ENHANCING PROPERTIES OF CONCRETE BY USING NANO SILICA AS A PARTIAL REPLACEMENT IN IN CEMENT

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Abstract— Concrete is most commonly used construction material and it consumes huge amount of cement. Manufacturing of cement produces increasing CO_2 emission which is harmful to the environment. Method used to reduce cement content in concrete is use of nano-silica as a partial replacement of cement in concrete. Nanotechnology is one of the most promising areas of science. The use of nano materials in concrete is new revolution. Nano silica is presently used in concrete to modify its strength properties. In this study strength properties such as Compressive strength, split tensile strength, of M40 grade of concrete with the use of nano silica 1.5%, 3%, 4.5%, 6% as partial replacement of cement were studied. It was observed from the experimental study that concrete composites with superior properties can be produced using of nano silica.

Keywords— Nano silica, Cement, Compressive strength.

1. Introduction

Concrete is the most widely used construction material in the world. It is the mixture of cement, coarse aggregate, fine aggregate and water. Fresh concrete is freshly mixed material which can be moulded into any shape. It is one of the most widely used construction material and has a long history of use.

Cement is the main ingredient in concrete. In manufacturing process of Portland cement, clinker in incinerated at about 1300ºC to 1500ºC resulting in emission of huge amount of CO2 into the atmosphere. Huge amount of CO2 emission causes very bad effects on the environment. So, nowadays a key issue for the construction industry is the need for sustainable concrete. Since last few decades concrete technology has experienced substantial advances, resulting in innovative use of supplementary additives and cementatious materials has developed new generations of concrete with improved properties. So, in present work cement is replaced by nano-silica to reduce cement content in concrete. Nanotechnology has changed our vision, expectations and abilities to control the material world. The developments in nano-science can also have a great impact on the field of construction materials and other fields in science. Also, Nanotechnology is one of the most active research areas with both novel science and useful applications that has gradually established in the last two decades. Nanotechnology concerns with the use of materials of dimension approximately 1 to 100 nanometers. Encompassing nanoscale science, technology and engineering involves imaging, measuring, manipulating and modeling matter at this length scale. Nanotechnology is the study of the controlling of matter on an atomic and molecular scale. Nano-concrete is produced by incorporating nano material into cement during mixing has established itself as a promising method, which encompasses the structure at the nanometer scale to develop multi-functional cementatious composites with superior durability and mechanical performance.

2. literature review

M.Bhaskar, S.Vijay Kumar, B.L.P. Swami (2013) "Concrete composite with Nano silica condensed silica flume and fly ash – Study of strength properties"–

Dr. D. V. Prasada Rao, M. Pavan Kumar (2014) "A study of effect of fly ash and Nano silica on strength properties of concrete"- This paper includes the experimental research is to find out the effect of Nano silica on properties specially for strength properties of concrete. They are used as partial replacement of cement and improving the strength properties

of concrete.

Lazaro A Quercia; Brouwers H.J.H(2014) "Production and application of a new type of Nano-silica in concrete"-

Abdul wahab (2010) "Nano-silica production by a sustainable process; application in building materials" This paper shows the production of Nano silica by using wastage of olivine material and not only improving the compressive strength but also reduces the co_2 emission.

A. Lazaro, and H. J. H. Brouwers, "Nano-silica production by a sustainable process; application in building materials," in 8 feb, pp. 1-6, 2010. Silica fume is obtained after the rice husk is subjected to chemical treatment and further burning it. Silica fume can also be produced by various other processes such as sol gel process, pyrogenic process, reduction process of quartz while manufacturing silicon and ferrosilicon and acid leaching procedure. For this purpose, acids like Hydrochloric acid, Sulphuric acid, Oxalic acid, Citric acids are generally used to obtain silica fume. Also, the silica fume finds its common application in construction materials.

H. S. Lee, B. Balasubramanian, G. V. T. Gopalakrishna, K. Seung-Jun, S. P. Karthick, and V. Saraswathy, "Durability performance of CNT and nano silica admixed cement mortar," *Construct. Build. Mater.*, vol. 159, pp. 463–472, 2018. In the recent past, the utilization of nano materials in construction has played a significant role in various applications. Especially, nano silica finds its application widely in concrete due to high specific surface area, which also improves the strength and durability of the concrete.

M. Alhawat, and A. Ashour, "Bond strength between corroded steel and recycled aggregate concrete incorporating nano silica," *Construct. Build. Mater.*, vol. 237, p. 117441, 2020.

The relative density and the bulk density of the nano silica was found to be around 1.2 and 1,200 kg m−3 respectively. The specific surface area of the nano silica is 250 m2 g−1 and the pH value is 6.8. The specific gravity of the nano silica is nearly 2.33 and it is found lesser then the specific gravity of cement.

