

Fourier Transform Infrared Spectroscopy, also known as FTIRAnalysis or FTIR Spectroscopy, is an analytical technique used to identify organic, polymeric, and in some cases, inorganic materials.

FTIR works relies on that fact that the most molecules absorb light in the infra-red region of the electromagnetic spectrum. This absorption corresponds specifically to the bonds present in the molecule. The frequency range are measured as wave numbers typically over the range 4000-600 $cm^{-1.}$ The FTIR spectra of flyash the peaks at 1,084 cm^{-1} are attributed to asymmetric stretching of Al-O and Si-O bonds originated from individual tetrahedral. The band located at 786 cm–1 is assigned to tetrahedral groups AlO_4 condensed and SiO_4. 1,083 cm^{-1} are attributed to asymmetric stretching of Al-O and Si-O bonds originated from individual tetrahedral. The band located at 693 cm–1 is assigned to tetrahedral groups AlO4 condensed and SiO4 .

C. XRD

X-ray diffraction ,used to study the structure, composition and properties of materials The analyzed material is finely ground, homogenized and average bulk composition is determined. The phase composition of the hydration products was investigated using XRD. As shown in fig 4 mostly quartz and magnetite are presented in nano flyash. The XRD peak pattern are obtained from Cu Kα radiation using (λ= 1.5406 Å) of an accelerating voltage of 40 kV in the current of 30 mA with a scanning rate of 0.02º/s. The probable reaction products would be calcium silicate hydrate (C-S-H) or calcium aluminosilicate either in amorphous or poorly ordered crystalline form which would be difficult to detect by XRD. After milling ash content of the XRD pattern are revealed as shown in fig 4.

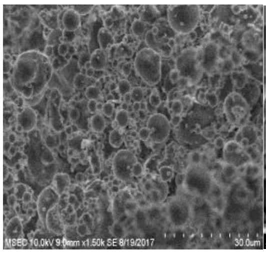

Fig 1:SEM Analysis of Flyash

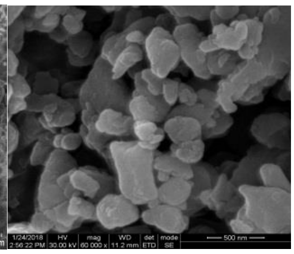

Fig2: SEM Analysis of as nano particles flyash

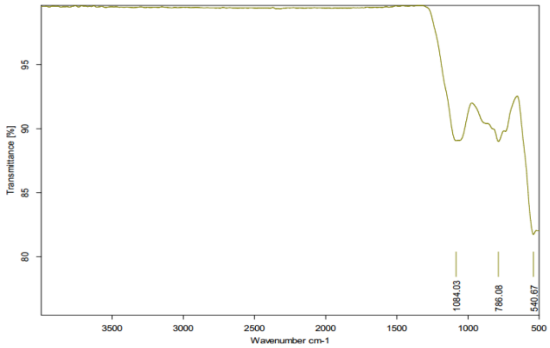

Fig3: FTIR Analysis of Nano Flyash

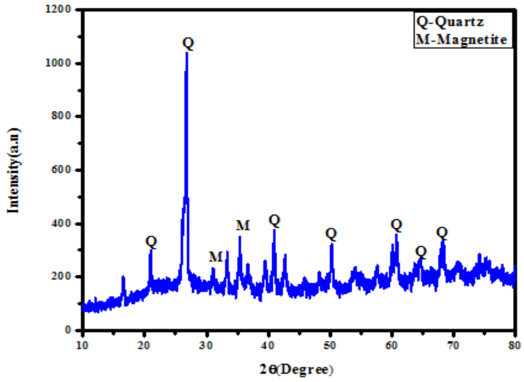

Fig4: X-ray spectrum for nano flyash

Table 1.chemical composition of OPC,Micro flyash and Nano flyash

Chemical composition	OPC	Micro flyash	Nano flyash
SiO_2	3.4	48.3	48.8
Fe_2O_3.	4.4	12.1	9.5
Al_2O_3	5.5	30.5	26
MgO	1.26	1.2	2.6
SO_3	1.92	0.3	3.8
K_2O	0.48	0.4	2.3
CaO	63	2.8	7.5
Tio2			0.3
Loss on ignition	3.15	1.7	6.6

III. EXPERIMENTAL PROGRAMME

A. Preparation of Test Specimens

Cube mortar of size 70.6mm x 70.6mm x 70.6mm, Cylinders of diameter 60mm and height 120mm and prism of length 500 mm and breath and depth 100 mm were cast for performing Compressive strength test, Split tensile strength test flexural strength test respectively at 7 days, and 28 days.

