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A STUDY ON MECHANICAL PROPERTIES OF M30 MIX CONCRETEWITH PARTIAL REPLACEMENT OF CEMENT WITH NANO SILICA

P.Neeharika[1] ,K. SANDEEP KUMAR[2],

1. Assistant Professor, Dept of Civil Engineering, University College of Engineering & Technology, A.N.U, Guntur, AP
2. Assistant Professor, Dept of Civil Engineering, University College of Engineering & Technology, A.N.U, Guntur, AP

ABSTRACT:

In present scenario of urbanization, the health, durability and efficiency of concrete and its by- products have decreased. And to tackle this problem researchers have extended their hand, which eventually showed progressing results. And in extension to that, we have utilized "Nano Silica Dioxide" to enhance the properties of concrete. considering the Mechanical properties, effective or optimum mixis picked.

In this perspective, present study was carried out to compare the performance of concrete withnano silica (NS) as a partial replacement of cement in concrete. For this study 20-30 nm nano silica (NS) particles in the form of powder have been considered and this is used as replacement to cement.

The main aim of project is to study variation of concrete properties like Mechanical properties (i.e., Compressive strength, Tensile strength and Flexural strength) with respect to different proportionsof Nano Silica. While studying the research results of many intellectual researchers, we concluded thatin order to get desired results, the NS is used in the proportion of 0 to 3% with an increment of 0.5% for every mix. For present work, total six concrete mixes are considered for the experimental work. The 0% mix is considered as reference mix and this used for comparison of results. For each increment of NS, Compressive, split tensile and flexural strength are evaluated.

The detailed experimental work and discussion of results are encapsulated in the project.

Keywords: *Concrete, Fine Aggregate, Coarse Aggregate, Compression strength, Tensile Strength, Flexural Strength, Nanomaterial, Nano silica (Sio2), M30, C-S-H gel.*

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INTRODUCTION

The concrete is generally used for the development of country's infrastructure in which the water absorption of the material should be low. The annual worldwide concrete production is approximately around one cubic meter for every individual on the earth. Eminent scientists state that "The most widely used construction material is concrete." It is commonly made by mixing Portland cement with sand, crushed rock and water. It is observed that the present consumption of concrete in the world is 11 billion metric tons every year which is foundto be greater than the past decades.

The demand of concrete shoots up further with the infrastructure development on the increase day by day. More demand for concrete pressurizes for increased production of cement which is significantly used in traditional concrete as the single binding ingredient.

NEED FOR PRESENT WORK

In an emerging country like India, infrastructure growth is very much essential at this point of time. For the faster growth of a nation's economy, execution of construction projects within a specified time frame is the need of the hour. For some of the key infrastructure projects there is a requirement of high compressive strength, early removal of the formworks and a sustainable life cycle. For achievement of high early and later compressive strength, it isessential to include nano-silica particles in cementitious composites. However, small particle size of nano-silica induces certain weaknesses in cementitious system such as low workability,shrinkage (autogenous and drying), high heat of hydration and non-economical. Hence, the present need is to use SCMs in conjunction with nano-silica as a multi-blended (binary, ternary and quaternary) cementitious composite. In order to counter balance, the drawbacks of SCMs (low initial strength, delayed setting time etc.) and nano-silica to obtain high performance sustainable cementitious composites. Optimized blended cementitious composites can beachieved by adopting the concept of particle packing theory (modified Andreasen and Andersenmodel).

In other perspective, global energy demand is increasing swiftly along with the rapid growth in economy, urbanization and industrialization. Reduction of energy consumption is the focal point on achieving toward energy efficient sustainable buildings. It can be made possible by blending thermally efficient smart material such as phase change materials (PCMs).PCMs has certain number of advantages mostly in controlling the peak temperature during initial days of hydration by absorbing energy there by reducing the rise in heat within the cementitious matrix. However, incorporation of PCMs greatly effects the mechanical performance of cementitious composites owing to its leakage issue. It is understood that incorporation of nano silica in cementitious composites benefits in early strength with enhanced engineering and microstructure properties. However, inclusion of highly pozzolanic nano-silica in cementitious material induces shrinkage there by developing a larger number of cracks in concrete because of the faster rate of hydration reaction. Hence, it is 6 believed that amalgamation of these two materials (nano particles and PCMs) can mitigate the problems of one another thus resulting in high performance and thermally efficient sustainableinfrastructure.