H. S. Lee, B. Balasubramanian, G. V. T. Gopalakrishna, K. Seung-Jun, S. P. Karthick, and V. Saraswathy, "Durability performance of CNT and nano silica admixed cement mortar," construct build mater vol. 159, pp. 463–472, 2018

The silica fume is generally called as nano silica when the particle size is between 1 and 700 nm and having high specific surface area. The chemical composition of nano silica is studied using X Ray Fluorescence Spectroscopy and it is found that a large amount of SiO_2 is present in silica fume, and other elements such as Al, Fe, Mg, Na and K are found in trace amounts. So, it can be said that nano silica acts as a good pozzolanic material as it is having high silica content.

The durability studies with the addition of nano silica showed improvement towards the sulphate resistance and water absorbtion. The nano silica has a pore filling effect and pozzolonic activity of nano silica with cement towards improvement of mechanical property and durability characteristics.

Maheswaran et al (2013). J onbi et al., (2012) on the investigation of incorporating nano silica along with silica fume in concrete reported that the percentage on nano silica to be incorporated in Concrete should not be more than 10%.

B.-W. Jo, C.-H. Kim, G.-H. Tae, and P. Jong-Bin, "Characteristics of cement mortar with nano SiO_2 particles, construct build mater., vol. 21, pp. 1351–1355, 2007.

The size of the particle was found by Scanning Electron Microscopy (SEM) and it showed that the particle size of silica fume ranges from 2 to 720 nm. The size of the nano silica will vary based on the production process adopted for manufacturing of silica fume. The average particle size is 40 nm of the nano silica utilized in this study.

Amit Srivastava, Kirti Singh, 2011, Nanotechnology in civil engineering and construction: a review on state of the art and future prospects, Indian Geotechnical society, 1077-1080.

Nanotechnology is the science of engineering that deals with particle which are less than 100 nm in size. It is the study of manipulating matter on molecular and atomic scale. In civil engineering and construction, the nanotechnology is applied in

- Concrete for reducing segregation in self compacted concrete,
- The use of copper nano-particles in low carbon HPS is remarkable,
- The use of nano sensors in construction phase to know the early age properties of concrete is very useful.

B. Bhuvaneshwari, Sasmal, Nagesh r. Iyer, Nanoscience to Nanotechnology for Civil Engineering – Proof of Concepts, Recent Researches in Geography, Geology, Energy, Environment and Biomedicine.

Conventional concrete improved by applying nanotechnology aims at developing a novel, smart, eco- and environment-friendly construction material towards the green structure.

Perumalsamy Balaguru and Ken Chong, 2006, National Science Foundation, USA, Nanotechnology and concrete: research opportunities.

Nanotechnology is one of the most active research areas that encompass a number of disciplines including civil engineering and construction materials. Interest in nanotechnology concept for Portland cement composites is steadily growing. Currently, the most active research areas dealing with cement and concrete are: understanding of the hydration of cement particles and the use of nano-size ingredients such as alumina and silica particles. If cement with nano-size particles can be manufactured and processed, it will open up a large number of opportunities in the fields of ceramics high strength composites and electronic applications.

Ali Nazari,et al (2010) investigated compressive, flexural and split tensile strengths together with coefficient of water absorption of high strength self- compacting concrete containing different amount of SiO_2 nanoparticles have been investigated. Strength and water permeability of the specimens have been improved by adding SiO_2 nanoparticles in the cement paste up to 4.0 wt. %. SiO_2 nanoparticle could accelerate C–S–H gel formation as a result of increased crystalline Ca $(OH)_2$ amount especially at the early age of hydration and increase the strength of the specimens. In addition, SiO_2 nanoparticles are able to act as Nano fillers and recover the pore structure of the specimens by decreasing harmful pores. Several empirical relations have been presented to predict flexural and split tensile strength of the specimens by means of compressive strength at a certain age of curing, all also indicate that SiO_2 nanoparticles up to 4 wt.% could improve the mechanical and physical properties of the specimens.

Li, et al (2004) showed that with 5% replacement of cement by ns (mean size 15±5 nm), 7- and 28-day compressive strength of mortars were increased by 20% and 17%, respectively, where as 15% silica fume replacement increased mortar strengths by 7% and 10% compared with those of control Portland cement mortar.

Hongjian Du, et al (2014), his study investigated the durability properties of concrete containing nano-silica at dosages of 0.3% and 0.9%, respectively. Due to the nano-filler effect and the pozzolanic reaction, the microstructure became more homogeneous and less porous, especially at the interfacial transition zone (ITZ), which led to reduced permeability.

V.R.Rathi, et al (2014), investigated the influence of Colloidal nano SiO2 (CNS) addition along with P-100 grade of fly ash on hydration of cement paste and compressive strength of cement mortar. addition of FA (P-100 grade) in various proportions ranging from 10 to 30 % along with varying dosage of CNS from 1 to 6%.The result revealed that fly ash hydration is accelerated by CNS at early age thus enhancing the early age strength of materials also it was observed that standard consistency of cement paste does not vary much more but by addition of CNS along with fly ash Initial and final setting time get accelerated, also the compressive strength of cement mortar was improved significantly.