B. Thermal Degradation

Mortar is a non-combustible material, according to the properties of its constituents. It has very low thermal conductivity. Allthough it does not catch fire and emit any toxic substances, its properties undergo serious deteriorations when exposed to very high temperatures such as building fires. Up to a certain temperature like 95˚C there is no drawback to the properties. The extraction of water from the mortar

C. Compressive Strength Test

Compressive strength is a very important parameter for deciding on the mortar quality and performance. The compressive strength test was conducted according to ASTM C 39 [9]. Cube mortar specimens measuring 70.6mm x 70.6mm x 70.6mm, were prepared for each mix and tested. The compressive strength was reported based on the average of three cube specimens tested.

D. Split Tensile Strength Test

The split tensile strength was tested on cylindrical specimens 60 mm in diameter and 120 mm in height, after 28 days of curing

E. Flexural Strength Test

Flexural strength was tested on a prism specimen measuring 100 mm x 100 mm x 500 mm, according to ASTM C78/ C496 [11].

IV. RESULTS AND DISCUSSIONS

The effects of compressive strength, split tensile strength, flexural strength, were tested on samples and the corresponding results are tabulated in fig.1 to 9

A. Compressive Strength Test

The cube were tested in the Compression Testing Machine (CTM) to get their Compressive Strength. Fig.1 and Fig.2 shows the variation of those results for using replacement of micro fly ash and nano fly ash respectively. The optimum replacement of micro flyash is 45% and nano flyash is 8 %.

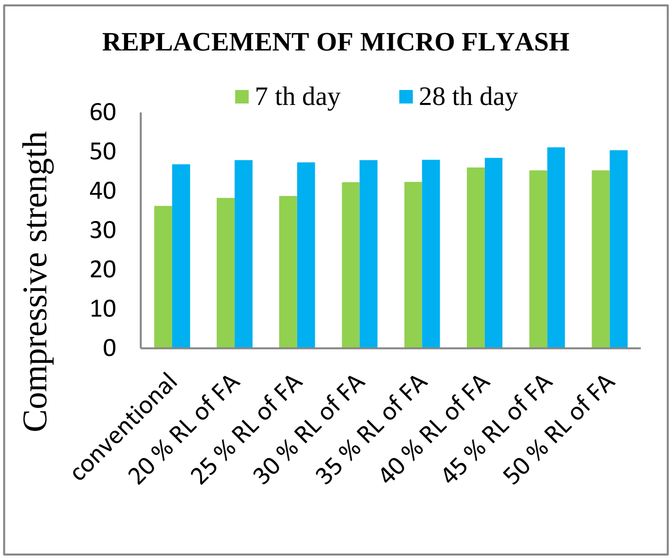

Fig.1 compressive strength using micro fly ash

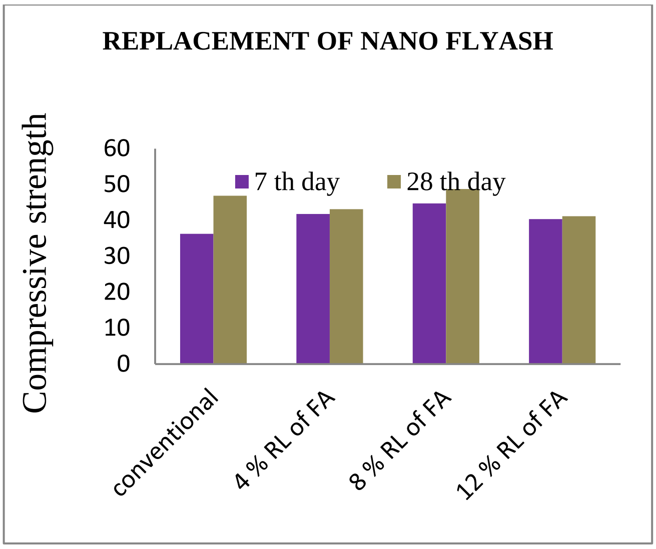

Fig .2 compressive strength using nano flyaash

B. Split Tensile Strength Test

The cylinder were tested in the Universal Testing Machine (UTM) to get their split tensile strength. Fig.3 shows the variation of those results for using 1:1 ratio.

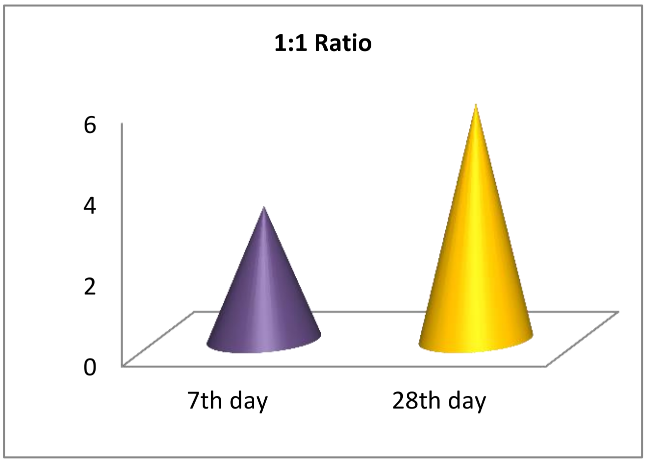

Fig.3 split tensile strength results

C. Flexural Strength Test

The prism were tested in the Universal Testing Machine (UTM) applies in 2 point loading to get their flexural strength. Fig.4 shows the variation of those results for using fly ash and nano fly ash.