NANO TECHNOLOGY

The nanotechnology was first introduced by Richard P. Feynman in 1959 at the California Institute of Technology. He had delivered a lecture on technology and engineeringat the atomic scale in the American Physical Society meeting at Caltech. Since the revolutionary developments have been taken place in physics, chemistry, and biology and have proved Feynman ideas of controlling matter at an extremely small-scale level of molecules and atoms.

In very particular here the discussion is emphasizing to the applicability of nano silica for cement-based materials related to the construction technology field.

Nano Materials and its Technologies

Nanomaterials can be defined as those physical substances with at least one dimension between 1…150 nm (1 nm = 10-9 m). The nano-materials properties can be very different from the properties of the same materials at a micro (10-6 m) or macro scale (10- 6…10-3m). The nano-science represents the study of phenomena and the manipulation of materials at the nanoscale and is an extension of common sciences into the nanoscale. The nanotechnologies can be defined as the design, characterization, production, and application of structures, devices and systems by controlling shape and size at the nanoscale. Currently, the use of nanomaterials in construction is at a slow phase.

Nano material' s for Construction

In nano technology the size of the particles is a critical factor, the material properties significant differ at the nanoscale from that at larger scales. Physical phenomena begin to occur differently below the boundary limit: gravity becomes unimportant, electrostatic forces and quantum effects start to prevail. In the same time, the proportion of atoms on the surface increases relative to those inside, creating so-called "nano-effect" and all these nano properties actually affect the materials behaviour at the macro-scale. In concern to the construction industry a few important nanomaterials with potential use presenting below

Carbon Nanotubes

Carbon nanotubes are a form of carbon having a cylindrical shape, the name coming from their nanometre's diameter. They can be several millimetres in length and can have one "layer" or wall (single-walled nanotube) or more than one wall (multi walled nanotube). Nanotubes are members of the fullerene structural family and exhibit extraordinary strength and unique electrical properties, being efficient thermal conductors. For example, they have five times Young's modulus and eight times (theoretically 100 times) the strength of steel, whilst being 1/6th the density. The expected benefits of carbon nanotubes are mechanical durability and crack prevention in concrete, enhanced mechanical and thermal properties in ceramics and real-time structural health monitoring capacity.

Titanium Dioxide Nanoparticles (TiO_2)

The titanium dioxide nanoparticles are added to concrete to improve its properties. This white pigment is used as an excellent reflective coating. The titanium dioxide breaks down organic pollutants, volatile organic compounds, and bacterial membranes through powerful photocatalytic reactions, reducing air pollutants when it's applied to outdoor surfaces.

Zinc Oxide Nanoparticles (ZnO)

Zinc oxide is a unique material that exhibits semiconducting and piezoelectric dual properties. It is added into various materials and products, including plastics, ceramics, glass, cement, rubber, paints, adhesives, sealants, pigments, fire retardants.

Silver Nanoparticles (Ag)

The nanosilver will affect, in contact with bacteria, viruses, and fungi, the cellular metabolism and inhibit cell growth. The nanosilver inhibits the multiplication and growth of bacteria and fungi, which causes infection, odour, itchiness, and sores. The core technology of nanosilver is the ability to produce particles as small as possible and to distribute these particles very uniformly.

Aluminium Oxide Nanoparticles (Al_2O_3)

Alumina (Al_2O_3) component reacts with calcium hydroxide produced from the hydration of calcium silicates. The rate was of the pozzolanic reaction is proportional to the amount of surface

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area available for reaction. The addition of nano-Al_2O_3 of high purity improves the characteristics of concretes, in terms of higher split tensile and flexural strength.

Zirconium Oxide Nanoparticles (ZrO_2)

Zirconium oxide (or Zirconia) nano powder or nanoparticles are white high surface area particles with typical dimensions of 5…100 nanometres and specific surface area in the 25…50 m2 /g range. Nano zirconium shows good aesthetics (translucency), superior physical resistance (hardness, flexibility, and durability), and chemical resistance (practically inert) and is a very good insulator.

Wolfram (Tungsten) Oxide Nanoparticles (WO_3)

In recent years, tungsten trioxide has been employed in the production of electrochromic windows, or smart windows. These windows are electrically switchable glass that changes light transmission properties.

Nanotechnologies for Construction

Nanotechnology can generate products with many unique characteristics that can improve the current construction materials: lighter and stronger structural composites, low maintenance coatings, better cementitious materials, a lower thermal transfer rate of fire retardant and insulation, better sound absorption of acoustic absorbers and better reflectivity of glass. In brief, the applicability of nanomaterials for construction materials was presented below.