3. METHODOLOGY

i. Ordinary Portland Cement

Ordinary Portland cement is the most common type of cement in general use around the world as a basic ingredient of concrete, mortar, stucco, and most non- specialty grout. It developed from other types of hydraulic lime in England in mid-19th century and usually originates from limestone. It is a fine powder produced by heating materials. to form clinker. After grinding the clinker, we will add small amounts of remaining ingredients. Many types of cements are available in market. When it comes to different grades of cement, the 53 Grade OPC Cement provides consistently higher strength compared to others.

Fig. 2 Cement

ii. Fine Aggregate

Sand is an industrial granular material which is mainly composed of finely divided rocky material and mineral particles. Hence, it is used as fine aggregate in concrete. The aggregate was tested for its physical requirements such as gradation, fineness modulus, specific gravity, moisture content, bulk density, bulking.

Fig. 3 Fine Aggregate

iii. Coarse Aggregate

Coarse aggregates refer to irregular and granular materials such as sand, gravel, or crushed stone, and are used for making concrete. In most cases, Coarse is naturally occurring and can be obtained by blasting quarries or crushing them by hand or crushers.

Fig. 4 Coarse Aggregate

iv. Nano-silica

It is a white fluffy powder composed of high purity amorphous silica powder. Because of its small particle size, nano-SiO_2 had the advantages of large specific surface area, strong surface adsorption, large surface energy, high chemical purity and good dispersion.

Fig. 5 Nano silica

MIX PROPORTIONS

S.no	Materials	Quantity
1	CEMENT	350 kg
2	FINE AGGREGATE	866 kg
3	COARSE AGGREGATE	1140kg
4	WATER	140kg
5	NANO SILICA	1.275 kg

4. TESTING & RESULTS

1. COMPRESSIVE STRENGTH

PROCEDURE:

Prepare the concrete in the required proportions and make the specimen by filling the concrete in the desired mould shape of 15cm x 15cmx 15cm cube with proper compaction, after 24 hrs place the specimen in water for curing. Take away the specimen from water when such as natural process time and wipe out excess water from the surface. Clean the bearing surface of the testing machine. Place the specimen within the machine in such a fashion that the load shall be applied to the other sides of the cube forged. Align the specimen centrally on the bottom plate of the machine. Rotate the movable portion gently by hand so it touches the highest surface of the specimen. Apply the load step by step at the speed of 140kg/cm³/minute until the specimen fails. Record the load at which the specimen failure takes place.

2. SPLIT TENSILE STRENGTH

Compact each layer using a tamping rod. Tap each layer 30 times. Uniformly stroke the concrete mix and remove the excess concrete. Then immerse the casted specimen in water for 24 hours at 27-degree celsius. After that remove the specimen from the mould and immerse it in freshwater. The splitting tensile strength of concrete should be conducted at 7, 28 days of curing. Before starting the test, take the specimen from the immersed water and wipe the water. Then note the dimension and weight of the specimen. Place plywood strip above and below the specimen After that place the specimen on the testing machine. Then gradually apply load at a rate of 0.7 to 1.4 MPa/min. Record the load at which the specimen breaks.

3. SLUMP CONE TEST

Generally concrete slump value is used to find the workability, which indicates water-cement ratio, but there are various factors including properties of materials, mixing methods, dosage, admixtures etc. also affect the concrete slump value.

Height of 12” (300 mm), Bottom Diameter of 8” (200 mm), Upper Diameter of 4” (100 mm).

Clean the internal surface of the mould and apply oil. Place the mould on a smooth horizontal non- porous base plate. Fill the mould with the prepared concrete mix in 4 approximately equal layers. Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mould. For the subsequent layers, the tamping should penetrate into the underlying layer. Remove the excess concrete and level the surface with a trowel. Clean away the mortar or water leaked out between the mould and the base plate. Raise the mould from the concrete immediately and slowly in vertical direction. Measure the slump as the difference between the height of the mould and that of height point of the specimen being tested.

RESULTS

3 TABLE 2. TEST RESULTS

S.NO	% Of Nano silica	Average Compressive Strength (N/mm^2)		Average Split Tensile Strength (N/mm^2)	
		7 DAYS	28 DAYS	7 DAYS	28 DAYS
M1	0	21.27	38.44	2.06	4.43
M2	1.5	23.07	34.22	3.24	4.53
M3	3.0	25.53	35.14	3.91	4.91
M4	4.5	23.78	33.52	3.45	4.48
M5	6.0	22.73	33.05	3.08	4.03

Slump cone result

- Slump for the sample of height is 200.

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