A Survey on Concrete Behaviour Using Nano-Silica and Nano-Alumina as Admixtures

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***Abstract*: Due to the rapid increase in the population growth and the increase in demand of various structures, a need for stronger and more durable concrete has been evident. Of the various technologies in use, Nanotechnology looks to be a promising approach in improving the properties of concrete. Concrete can be Nano Engineered by incorporating Nano particles such as Nano-Silica and Nano-Alumina as mineral admixtures. The present study discusses the effects of Nano-Silica and Nano-Alumina as mineral admixtures in cement, with various doses of partial replacement of cement by weight. This survey paper takes into account the effect Nano-Silica and Nano-Alumina have over certain tests such as consistency and Initial setting time tests which are cement based tests. The compressive strength, flexural strength, pull out strength and split tensile strength of both Nano-Silica and Nano-Alumina concrete at all the various doses are also analysed by referring previous journals and research paper. A comparison is also drawn between the conventional concrete, Nano-Silica concrete and Nano-Alumina concrete.**

Index Terms: Nano-Silica, Nano-Alumina, Compressive strength, Split tensile strength, Flexural strength, Pull out strength

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I. INTRODUCTION.

Nanoscience and nanotechnology are the research and application of very small and minute things which can be used across various fields of science such as chemistry, biology, physics, materials science, and engineering. Today's scientists and engineers are seeking to intentionally manufacture materials at the nanoscale to take advantage of their enhanced properties such as higher strength, lighter weight and greater chemical reactivity than their larger-scale counterparts. Nanotechnology has immense potential and the ability to control materials including cement-based materials. There is a steady increase in interest in the concept of nanotechnology for portland cement composites. The most widely published theoretical work regarding application of nanotechnology in cement-based materials is either related to coating or enhancement of mechanical and electrical properties. Some of the widely reported nanoparticles in cement concrete industries are Titanium dioxide (TiO2), Silica dioxide (SiO2), Alumina (Al2O3) etc.

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. This will upgrade the status of Portland cement to a high tech grade material in addition to its current status of the most widely used construction material. Very few inorganic cementing materials can equal Portland cements cost and its capability to be readily available. The most prominent areas of research currently 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.

II. SCOPE AND SIGNIFICANCE

In the beginning of the 21st century, huge advancements occurred that lead to the invention and use of Nano-concrete, a form of concrete with Nano additives to improve its performance on the nanoscale structure. Nano-concrete provides many advantages over the conventional concrete mixes such as self-compacting, self-cleaning, eco-friendly, depollution property, improved strength and durability, high liquidity and other properties. These properties had an immense influence on architects around the world as it gave them more versatility and made concrete go back in line with the new architectural and construction requirements and ambitions. Self-Compacting Concrete (S.C.C.) which is produced through the addition of small amount of nano-SiO2 results in concrete with high strength and durability properties. Thus, it could be used to construct complex shapes and improved concrete's mechanical strength. Self-cleaning concrete could be made by adding nano-TiO2. This results in a self-cleaning concrete with special photo-catalytic property to convert air pollutants into harmless substances with sunlight help. It also causes cement to rapidly hydrate. Carbon nanotubes (CNTs) and nanofibers (CNFs) can improve concrete's mechanical durability and prevent after-curing cracks, CNTs improve resistance to corrosion, fatigue, wear and tear, and abrasion. In addition, it contributes indirectly to energy savings that are usually required to fix or replace deteriorated infrastructure. All these new features applied to characteristics and properties of concrete has made Nano-concrete by architects a new favorite building material as it makes and includes long-spans, unique and complex forms with consistent appearance and many more properties.

