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Experimental analysis of high strength self cleaning concrete

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ABSTRACT

An undying demand for novel construction materials and the need for sustainability has motivated this study of high strength self-cleaning concrete. The nanotechnology has made a great impact on the development of new and eco-friendly material which fulfil the need for sustainable and low carbon footprint future. This study uses Titanium Dioxide as the self-cleaning agent to be added in the concrete with 3%, 10% and 15% by weight of cement. The ultra-high strength was achieved with the help of nano PCE (nano silica + Polycarboxylate ether superplasticizer). It was procured from the manufacturer as a mixture with a proportion of 1:1. The titanium dioxide increased the compressive strength as well as performed the self-cleaning action which was observed by applying phenolphthalein on the surface. The decolorization was maximum in 10% and 15 % specimens.

Keywords*— Self cleaning concrete, Nano PCE, UPV*

1. INTRODUCTION

Nanotechnology is a science in its growing stage. In general, all of today's practical nanotechnologies are those using nano-sized particles in so-called nano materials and nanometer- size features on integrated circuits. Nanomaterial's either refer to materials with nanoscale dimensions or bulk materials containing nano sized particles. Nano particles are defined as particles of less than 100 nm in diameter. These materials demonstrate characteristics such as extraordinary strength or unsuspected electrical, physical or chemical properties that are completely different from those demonstrated by the same products with larger dimensions. A reason for this can be found in the increased relative surface area of minute particles. Chemical reactions involving solids happen mainly at their surface (where chemical bonds are also often incomplete). If nano particles are integrated with traditional building materials, the new materials might possess outstanding or smart properties for the construction of different parts and uses in civil structures. Cement was partially replaced with NS at levels of 0% and 10%, by weight. They reported that the addition of NS increased the amount of heat evolved during the setting and hardening of the cement. NS also decreased workability and increased compressive strength. Keeping in mind the ways the super Plasticizer to be added, a mixture of nano silica and Polycarboxylate Ether (PCE) was obtained from the manufacturer as the nano particles now have a larger surface area and hence a good reaction could take place. TiO2 was added in concrete mixture by 3%, 10% and 15% of cement by weight.

2. LITERATURE REVIEW

Jay Sorathiya, Dr Siddharth Shah, Mr Smit Kacha, (2017) added Titanium Dioxide (TiO_2) in the M20 grade Conventional Concrete (CC) as 0.5 %, 0.75%, 1%, 1.25% and 1.5% of the cement content in which the average size of particles was 15 nm. The conclusion depicted that percentage of 1.0% was found the optimum percentage as the compressive strength increased considerablyto the optimum limit but decreased with further increase in the percentage of TiO_2. The workability was found to decrease with increase in percentage, by weight of cement, of added TiO_2.

M. Berra, F. Carassiti, T. Mangialardi, A. E. Paolini, M. Sebastiani, (2012) added nano-silica in a cementitious matrix to study the effects on compressive strength and workability. The workability decreased considerably while the requirement of water increased in the mix due to high interaction between particles of nano silica and cement matrix. The study suggested that the delayed addition of superplasticizer in the mix is a good practice as it doesn't negate the effect of nanosilica in the mix. It also presents the argument that the comparison of the NS and normal OPC should not be done as the same Water Cement (w/c) ratio doesn't stand for the NS and superplasticizer mix.

Haoliang Huang, Chunxiang Qian, Fei Zhao, Jun Qu, Jingqiang Guo, Michael Danzinger, (2016) performed research to compare the effects of Polycarboxylic Ether (PCE) and Polynaphthalene Superplasticizer (PNS) in the durability of concrete by performing various tests like Carbonation, water impermeability and rapid chloride permeability. It was concluded that mass transport is more difficult in concrete with PCE as compared to concrete with PNS due to smaller carbonation depth, water penetration depth and chloride permeability of concrete. The arrangement of C–S–H in concrete with PCE is more uniform unlike in the case of PNS. Hence, a higher degree of cement hydration in concrete with PCE is obtained.