Concrete

Concrete is a macro-material strongly influenced by its nano-properties. The addition of nano-silica (SiO_2) to cement-based materials can control the degradation of the calcium-silicate-hydrate reaction caused by calcium leaching in water, blocking water penetration and leading to improvements in durability. Nano-sensors have great potential to be used in concrete structures for quality control and durability monitoring. Carbon nanotubes increase the compressive strength of cement mortar specimens and change their electrical properties which can be used for health monitoring and damage detection. The addition of small amounts (1%) of carbon nanotubes can improve the mechanical properties of mixture samples of Portland cement and water. Oxidized multi-walled nanotubes show the best improvements both in compressive strength and flexural strength compared to the reference samples.

Nano Silica (SiO_2)

Nano-SiO_2 could significantly increase the compressive strength of concretes, by filling the pores between cement particles. Nano-silica decreases the setting time of concrete and reduces bleeding water and segregation by the improvement of the cohesiveness.This material with very high specific surface and high proportion of very fine particlesconsisting of nearly clean SiO_2 (99%) provides an excellent alternative to further alter the concrete characteristics, especially for higher end uses. however, they are amplified further primarily due to higher specific surface, hence higher reactiveness.

In the current research, the mineral admixture in the form of nano silica is used as partial replacement of cement by weight to improve the strength parameters of concrete. In the proposed work the cement is replaced by nano-silica in the proportion of 0, 0.5, 1, 1.5, 2, 2.5 and 3% by weight of cement.

APPLICATIONS

Some possible applications of nano silica concrete that can be explored in this project are:

1. HIGH-STRENGTH AND DURABLE CONCRETE STRUCTURES: Nano silica can enhance the mechanical and durability properties of concrete, such as compressive strength, flexural strength, abrasion resistance, and permeability. This

can lead to the construction of stronger and longer-lasting buildings, bridges, tunnels, dams, and other infrastructure.

2. SELF-COMPACTING AND WORKABLE CONCRETE: Nano silica can improve the rheological properties of concrete, such as viscosity, flowability, and segregation resistance. This can enable the production of self-compacting concrete (SCC) that can fill complex shapes and narrow gaps without the need for vibration or compaction. Nano silica can also reduce the water demand of concrete, which can improve its workability and reduce the risk of shrinkage and cracking.

3. SUSTAINABLE AND ECO-FRIENDLY CONCRETE: Nano silica is a byproduct of the production of silicon metal or ferrosilicon alloys, which are used in various industries. By using nano silica in concrete, waste materials can be recycled and environmental impacts can be reduced. Additionally, nano silica can reduce the carbon footprint of concrete by improving its strength and durability, which can lead to less frequent repairs and replacements.

4. INNOVATIVE AND ADVANCED CONCRETE: Nano silica is a relatively new material in the field of concrete technology, and its properties and applications are still being explored. By studying the strength properties of nano silica concrete with M30 grade, this project can contribute to the development of innovative and advanced concrete materials that can meet the evolving needs and challenges of the construction industry.

COMPARISON BETWEEN CONVENTIONAL CONCRETE & NANO SILICA CONCRETE:

Comparison between conventional concrete and nano silica concrete can be made on the basis of various factors such as strength, durability, workability, and sustainability.

Strength: Nano silica concrete has higher compressive strength, flexural strength, and abrasion resistance compared to conventional concrete. This is due to the increased packing density and reduced porosity of nano silica concrete.

Durability: Nano silica concrete has improved durability due to its reduced shrinkage and cracking tendency. It also has better resistance to chemical and environmental attacks, which can lead to longer-lasting structures.

Workability: Nano silica concrete has improved workability due to its increased viscosity and reduced water demand. This can lead to easier placement and compaction of the concrete.

Sustainability: Nano silica concrete is more sustainable compared to conventional concrete as it reduces the carbon footprint of construction by using waste materials and improving the durability of structures. It also reduces the need for frequent repairs and replacements, leading to less material waste.

Overall, the use of nano silica in M30 grade concrete can lead to significant improvements in strength, durability, workability, and sustainability compared to conventional concrete.

Research Significance of present work

From the above, it is known that nanomaterials are more attractive for many applications in society. In this view, experimental work is planned to assess the strength properties of cement concrete, prepared with ordinary Portland cement. In the proposed work the cement is replaced by nano-silica in the proportion of 0, 0.5, 1, 1.5, 2, 2.5 and 3% by weightof cement. Though many research works are limited to compressive strengths of cement mortarand concrete, it is found that there is a lacuna in the view of other areas of strength and durability. Hence the research work planned to

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evaluate the following properties pertaining to cement concrete specimens.