Nanotechnology is infiltrating the Civil Engineering sector as a new industrial revolution and has provided a new impetus for the development of high-performance and smart or multifunctional concrete. Restructuring or alteration of nanoscale material structural units by interpreting material genetic code and drawing the blueprint of nanoscale properties offers new theory and method for creating high-performance, durable and environmentally friendly concrete. By utilization of nanotechnology, it is possible to promote the understanding and knowledge of concrete behavior, one can control and improve concrete efficiency as well as lower concrete production and ecological cost, and it can prolong the service life of engineering infrastructures and reduce the relative demand of concrete. Guiding the sustainable production and application of concrete materials is of utmost importance. The important developments made in concrete technology are ultra-high strength concrete, photocatalytic concrete, self-heating concrete, bendable concrete and concrete containing CNTs. The application of nanotechnology is being extended to the every nook and corner of civil engineering sector, but a lot of awareness and research should be carried out to completely exploit its benefits. No doubt nanotechnology will help add new properties and excellent functionality to concrete.

PROBLEM STATEMENT

- Understanding cement behaviour when partially replaced with Nano-Silica and Nano-Alumina.

- Study the effects due to various dosages of Nano-Silica and Nano-Alumina on the split tensile strength, compressive strength, pull out strength and flexural strength of concrete.

III. LITERATURE SURVEY

A paper published by Ibadur Rahman and Nirendra dev [1] gives us insight on how to incorporate Nano-Alumina into the concrete matrix. In this research M50 grade of concrete was utilized and a total of 36 cubes were produced. Numerous tests were conducted on the hardened concrete to understand the behaviour of this modified concrete. Cement, fine aggregates, coarse aggregates and superplasticizers is used to cast the concrete cubes along with Nano-Alumina. Nano-Alumina was incorporated in the dosages of 0.5 %, 1 % and 1.5 %. Compressive strength tests were conducted in a normal environment as well as in an aggressive environment which is done by adding 4 % NaCl to water. They even studied the particle size of cement and its morphological properties with the help of Scanning Electron Microscope whereas Nano-Alumina was studied with the help of Transmission Electron Microscope. A total of 24 cubes of size 150x150x150 mm were cast to check the compressive strength of Nano-Alumina concrete in a normal environment and 12 cubes of size 150x150x150 mm were cast to check the compressive strength of Nano-Alumina concrete in an aggressive or harsh environment. After curing all the cubes were tested with the help compressing testing machine. It was observed that the 7th and 28th day compressive strength of the Nano-Alumina concrete in a normal environment was higher than that of the conventional PCC concrete. A percentage increase of 9%, 21% and 27% was observed for 0.5%, 1% and 1.5% doses of Nano-Alumina respectively. Whereas in the case of the aggressive environment, the 28th day compressive strength of Nano-Alumina concrete was higher than that of conventional M50 grade concrete. An increase of 2.5%, 6% and 10% was noticed for 0.5%, 1% and 1.5% doses of Nano-Alumina concrete respectively. It was then concluded that properties of concrete were enhanced due to the addition of Nano-Alumina and its increment because the Nano-Alumina has the tendency to fill in the voids in between the grains of cement and hence it reduces the CaOH content which promotes the formation of calcium silicate hydrate bonds thereby improving the interface structure of concrete. The gain in strength is also due to the fineness of Nano-Alumina particles which causes the large surface area of Nano-Alumina to come in contact with water and cement easily.

In the research paper published by Darshan A Patel and C.B. Mishra [2] an introduction to addition of Nano-silica as an admixture was provided. They partially replaced cement with 1%, 2%, 3% and 4% Nano-Silica by weight. Compression strength test and flexural strength test were conducted in the universal testing machine to prepare a comparison between concrete whose cement was partially replaced with Nano-Silica in various dosages as well as concrete without any partial replacement with Nano-Silica. For this research M40 grade of concrete was cast which was prepared according to IS 10262:2009. Cement, fine aggregates, coarse aggregates and an another admixture namely MasterRheobuild1126 was used as it is a superplasticizer for high strength concrete and it was added in by 0.9% weight of cement. A total of 45 cubes were cast for compression strength test and 5 concrete beams of size 150x150x700 mm for flexural strength test. The cubes were cured for 3,7 and 28 days so as to obtain the results of 3rd day, 7th day and 28th day compressive strength whereas the beams were only cured for 28 days in order to obtain the 28th day flexural strength. It was then observed that the compressive and flexure strength of concrete linearly increased when the dosage of Nano-Silica was increased while partially replacing the cement. However this trend was only visible for 1%, 2% and 3% partial replacement of Nano-Silica whereas when it was partially replaced by 4% the values decreased but not significantly. The maximum compressive strength was obtained at 3% replacement of cement by weight with a value of 64.33 Mpa and the maximum flexural strength was also obtained at 3% replacement of cement by weight with a value of 5.82 Mpa. Another observation was made which was related to the workability of concrete. Apparently the workability decreased with increase in dosage of Nano-Silica. It was also concluded that concrete whose cement has been partially replaced by Nano-Silica can be used for the construction of rigid pavements. Due to its high flexural strength it can be used to reduce the thickness of the pavements which would make it extremely economically feasible.

