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Development of Cost Effective Nano Materials and Egg Shell Waste Wall Tiles and Their Strength Behavior Studies

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Abstract: *Concrete, as the most popular cement composite in practical applications, was subjected to modification by replacing a portion of binder with Nanoparticles such as Nano silica and Nano fly ash. In arecent years, modification of cement composites by a Nanoparticles has attracted intense attention among researchers. Day-to-day activities of humans often generate solid wastes such as egg shell waste and the disposal of the same is usually a problem. The aim of this study was to investigate the feasibility of using Nano materials (Nano silica and Nano Fly ash) and egg shell together with white cement in the production of floor tiles.The cubes of different proportions that is (white cement, Nano silica, Egg shell) and (white cement, Nano fly ash, Egg shell) were cast. The compressive strength of concrete for these proportions were determined and also other mechanical and physical properties such as water absorption, impact resistance, wet transverse strength and bulk density were measured. The use of Nano particles in developing materials with desired properties has gained popularity and is being applied in the construction field. Nano-technology potentially offers the opportunity to improve the properties of concrete to suit the specific requirements.*

Index Terms: ***Wall Tiles, Egg Shell waste, Nano Silica, Nano Fly ash, Physical and Mechanical Characteristics.***

I. Introduction

Tiles are generally the manufactured piece of hard-wearing material such as ceramic, stone, metals, baked clay or even glass, commonly used for covering roofs, floors, walls or other objects and can range from simple square tiles to complex or mosaics. Tiles are most often made of ceramic, typically glazed for internal uses and unglazed for roofing, although recent technological advances have resulted in variety of tiles.

Nano Materials:

In general, it is easily noticeable that, the reduction in the particle size results in increase in surface to bulk atom ratio and increase in the surface area.

The increases in the surface area can be understood from the following example. The total surface area proportional to a given 1 cm^3 volume filled by particles with 1 cm^3 cube in size is 6 cm^2, whereas when the particle size is reduced to 1 μm^3 cubes and 1 nm^3 cubes in size, the surface area increases to 6 m^2 and 6000 m^2 respectively. Similarly the proportion of number of surface atoms to bulk atoms in 1 cm3 cube and 1 mm3 cube particles is < 10%. While, in the case of particles in the Nano meter range, i.e. 1 nm3 cube, 80% of atoms will be present on the surface.

Physicochemical Properties of Nano Materials:

The physical properties of nanostructured materials differ fundamentally from that of the corresponding bulk materials. This is due to the reduced dimensionality on the one hand, and to the modification of fundamental properties on the other hand as the system size approaches quantum mechanical scale. Optimization of geometry, structure, morphology and the electronic. Mechanical, and optical properties of Nano meter-sized systems are of fundamental importance for the design of nanostructures with favourable properties. Essentially, the reduction in the panicle size from bulk to Nano size results in an increase in the proportion of surface energy and also alters the inter-particle spacing.

Mechanical Properties:

Because of the Nano size, many of the mechanical properties of the materials are modified, among others, hardness and elastic modulus, fracture toughness, scratch resistance, fatigue strength, and hardness. Cutting tools made of nanomaterials, such as tungsten carbide, tantalum carbide, and titanium carbide, are harder, more wear-resistant, erosion-resistant, and last longer than their conventional (large-grained) counterparts. Similarly, ductile nature of the ceramics materials is also modified when the particle size is reduced to nanometer scale. Generally, ceramics are very hard, brittle, and hard to machine even at high temperatures. However, with a reduction in grain size, the properties change drastically that, the Nano-crystalline ceramics can be pressed and sintered into various shapes at significantly lower temperatures. Energy dissipation, mechanical coupling within arrays of components, and mechanical nonlinearities are influenced by structuring components at the nanometer scale.