Nazari et al., (2011) studied the effect of using limewater as a curing medium for TiO_2 added concrete. The TiO_2 nanoparticles are partially replaced by 0.5, 1.0, 1.5 and 2.0 weight per cent of cement. The results showed that the nano-TiO_2 particles, of the average size of 15 nm, combined concrete had higher flexural strength compared to that of the CC. Further, the optimal replacement percentage, of nano-$TiO_{2,}$ was found to be 1% for the curing period of 7, 28 and 90 days. Experimental test outcomes portray a considerable decrease in the percentage of the rate of water absorption and water absorption at all stages with TiO_2 nanoparticles. (Nazari et al., 2011)

M. S. Muhd Norhasri, M. S. Hamidah, A. Mohd Fadzil, (2016) discusses the use of nano technology and nano materials in place of traditional concrete practices. Concrete with added nano silica gained early strength as compared to that of silica fume. The self-cleaning ability of TiO_2 in UHPC has made it a green construction material. This effect of self-cleaning has been used in pavement, buildings and finish product. Another benefit of TiO_2 consists of early strength in concrete and improvement in performance and resistance to abrasion. The unexplored nano materials are nano metakaolin and nano Meta clay are also mentioned.

L. P. Singh, S. R. Karade, S. K. Bhattacharyya, M. M. Yousuf, S. Ahalawat, (2013) did research on the application of nano silica and nano materials in different types of special concrete namely recycled aggregate concrete, fly ash concrete and self-compacting concrete. The properties, of the nano silica incorporated concrete, like mechanical, calcium leaching, thermal behavior, hydration and durability were studied. Nanosilica made the cement matrix denser and with fewer pores which increased the durability and strength of concrete. Nano materials and nano technology will aid in designing concretes with specialized purposes. This paper also mentions about different scenarios in which the nano material added concrete is helpful and the different research works which still requires an innovation.

Konstantin Sobolev, (2016) finds that nanotechnology has the potential to improve the performance of cement-based materials. The use of Polycarboxylic Ether (PCE) has been discussed in getting slump retention and higher strengths. Nano silica has been found to increase workability as it resists the segregation in the cement matrix. Also, with increased density and filled pores, the concrete is less permeable and more durable towards environmental deterioration factors such as acid/sulphate attack or corrosion in RCC, etc. Addition of nano-TiO2 particles gives new characteristics such as self-cleaning effect, due to its photocatalytic properties. (Konstantin SOBOLEV, 2016)

3. MATERIALS USED

3.1 Cement

Cement procured from SRMIST, Delhi NCR Campus

3.1.1 Fine aggregate: It has taken from Srmist, Delhi NCR Campus**.** Sand, in the surface dry condition, is taken from SRM IST laboratory. Manufactured Sand (M-Sand) Is a Substitute of River Sand for Concrete Construction Manufactured Sand is obtained by crushing hard granite stone.

Table 1: Properties of fine aggregates

Size	<4.75mm
Zone	II
Water Absorption	0.9

3.1.2 Coarse aggregate: It has taken from SRMIST, Delhi NCR Campus. The coarse aggregates were crushed to granite-type aggregates and after procurement, we washed those with water and sun dried them.

Table 2: Properties of coarse aggregates

Size	20mm
Fineness modulus	5.0
Water absorption	0.5

3.2 Titanium dioxide

Used for self-cleaning of concrete and to enhance the strength. In the concrete world, TiO_2 has been identified as a self-cleaning agent which has the property to absorb carbon dioxide and nitrogen oxide from the surrounding environment. Also, studies show that this property of titanium dioxide helps in inhibiting the growth of bacteria in concrete and a further improvement in compressive strength when the sun rays strike the concrete titanium dioxide uses this energy to convert the dirt into molecules of water and sulphate.

