

Influence of Nano-Silica and Nano-Alumina on Properties of Concrete

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Abstract - Due to modernization, urbanization concrete become the most usable material after water in the world. India stood 2nd largest manufacture of cement after china. Today different types of concretes are preparing according to the requirement of the works. These are possible by replacing ordinary Portland cement with mineral admixtures also called supplementary cementitious material. Now a days tall buildings are becoming common therefore high and ultra high strength concrete need to produce, this can be possible by replacement Nano materials which changes the cement composites property from nano scale level. Some nano material such as nano silica, nano alumina, graphene oxide, carbon nano tubes, etc. This paper review the effect of nano silica and nano alumina on cement mortar and concrete. These two nano materials has the pozzolanic behaviour which accelerates the (calcium silicate hydrates) C-S-H gel formation and also produce the extra CSH gel by consuming the calcium hydroxide. This paper also discusses the reasons to improvement in concrete properties. Incorporation of nanoparticles not only improve the existing properties of concrete but generate new properties in to existence Further, discusses the applications, practical challenges and conclusions.

Keywords- calcium silicate hydrates, calcium hydroxide, Nano-Silica, Nano-Alumina, pozzolanic, supplementary cementitious materials.

1. INTRODUCTION

Due to modernization, urbanisation concrete become the most usable material after water in the world which shows large negative impact on environment therefore its required to reduce the negative impact and improve the properties of concrete as per todays requirement. From last few decades a rigorous research has been done to strength the concrete which results a high strength concrete and special concretes. Now a days application of nanoparticles has received numerous attention to improve the properties of conventional concrete. Nano materials incorporation in concrete is improves its strength and durability properties. Nano materials are one which particle size which is less than 200nm. Some of nanomaterials are nano silica(NS), nano alumina(NA), graphene oxide (GO), carbon nano tubes, etc. This paper covers about the literature review of NS and NA incorporated in cementitious materials. This nano materials added benefits of improving the microstructure which increase in tensile and compressive strength, improved resistance to heat, physical and chemical attacks. Further more discusses about NS and NA applications and challenges. Further research gaps has been analysed and conclusions are drawn based on thorough research.

2. LITERATURE REVIEW

When Nano particles are incorporated into Portland cement paste, mortar or concrete, it modifies the properties of

cement composites. The following the research on Nano-silica and Nano-Alumina incorporated in cementitious materials over the past few years.

2.1.Nano-silica

Mohammed Maslehuddin et al. (2020) This study dealt with improving properties of concrete using two industrial waste materials along with adding nano silica. Experiment conducted to develop high performance concrete (HPC) using two industrial waste materials (IWM), which are cement kiln dust(CKD) and electric arc furnace dust (EAFD), along with addition of nano-silica (NS). The mechanical properties, and durability properties of the HPC were studied. There were 11 mixes are prepared one control mix, others 10%, 15%, 20% of replace of cement with CKD and 10%, 15%, 20% of CKD along with 5% Nano silica in each mix similarly prepare other mixes 5%, 10% cement replace by EAFD without NS 2 mixes and 2 mixes with nano silica. The compressive and flexural strength properties of concrete reduced because of the use of CKD and EAFD. However using NS with CKD and EAFD increases the flexural and compressive strength properties of concrete. The chloride permeability of concrete decreased by adding selected (IWM) with NS. Whereas drying shrinkage strain increased. Finally concluded that developed HPC with selected (IWM) with NS lead to environmental, technical, economical benefits.

Hongjian Du et al.(2019) In this study strength and durability properties of high performance cement composites discussed with the incorporation of nano-silica in different percentage of wt of cement. The percentages are 0.5%, 1%, 1.5%, 2% of silica as wt of cement. Due the nano size of silica it shows filler effect and undergo pozzolanic reaction, which increase the mechanical and durability properties of cement composites. Durability properties as impermeability to water and chloride ions.

Haruehansapong et al. (2014) this research focused on finding strength properties of mortar by inclusion of nano silica (size 12 to 40nm) and silica fume separately and then comparison the results. nine mixes (3%, 6%, 9%, 12% for both) prepared with water/paste ratio is 0.65, four mixes for nano silica, other four for silica fume and one control mix. The results does not shows any good increment in strength. But 40nm size nano silica shows highest strength. The optimum results obtained at 9% mix proportion in both the cases.

Shaikh et al. (2014) This paper discussed on incorporation of nano-silica partially in cement mortar and concrete and conducted various experiments. Eight mixes of (1% to 6%)wt as partial replacement of cement by nanosilica were prepared. Compressive strength test done at 7 and 28 days.



It shows that incorporating 2% nano silica gives peak strength both at 7 and 28 days.

Ghafari et al. (2014) The study carried out to find the effect of nanosilica on the properties of ultra-high performance of concrete. The compressive strength of concrete increases at initial ages by increasing the nanosilica content as partial replacement in cement. 3% wt of replacement of cement by nano silica shows optimum results.

2.2. Nano alumina

Raje Gowda et al. (2016) This paper study the effect of nano alumina (NA) on mechanical strength properties of cement- mortar. For this reason, 1%, 3% and 5% of the NA incorporate in to cement. Due to its pore filling capability and hydration accelerating nature shows that at 1% incorporating of NA in cement compressive strength at 7 day greater than that of 28 days. At 5% incorporating of NA shows the peak compressive strength occur at 28 days. And the Workability of the cement mortar decreases with the increment of nano Alumina incorporating, due to high amount of water absorption by NA. It was also observed that the aggregates lost their integrity, cracks developed and partial spalling along the edges, as the temperature reached to 600 °C. finally concluded that test results, at 3% incorporation of NA is to be optimum.