Nano Silica:

A certain Nano silica content produced different effects on the strength when Nano silica wasincorporated into concrete with different water/cement (w/c) ratios. For instance, employing a content of Nano silica around 1% Nano silica into concrete with w/c ratio of 0.4 and 0.48 resulted in quite different gains in compressive strength of about 20% and 12%, respectively. Similarly, utilization of 2% Nano silica in high volume binary blended concrete with water to binder (w/b) ratio of 0.4 and 0.45 produced null and 16% strength gain, respectively.Concrete is normally reinforced by steel rebar's. Besides compressive strength, durability properties are also of high importance, when dealing with reinforced concrete. While strength of concrete containing Nano silica has received particular attention in the last decade, less consideration has been paid to its durability properties. So, recently, there are increasing number of studies in which several durability related properties of cement composites were investigated such as water sorptivity, resistance to chloride penetration, electrical resistivity, and carbonation resistance. Jalal et al. found that the water absorption of concrete decreases with the addition of Nano silica.

Nano Flyash:

Fly ash not only improves the durability and strength but also reduces the requirement of cement. However, the unique properties of fly ash such as fineness, specific surface area, particle shape, hardness, freeze-thaw resistance, etc. have paved way for its use in Construction and polymer industry. The utilization of fly ash is determined based on their properties.Fly ash also makes substantial contributions to workability and chemical resistance. In India, about 75% of energy supply is coal based and shall be so for the next few decades. Approximately 110 million tons of fly ash is produced per annum in the Country. Nearly 38% of the fly ash waste is utilized in the Country at present, in various fields including landfills, cement making and for the production of concrete.

During the past decade numerous researches have been carried out towards the effective utilization of fly ash and with understanding of potential environmental and health impacts associated with its disposal by land filling. In this paper, an attempt has been made to modify the particle size fly ash by transforming the micro sized fly ash into nanostructured fly ash using high energy ball mill. The surface properties can be modified by ball grinding. The smooth, glassy and inert surface of the fly ash can be altered to a rough and more reactive product by this technique. Nano-fly ash is used for the partial replacement of coarse aggregate.

Applications of Nanomaterials:

Nanotechnology has already contributed to number of innovative products in various engineering disciplines because of their unique and rewarding chemical, physical, and mechanical properties. One of popular application of nanomaterials is nanotubes. Carbon nanotubes (CNT) are one of an illuminative example for the potential of nanotechnology. The tensile strength of high carbon steel is around 1.2 GPa but the tensile strength of carbon nanotubes (CNT) is 63 GPa. Also they are known to be one of the strongest materials having been produced by nanotechnology so far.

Basically nanotechnology applications can be divided in to several categories. Thin films and engineered surfaces fall in to the one dimensional applications of nanomaterials. They have been used for fields like electronic and chemistry so they can't be considered as a new material. Two dimensional materials like tubes and wires are the other type of applications of nanotechnology. Nanowires are ultrafine wires or linear arrays of dots that are formed by self-assembly. Semiconductor nanowires are produced of silicon. There dimensional nanomaterial applications include nanoparticles like dendrimers and fullerenes. Dendrimers are spherical polymeric molecules that are formed through a nanoscale self-assembly process.

Egg Shell: Agricultural waste constitutes a significant proportion of the accumulated solid waste in many parts of the world. Egg shells are part of agricultural wastes that litter the environment. In the ever-increasing endeavors to convert waste to wealth, the efficacy of converting Egg shells to beneficial use becomes an idea worth investigating. The composition of the Egg shells lends the effects of its ash on the cement to be articulated. It is scientifically known that the egg shell is mainly composed of compounds of calcium.

II. Materials And Methodology

2.1 Collection of materials and its process

1. Nano materials

Required Nano materials (Nano Silica and Nano Fly ash) were supplied from two different firms, which we had contact the person and brought to our work. The process involves adding of two different Nano materials to a ratio to get the physical and mechanical properties.

Fig 2.1: Nano Silica

Fig 2.2: Nano Fly ash

2. Egg shells

The egg shells are collected from poultry farm and locals as a waste material. This process involves soaking of egg shells in water for 24 hours for easy removal of dirt and membrane. These Eggshells were then dried and crushed using mortar and pestle. The crushed eggshells are then sieved to get the fine powder. The presence of Calcium Carbonate in them plays a vital role in providing strength to the tiles.