Table 3: Properties of titanium dioxide

Ph content	6.5-8.5
Type	Anatase Base
Specific gravity	3.9
Melting point(k)	2100

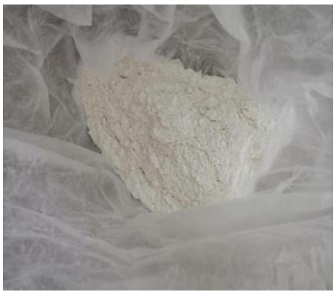

Fig. 1: Titanium Dioxide

Fig. 2: Nano silica PCE

3.3 Nano Silica PCE

Procured from Asian Laboratory. It is used to gain early strength. The nano-silica PCE used as a proportion of NS and PCE in the ratio of 1:1. It was advised by the manufacturer to use the same to obtain the maximum reactivity which further assists in achieving higher compressive strength.

Table 4: Properties of nano silica

Size Of Particles (NM)	15-115 Diameter
Melting point	1980K
Boiling point	3200K
Specific gravity	1.03
Ph content	6

Table 5: Properties of super plasticizer

Color	Light yellow
Specific gravity	1.10+-0.20
Air entrainment	Max. 1.5%
Chloride content	nil
Water reduction	Up to 30%

4. EXPERIMENTAL WORK

Design mix of M40 is prepared using code IS10262-2009. Batching is done in three ways. In the first batch, 2% super plasticizer of cement is used and titanium dioxide is used in a proportion of 3% of cement. The proportion of super Plasticizer is kept constant in all batches and proportion of titanium dioxide is changed as of 3%,10%, and 15%.0.32 W/C ratio is adopted in all batches. In the first two batches, 30% of water is replaced by super plasticizer and in Batch-3, 27% of water is replaced by the super plasticizer.

Fig. 3: Curing of cubes

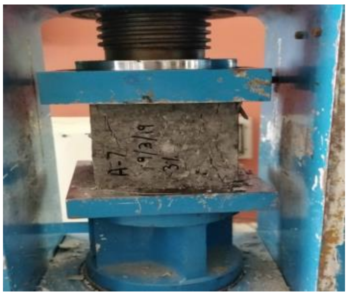

Fig. 4: Compression test

Fig. 5: Compression test reading

Fig. 6: UPV test

Table 6: Mix design proportion

Materials	Mix 1	Mix 2	Mix 3
Cement	430	430.9	450
Fine aggregates	687.349	774.62	771.06
Coarse aggregates	1264	1176	1096
Water	137.9	137.9	143.81
Super plasticizer	59.1	8.6	9
Titanium dioxide	12.93	43	67.5