B. A. Hase, Prof. V. R.Rathi (2015) In this paper addition of 1%, 2%, 3% and 4% of the colloidal nano-alumina particles by wt of cement in to the concrete and compare results with control concrete mix. For this, M60 mix grade was taken with w/c ratio 0.26. Mechanical strength properties are founded by compression test, flexural test and split tensile strength test at 28 days. Samples containing 3% colloidal Al₂O₃ nano particles, shows good results than normal control concrete. Increasing colloidal nano-Al₂O₃ greater than 4 % replacement of cement, decreases the mechanical strength properties of concrete.

3. OBSERVATIONS & REASONS

- Due to nano size of NS and NA occupy the gaps between cement paste and between paste and aggregate which improve ITZ (interfacial transition zone) which is the weakest portion in concrete. About the interfacial transition zone is explained through below figure.

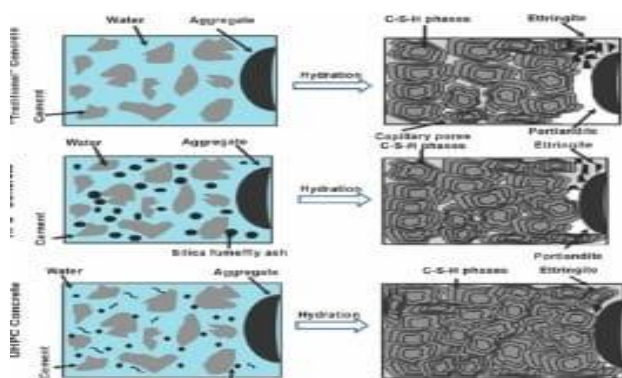


Figure shows gap/pore filling effect of cementitious materials in cement composites

- Some times this nanoparticles are fail to improve the strength of concrete because of addition of nanoparticles at random percentages and due the effect of size of particle. This reasons are explained in two ways as follows.

1. The nanoparticles are adsorbed on the cement particles which restrict the cement particles to undergo in hydration process therefore incomplete hydration of cement can improve the strength.
2. Very fine particles of NS and NA could undergo agglomeration and poor dispersion.
 - Constant increment of incorporation of percentage of Nano silica and Nano alumina in cement improve the properties of concrete but after certain percentage onwards the strength and durability properties of concrete are reduced.
 - This Nano silica and Nano Alumina has pozzolanic in nature which speed up the hydration reactions and accelerates the formation of C-S-H gel.
 - The nanoparticles in cement concrete produces additional C-S-H gel by consuming calcium hydroxide which has no role in improvement in concrete properties.
 - The consistency (workability) decreases because of high surface area of nanoparticles which demand large amount of water in cement paste.

4. APPLICATIONS

- In the severe environmental conditions such coastal areas and under sea structures where high chance of chloride attack, sulphate attack etc. which Detroit the concrete. Therefore by addition of mineral admixtures and nano materials in concrete can improve the durability properties.
- NS and NA incorporating in conventional concrete one could makes High strength concrete and high performance concrete. This has high resistance under high temperature.
- Refines the pore structure thereby improving the total porosity of the cement matrix, making the matrix more dense and compact.
- Concrete can make suitable for environmental such as freeze and thaw

5. CHALLENGES

There are some of the practical challenges regarding nano particles are follows

- Presently, Production of NS and NA are not well developed and also the per gram of nano material cost are very high.
- Production and processing techniques of nanomaterials should be improved to make them commercially viable.
- NS and NA reduces consistency (workability) of cement composites because of its large surface area.
- Maintaining flow properties and strength properties is the challenging task since flow (workability) inversely proportional to the strength

6. RESEARCH GAP

This study reveals that there are the research gaps that need to be fulfil so that better, strong, and durable concrete could obtained. Study on nano materials incorporation in concrete started from last two decades but yet lot of research need to be required. From literature survey there are few research gaps are found they are as follow

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- Thorough research are needed to fix up the optimum percentage of incorporation of nano particles in cement composites
 - Studies on the influence of alkali-activatednanoparticles and durability studies are very limited.
 - There is a scope in Research to improve the dispersion and workability properties of concrete incorporated with nanoparticles.
 - Very limited research had done on bond strength between cement paste with aggregates and steel, structural behaviour, permeability, chloride attack sulphate attack, acid attack, Carbonation tests has to be done.
5. The incorporation of NS and NA in cement paste, the Workability of cement mortar decreases due to large surface area which results high amount of water absorption by NS and NA.
 6. NS added to cement paste at different dosages shows different values of strength, the range between (1% to 3%WT of cement) shows good increment in strength properties.andinclusion of NA in cement paste in different dosages the range between (0.5% to 1.5%WT of cement) shows good increment in strength properties of cement mortar and concrete.
 7. The high activity of nano-SiO₂ helps to improve the hydration reaction of concrete, which shortens the setting time of nano-SiO₂.

7. CONCLUSION

Addition of the nanoparticles (NS and NA) in cement materials results in enhanced the properties of concrete thereby obtain a good strength and durability properties. The summary this paper is concluded as follows.

1. NS and NArefine the pore structure by filling the gapes thereby decreases the capillary pores results in dense and compact concrete.
2. As the microstructure is improved, strength and durability properties are enhanced.
3. This Nano Silica and Nano Alumina has high specific surface area which accelerates the hydration of cement and formation of hydrated products.
4. As capillary pores are reduced, chloride penetration and water absorption was effectively prevented.

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