Fig 2.3: Egg shell

3. White Cement

The cement which is used for our research work is J.K White cement confirming to IS 8042:2015. The White Cement was collected from the nearby shop. White cement resists the water penetration by binding with Nano materials and egg shell since White cement contains little iron-oxide (Fe_2O_3) and manganese (Mn).

Fig 2.4: White Cement

4. Pigments

Pigments, synthetic or otherwise, used for colouring tiles shall have durable colour. These pigments were collected from the shop. It shall not contain detrimental to concrete and shall be according to the colour required by one of the following or their combination.

Black or red or brown pigment IS 44, Green pigments IS 54, Blue pigments IS 55 or IS 56 or IS 3574 (Part 2), White pigments IS 411, Yellow pigments IS 50 or IS 3574 (Part 1).

Fig 2.5: Pigments

2.2 Methodology

The cubes of size (150 X 150 X 150) mm of different Proportions of (White Cement: Nano Silica: Egg shell) and (White Cement: Nano Fly ash: Egg shell) were cast and cured for 28 days.

Table 2.1: Mixing proportion of Nano Silica, Egg shell, Cement.

Cement: Nano Silica: egg shells	Cement(Kg)	Nano Silica(Kg)	Egg shells(Kg)
(1:1:0)	0.94	0.26	0.00
(1:1:1)	0.62	0.17	0.56
(1:1:2)	0.47	0.13	0.84
(2:1:1)	0.94	0.13	0.42
(1:2:1)	0.47	0.26	0.42
(1:2:2)	0.37	0.21	0.67
(2:1:2)	0.75	0.10	0.67
(2:2:1)	0.75	0.19	0.30
(1:0:1)	0.84	0.00	0.84
(2:0:1)	1.25	0.00	0.56

Table 2.2: Mixing proportion of Nano Fly ash, Egg shell, Cement.

Cement: Nano Fly ash: egg shells	Cement(Kg)	Nano Fly ash(Kg)	Egg shells(Kg)
(1:1:0)	0.94	0.26	0.00
(1:1:1)	0.62	0.17	0.56
(1:1:2)	0.47	0.13	0.84
(2:1:1)	0.94	0.13	0.42
(1:2:1)	0.47	0.26	0.42
(1:2:2)	0.37	0.21	0.67
(2:1:2)	0.75	0.10	0.67
(2:2:1)	0.75	0.19	0.30
(1:0:1)	0.84	0.00	0.84
(2:0:1)	1.25	0.00	0.56

These cubes were then subjected to Compressive strength test and water absorption test. After obtaining the proportion that gave the maximum compressive strength and minimum water absorption, the tile moulds of size (200X200X10) mm are fabricated and making of tiles is commenced. These tiles were then subjected to Impact resistance test, Wet Transverse strength test and Bulk density.

Fig 2.6: Cubes curing

Fig 2.7: Prepared Floor tile

2.2.1 Test conducted on cubes

1.Compressive strength test (IS 516:1959)

The Compressive strength of two cubes of all the proportions were tested by using Compressive testing machine of capacity 2000 KN. The average Compressive strength of each proportions is calculated.

2. Water absorption test (IS 2185 (Part 1): 2005)

For Water absorption test the dry weight of the specimen is taken first then the test specimen is completely immersed in water at room temperature for 24 hours. After 24 hours the specimen is removed from water and allowed to drain for one minute by placing on a 10 mm or coarser wire mesh, visible surface water is being removed with a damp cloth and immediately weighed.
Therefore, Water absorption is given by:

$$\text{Water absorption, percent} = \frac{A-B}{B} \text{ X } 100 \ldots\ldots (1)$$

Where, A=wet mass of unit in kg.
B=dry mass of unit in kg.

2.2.2 Test conducted on tiles

1. Impact resistance test (BS-1966)

In this test the spherical steel ball weighing approximately 438 grams and 19 mm diameter which was dropped from height related to the actual thickness of wall tile and the degree of shuttering or indention was recorded.

2. Wet Transverse strength test (IS 1237-1980)

In this test six full size tiles are selected and are immersed in water for 24 hours. After 24 hours the specimen is placed horizontally on two parallel supports with wearing sides upwards. The load is then applied and the breaking load 'P' is noted.
The wet transverse strength (f) shall be calculated as follows:

$$f = \frac{3PI}{2bt^2} \text{ N/mm}^2 \ldots\ldots (2)$$

Where, P is breaking load in N.
I is span between supports in mm.
b is tile width in mm.
t is tile thickness in mm.