The paper published by Saba Jahangir and Seyed Kazemi [3] focuses on many tests which gives us an idea regarding the concrete behaviour when Nano-Silica and Nano-Alumina are utilized as admixtures. The various tests conducted involve investigation various properties of concrete and cement such as compression strength, sulfate attack resistance and setting time. The properties and characteristics of the nano-materials were analyzed with the help of scanning electron microscope, FITR and X-Ray diffraction. Two samples were produced one without the replacement of cement with nano-particles and the other with 10% Nano-Silica and 5% Nano-Alumina replacement of cement by weight. Cubes of 100x100x50 mm size were used and the compressive strength test was carried out according to ASTM 39-83 and was determined for 3rd, 7th and 28th day. It was observed that the sample with partial replacement of cement with Nano-Silica and Nano-Alumina by weight performed better than the sample without the nano-particles for every age. It was determined that the combination of both Nano-Silica and Nano-Alumina enhances the compressive strength as it decreases the capillarity hence there is an increase in the density of the interfacial zone. This actually results in an increase in compressive strength even compared to those concrete with cement only partially replaced by Nano-Silica. The final setting time of the samples with Nano-Alumina and Nao-silica replacement met all the requirements. However the initial setting time did not meet the requirements of ASTM C 595 and ASTM C 1157. The setting time was higher than that of the conventional grade of concrete hence activity such as curing requires a lot of consideration. In order to check the sulfate resistance the samples were exposed to 5% magnesium sulfate and 5% sodium sulfate solutions. It was observed that the samples containing Nano-Silica and Nano-Alumina did not expand as much as the samples without Nano-Silica and Nano-Alumina in their concrete matrix. The samples with Nano-Silica and Nano-Alumina exhibited lower porosity than the sample without the nano admixtures. It was also observed that porosity of the sample with Nano-Silica and Nano-Alumina was less than that of the sample with even just Nano-Silica in the concrete matrix. Hence in this study the addition of Nano-Silica and Nano-Alumina reduced the continuity in pore distribution in the samples ultimately making the concrete less permeable.

A research paper published by R. Shashank and E. Balaji [4] properties of concrete such as flexural strength and crack width are investigated when admixtures such as Nano-Silica is incorporated. In this study they varied the Nano-Silica dosage from 1% - 8 % and cast concrete beams of dimensions 150x190 with a length of 1.8m. They have also utilized fine aggregates, coarse aggregates and even mineral admixtures such as GGBS and even silica fume in the concrete matrix. An XRD test was conducted alongside in order to analyze the particle size and distribution of Nano-Silica. A compressive strength test was also carried out using the compression testing machine so as to determine the optimum dosage of Nano-Silica. The compressive strength test results of 3rd day, 7thday and 28th day was compared. The optimum dosage of Nano-Silica was obtained at 4%.It was observed that with increase in dosage beyond the optimum dosage of Nano-Silica the compressive strength decreases irrespective of the age of concrete. The 3rd day compressive strength increased by a value of 47.2% when compared to the conventional concrete. The 7th day compressive strength increased by a value of 28.9% when compared to the conventional concrete. The 28th day compressive strength increased by a value of 12.9% when compared to the conventional concrete The flexural strength was conducted by subjecting the beam to a two point load. The load was provided at an interval of 4 kN. It was found that there was a gradual increase in deflection in the case of the Nano-Silica concrete until the ultimate load was reached, this is observed due to the fact that the Nano-Silica has the ability to fill the voids or the pores in between cement. Whereas a rather irregular deflection was noticeable in the case of traditional or conventional concrete due to the absence of pore filling effect. The durability quotient was determined with the help of the cracks formed on both Nano-Silica concrete as well as conventional concrete. The cracks formed on both the concrete were measured. The initial formation of the cracks along with their development were investigated. It was then concluded that the width of the crack formed on the conventional concrete was 83.1% more in size than that of Nano-Silica concrete.