Table 7: Compression test results

Cubes	7 Days	14 Days	28 Days
1	23.2	31.3	48.5
2	30.86	35.8	49.7
3	31	40.3	52.86

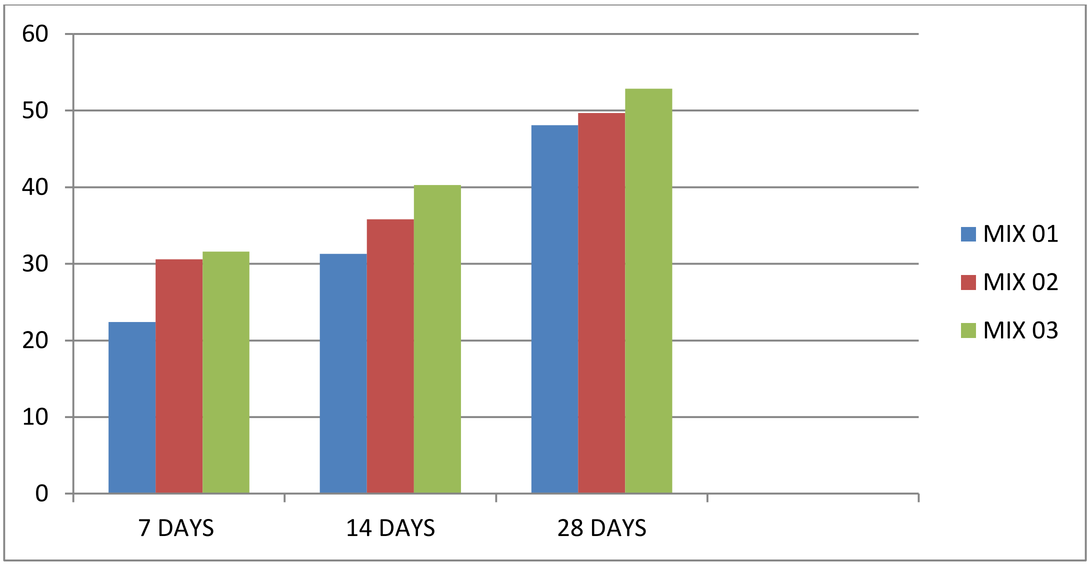

Fig. 7: Compression of Compressive strength of batches

Table 8: UPV test results of a mix

Cubes	Mix 1	Mix 2	Mix 3
1	3.59	3.75	3.81
2	3.73	3.87	4.0
3	3.8	3.76	3.85

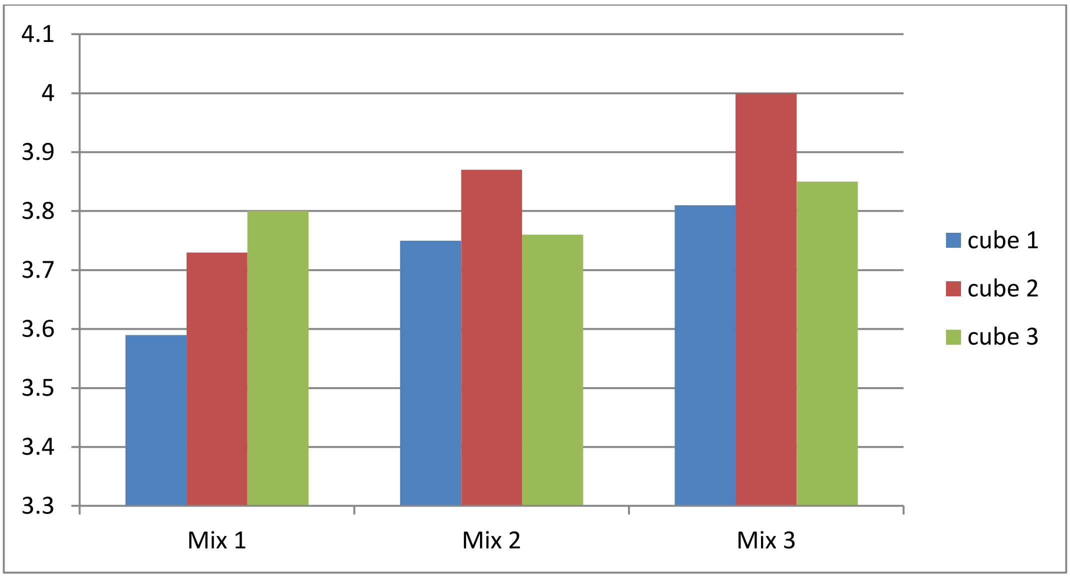

Fig. 8: Compression of UPV strength of batches

5. CONCLUSION

- The early high strength of nearly 75-80% is obtained in 7 days.
- A very little change in compressive strength is observed in the graph after 14 days.
- Due to addition Nano silica PCE and an increase in the percentage of TiO_2, we observe that the workability of concrete mix

decreases.

- With an increase in the percentage of TiO_2 compressive strength of the concrete increases.
- Decoloration of the pink color of Rhodinum dye is seen on 10% and 15% TiO_2 cubes which prove the test for the absorption of CO_2, NO_2 and other gases from the atmosphere.

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