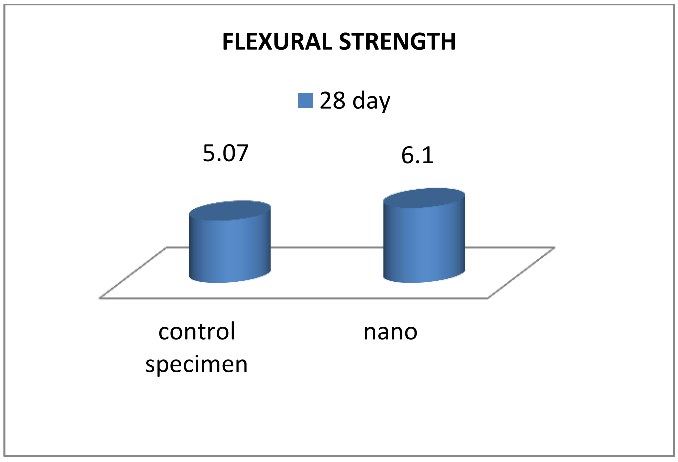

Fig.4 Flexural strength using nano fly ash

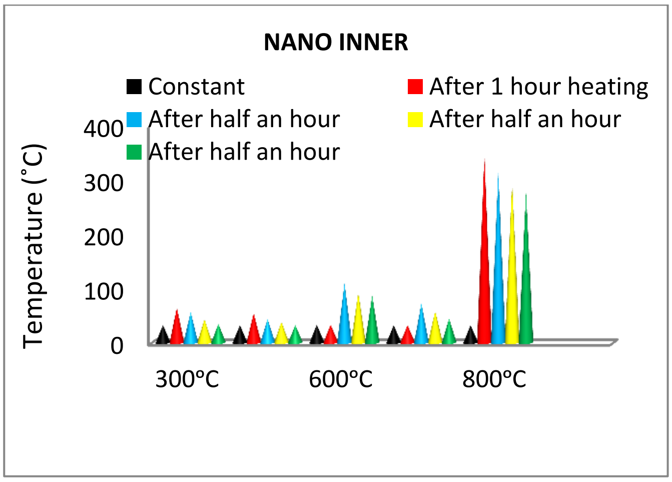

Fig.5 Inner thermal behaviour of flyash

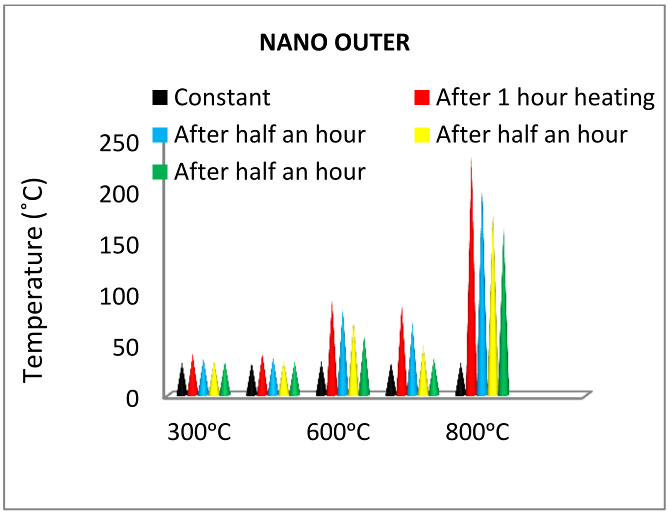

Fig.6 Outer thermal behaviour of flyash

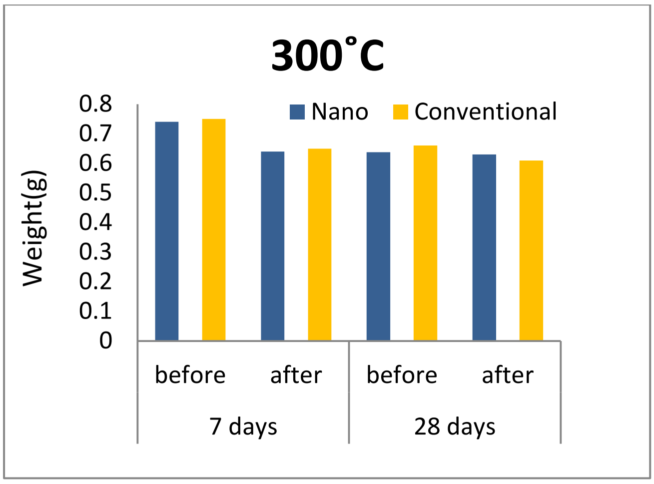

Fig 7. Weight loss at 300˚C

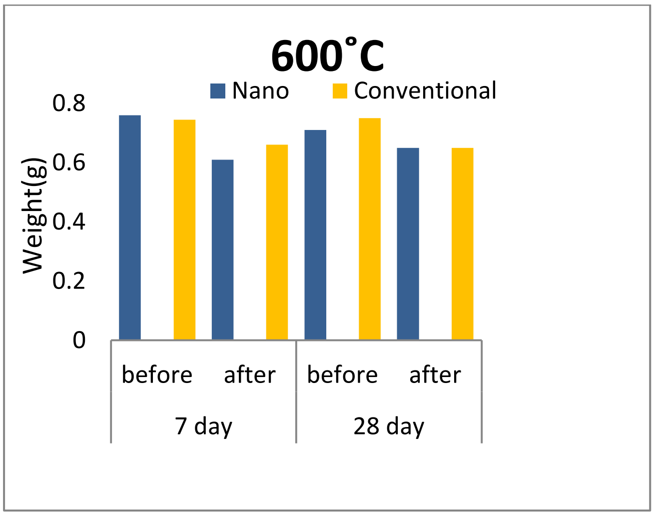

Fig 8. Weight loss at 600˚C

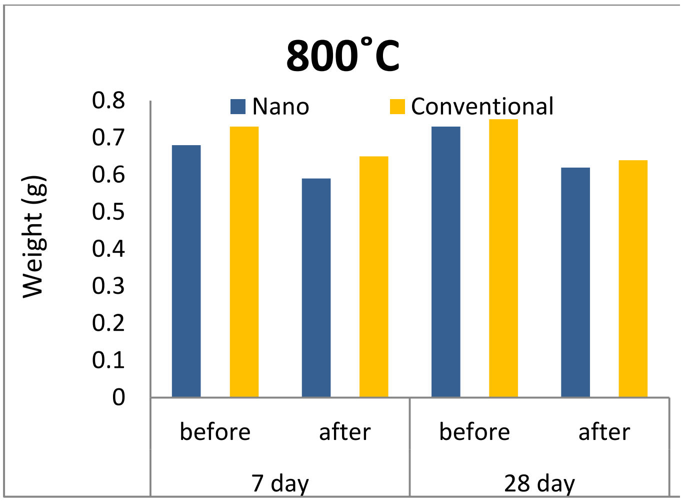

Fig 9. Weight loss at 800˚C

The specimens were then placed in the muffle furnace at different elevated temperatures for a time period of 1 hour. The specimens were again tested in the CTM to find out the residual compressive strength present in them. Fig 7 shows the values of compressive strength for various elevated temperatures. The results indicate that the compressive strength undergoes a considerable reduction on exposure to high temperatures. Upto 600˚C flyash and nano flyash combination resist the heat. At 800˚C the specimen underwent spalling along the edges, right after the application of temperature even before the application of any loads.

From the variation of core and surface temperature of the treated specimens, it can be observed that once the heat exposure is stopped and the concrete specimen is brought to room temperature, the core temperature reduces at a much slower speed when compared to the surface temperature as shown in fig 5 and fig 6.