S.B. Gagare and U.R Kawade [5] published a paper regarding the enhancement of concrete properties when the cement was partially replaced with Nano-Silica. They replaced cement with 1.5%, 3%, 4.5%, 6%, and 7.5% doses of Nano-Silica along with 10% constant fly-ash. Various tests such as compressive strength test, split tensile strength and pull out strength was carried out. Finally it was compared to ordinary M40 grade of concrete. Cubes of 150x150x150 mm and cylinders of 300 mm length and 150 mm diameter were cast. The cubes were tested after 3,7 and 28 days of curing whereas the cylinders were only tested after 28 days. For the pull out strength cubes of 150x150x150 mm were cast and bars of 12 mm Diameter were inserted which were then removed axially from the cube with the help of the universal testing machine. This test helps us analyze the bond stress between concrete and steel. It was observed that the 3rd day compressive strength of Nano-Silica concrete was 3.6%, 6.25%, 4.13%, 2.91% and 2.12% higher than that of the conventional M40 grade concrete when the cement was replaced by 1.5%, 3%, 4.5%, 6% and 7.5% by Nano-silica and 10% Fly ash respectively. The 7th day compressive strength of Nano-concrete was found to be 14.92%, 19.39%, 15.66% and 13.97% higher than that of conventional M40 grade of concrete when the cement was replaced by 1.5%, 3%, 4.5% and 6% by nano-silica and 10% Fly ash respectively. The 28th day compressive strength of Nano-Silica concrete was found to be 2.53%, 15.86%, 13.23%, 6.33% and 3.01% higher than that of conventional M40 grade of concrete when the cement was replaced by 1.5%, 3%, 4.5%, 6%, and 7.5% by Nano-silica and 10% Fly ash respectively. The split tensile strength of nano-silica and Fly ash based concrete was higher by 2.35%, 29.58%, 15.96% and 3.66% than that of conventional concrete for the replacement of 1.5%, 3%, 4.5% and 6% at the age of concrete 28 days. Whereas replacement by 7.5% of nano-Silica and 10 % fly ash produced a decrease in split tensile strength by an amount of 16.23% than that of conventional M40 grade of concrete. The 28th day pullout strength was found to be 4.19%, 13.22%, 17.31%, 22.04% and 0.005% higher than that of conventional M40 grade of concrete when the cement was replaced by 1.5%, 3%, 4.5%, 6% and 7.5% Nano-silica respectively and 10% Fly ash.

IV. CONCLUSION.

It is quite clear from the above mentioned research papers that the addition of nano materials such as Nano-Silica and Nano-Alumina often enhance the properties of cement and concrete namely setting time, porosity, compressive strength of concrete, split tensile strength of concrete, pull out strength of concrete and even flexural strength of concrete. These properties vary according to the dosage of Nano-Silica and Nano-Alumina along with various other factors such as water-cement ratio, grade of cement, grade of concrete, super plasticizers and even the use of other mineral admixtures. A general trend which is noticeable is that the Nano-Silica concrete has proved to be more effective compared to Nano-Alumina concrete as it contributes to the strength of the concrete. The compressive strength of Nano-Silica concrete follows a general pattern where the value starts to decrease around and above 4% dosage. Similarly the split tensile strength, flexural strength and the pull out strength of Nano-Silica concrete generates higher values than conventional plain cement concrete as well as Nano-Alumina concrete. Though there is scope for application of nano concrete in real time still a lot of research has to be carried out.

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