3. Bulk density (IS 13630 (Part 2): 2006)

In this test dry mass of the specimen is noted first and then the specimen is immersed in boiling water for 3 hours. The height of the water should be at least 50 mm. The specimen is then cooled and measured after 1 hour. Therefore, Bulk density is calculated by the formula given below:

$$\text{Bulk density} = \frac{m_1}{V} \text{ g/cm}^3 \ldots\ldots (3)$$

Where, m_1 = mass of the dry tile in gm.
V =exterior volume in cm^3 (m_2-m_3).
m_2 = mass of the wet tile in gm.
m_3 = mass of the tile impregnated by boiling water method.

III. Results And Discussion

1. **Compressive strength and Water absorption for all the Proportions of (White cement: Nano Silica: Egg shells)**
2.

1. Compressive strength and Water absorption for all the Proportions of (White cement: Nano Silica: Egg shells)

Table 3.1:Avg Compressive strength values for 28 days.

Ratio	Avg Compressive strength (MPa)
(1:1:0)	9.2
(1:1:1)	8.05
(1:1:2)	8.00
(2:1:1)	17.68
(1:2:1)	6.20
(1:2:2)	1.30
(2:1:2)	11.1
(2:2:1)	9.9
(1:0:1)	9.12
(2:0:1)	10.13

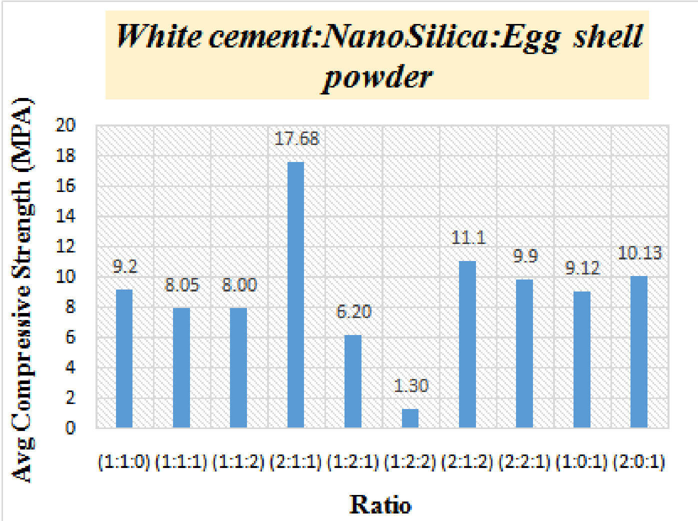

Fig 3.1: Graph represents Compressive Strength of cubes for 28 days.

As we all know compressive strength should always be high So, from the graph we can see that the highest ratio that satisfies our requirement is 2:1:1 with the higher compressive strength of 17.68 MPa. As the (White cement: Nano Silica: egg shell) ratio changes, the values also increases and decreases respectively.

Table 3.2: Water absorption values for 28 days.

Ratio	Water Absorption (%)
(1:1:0)	5.12
(1:1:1)	4.28
(1:1:2)	5.20
(2:1:1)	3.26
(1:2:1)	4.75
(1:2:2)	5.38
(2:1:2)	6.71
(2:2:1)	5.85
(1:0:1)	6.45
(2:0:1)	5.90