The reduction in mass of mortar due to the effects of high temperature is also taken into account which is shown in fig 7. The percentage loss in mass is due to the creation of voids from the evaporation of water in the pores.

V. CONCLUSION

- ✓ Flyash increases the strength of mortar only upto certain level. On further addition, it becomes detrimental to the mortar.
- ✓ Nano flyash, does bring about any significant increase to strength or fire rsisitance of mortar.
- ✓ Optimum percentage of mortar is 8.4 % higher than the conventional mortar.
- ✓ While subjecting cured sample to an elevated temperature of 300 ˚C to 800˚ C, there is a decrease in strength of about 56%. There is damage at 800 ˚C and there is a little discoloration from grey to dark grey has been noticed.
- ✓ The addition of nano flyash greatly enhanced the early and higher age strength of flyash mortar.
- ✓ It is clearly seen that the influence of 8%nano flyash was very much effective in all fly ash

blended mixes. But, further increase in nano flyash beyond 12% decreased the compressive strength of flyash blended mixes at all ages.

- ✓ When seen from thermal analysis point of view a 8 % substitution of nano flyash showed a very good resistance to thermal effect.
- ✓ . Upto 600˚C flyash and nano flyash combination resist the heat. At 800˚C the specimen underwent spalling along the edges, right after the application of temperature even before the application of any loads.

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