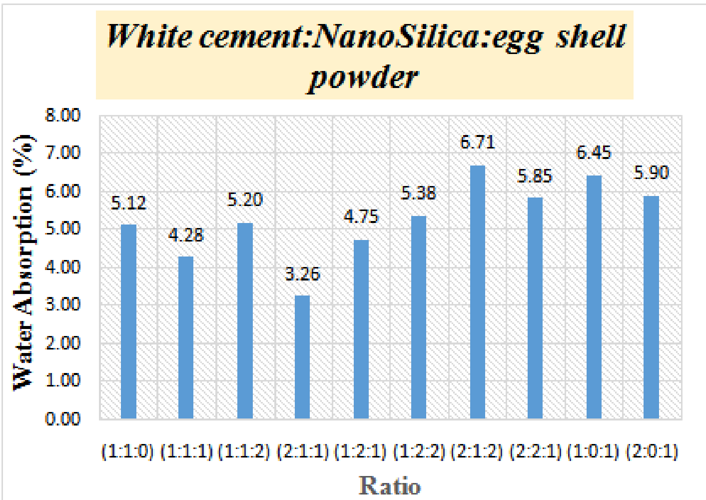

Fig 3.2: Graph represents Water absorption of cubes for 28 days.

In general, the water absorption with less value will be considered for making of tiles. From the graph the ratio that satisfies our requirement is 2:1:1 with the minimum water absorption of 3.26 %.

2. Compressive strength and Water absorption for all the Proportions of (White cement: Nano Fly ash: Egg shells)

Table 3.3:Avg Compressive strength values for 28 days.

Ratio	Avg Compressive strength (MPa)
(1:1:0)	8.13
(1:1:1)	6.98
(1:1:2)	6.58
(2:1:1)	15.98
(1:2:1)	6.03
(1:2:2)	0.86
(2:1:2)	10.29
(2:2:1)	9.68
(1:0:1)	8.57
(2:0:1)	10.95

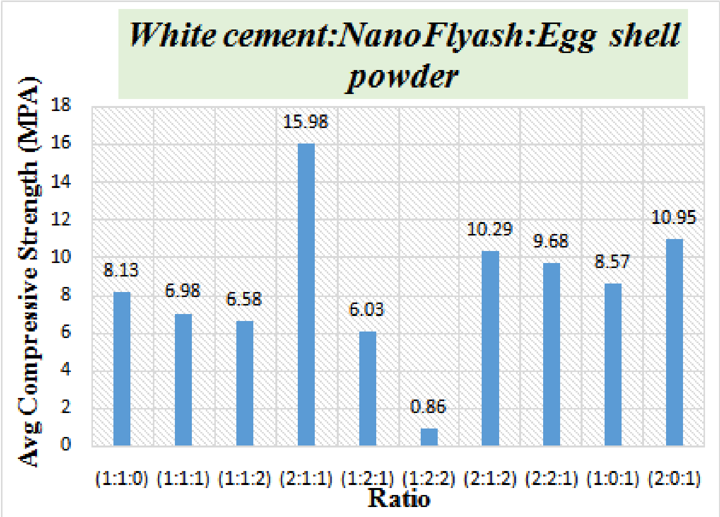

Fig 3.3: Graph represents Compressive Strength of cubes for 28 days.

From the graph we can see that the highest Compressive strength is 15.98 MPA for Proportion 2:1:1. But, this value is less than 17.68 MPA which is the Compressive strength of (White cement: Nano Silica: egg shell) for Proportion 2:1:1. Hence, Nano Fly ash is not considered for making of wall tiles.

Table 3.4: Water absorption values for 28 days

Ratio	Water Absorption (%)
(1:1:0)	4.75
(1:1:1)	4.28
(1:1:2)	4.55
(2:1:1)	3.66
(1:2:1)	5.43
(1:2:2)	6.45
(2:1:2)	5.50
(2:2:1)	4.73
(1:0:1)	6.21
(2:0:1)	5.10

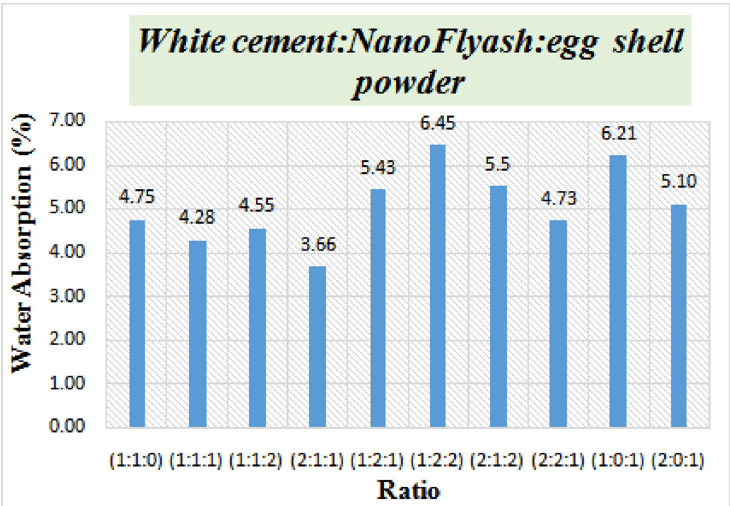

Fig 3.4: Graph represents Water absorption of cubes for 28 days.

Here, We can see from the above graph the minimum water absorption is 3.66 % for Proportion 2:1:1 which is more compared to 3.26 % which is the Water absorption obtained for Proportion 2:1:1 (White cement: Nano Silica: egg shell) .

3. Impact resistance test

As the steel ball was dropped 1st from a height of 0.3 m there was no dents or cracks or marks on the tile. Then the height was increased to 0.4m and the steel ball was dropped again but, still there was no cracks or dents. Later the height was increased to 0.7m and there was some dents that occurred on the tiles.

4. Wet Transverse strength test

3 tiles of the ratio (2:1:1) of size (200X200X10) mm was dried and tested on the same day on the machine.

Table 3.5: Wet Transverse strength of floor tiles.

Specimen identification	Wet Transverse strength(f)	Average Wet Transverse strength
Tile 1 (T1)	4.6	4.6N/mm^2
Tile 2 (T2)	4.8	
Tile 3 (T3)	4.4	

As per IS Specification the Wet Transverse strength should not be less than 3 N/mm^2. The average Wet Transverse strength of 3 tiles have been recorded as 4.6 N/mm^2 which satisfies the above condition.

5. Bulk density test

As per the IS Specifications for ceramic wall tiles the Bulk density is 2.94 g/cm^3. The value obtained after calculating the bulk density for the wall tiles was found to be 2.56 g/cm^3 which is close to the bulk density of the ceramic wall tiles as per IS Specifications.

IV. Cost Analysis

Table 4.1: Cost comparison for wall tiles.

Cost Comparison for 100 wall Tiles (2:1:1) of Size (200 x 200 x 10) mm			
Material	**Quantity in Kg**	**Rate/Kg**	**Total Cost**
White Cement	28.2	Rs. 37 /-	Rs. 1044 /-
Nano Silica	1.6	Rs. 780 /-	Rs. 1248 /-
Egg Shell Powder	12.6	Nil	Nil
Note: Since Egg Shell is a Waste Material, the Cost is Generally Nil			
Pigments	1	Rs. 250 /-	Rs. 250 /-
Total cost for our 100 Wall tiles			Rs. 2542 /-
Market Price for 100 (Ceramic) Wall tiles			Rs. 3500 /-
Therefore Total Savings made for our 100 Wall tiles			Rs. 958 /-

Hence From the cost analysis we can say that the Wall tiles made by using White Cement, Nano Silica and Egg shell Powder of Proportion (2:1:1) is cost effective compared to tiles available commercially.

V. Conclusions

- These kind of tiles are easy to manufacture, easy to install and replace in household.
- The production process is cheap since it does not involve more expensive industrial equipment hence the tiles made using White cement, Nano material and egg shell mixture are affordable compared to ceramic tile available commercially.
- Areas with poor waste disposal facilities can be used for these wastes (egg shell) in making wall tiles, this study is very important in protecting the environment.

- Compressive strength, wet transverse strength, impact resistance test intensifies the reliable means of judging the quality of wall tiles.

VI. Future Scope

- In India, the growth rate of building material industry is at very high and with this increase in growing rate our project finds the opportunities and demand of various tile making organisations for their commercial and residential needs.
- In this study, the following physical and mechanical properties were not performed on to the tiles, that is: chemical resistance, freeze/thaw resistance, strain resistance, deep abrasion resistance, thermal shock resistance, warpage, wedging, thermal expansion, Perpendicularity, Straightness and etc. Therefore future research can be carried out on the tiles concerning the properties to enable their suitability for use in the different environments.

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