1. Compressive Strength
2. Flexural strength
3. Split tensile strength

2. The aim, scope and objectives of the present research are set as below:

AIM

To determine mechanical properties of concrete with addition of Nano material (Nano silica SiO_2).

SCOPE

The scope of this project is to conduct Comparative study on the mechanical properties of concrete by using Nano Silica as a partial replacement of cement. The study will involve preparing concrete specimens with varying percentages of Nano Silica and comparing their strength properties with those of conventional concrete.

OBJECTIVES

1. To determine the optimum percentage of Nano Silica as a partial replacement of cement material for maximum strength improvement in M30 grade concrete.
2. To evaluate the flexural strength and split tensile strength of M30 grade concretewith Nano Silica.
3. To compare the strength properties of M30 grade concrete with Nano Silica with those of conventional M30 grade concrete.

METERIALS AND METHODOLOGY

GENERAL

Concrete in general is made up of cement, aggregates and water. In current research, nana-silica is added to the concrete to get better durability and strength properties. The details of the experimental investigations are explained in this chapter.

MATERIALS USED

- Cement
- Water
- Aggregates
- Nano Silica (NS)

FIGURE 2: FINE AGGREGATE

FIGURE 3: COARSE AGGREGATE

Nano silica

Nano silica (NS) is a synthetic product with spherical particles in the range of 1-100 nanometres. The physical state of nano silica is either dry powder or colloidal suspension. The properties affected by nano-sized particles or voids are workability, strength, durability, shrinkage and bond. Nano silica fills the spaces between particles of C-S–H gel, acting as a nanofiller. The pozzolanic reaction of nano silica with calcium hydroxide liberated during hydration increases the amount of C–S–H gel, resulting in a higher densification of the matrix. The above parameters improve the strength and durability of the concrete. Nano-silica decreases the setting time of concrete when compared with silica fume. Addition of nano silica to concrete reduces bleeding of water, segregation and improves the cohesiveness of the mixtures in the fresh state. Nano Silica is a fine non–crystalline by product of Nano–silicon industry. It is approximately made at 20000C temperature. It is considered as an excellent pore filling material. It can be used as replacement of 2 – 10 % of cement content in a mixture. In the present study, colloidal nano silica (Figure 4) was used and their properties are presented in Table 3.

TABLE 3: PROPERTIES OF NANO SILICA

S. No	Properties of Nano-silica	Values
1	Specific gravity of Nano silica	1.06
2	Particle size	20-30 nm
3	Specific surface area	200 m2/g
4	Density	1.2 g/cm2
5	Colour	Translucent
6	pH value	8.5-10
7	Viscosity	≤7 mp


FIGURE 4: NANO SILICA

There are different methods to produce nano silica. The most common method for production of nano silica is sol-gel process (organic or water route) at room temperature. Nanosilica is also produced as a by-product of the manufacture of silicon metals and ferro-silicon alloys. It is collected by subsequent condensation to fine particles in a cyclone which is a very fine powder consisting of spherical particles or microspheres with a main diameter of 150 nm with high specific surface area. The study of concrete at the nanoscale shows that particle packing in concrete is improved by using nano silica, which densifies the micro and nanostructure resulting in improved mechanical properties. Incorporation of nano silica to cement based materials control the degradation of the fundamental C-S-H reaction of concrete caused by calcium leaching in water as well as blocks the water penetration and therefore leads to improvements in durability. There are different methods to produce nano silica. The most common method for production of nano silica is sol-gel process (organic or water route) at room temperature. Nano silica is also produced as a byproduct of the manufacture of silicon metals and ferro- silicon alloys. It is collected by subsequent condensation to fine particles in a cyclone whichis a very fine powder consisting of spherical particles or microspheres with a main diameter of 150 nm with high specific surface area. The study of concrete at the nanoscale shows thatparticle packing in concrete is improved by using nano silica, which densifies the micro and nanostructure resulting in improved mechanical properties. Incorporation of nano silica to cement based materials control the degradation of the fundamental C-S-H reaction of concrete causedby calcium leaching in water as well as blocks the water penetration and therefore leads to improvements in durability.

SLUMP VALUES:

S.NO	Name of modified mix	Slump Value (in mm)
1	NC	95
2	NS1	86
3	NS2	84
4	NS3	78

5	NS4	75
6	NS5	73
7	NS6	73

CONCLUSION GENERAL

A study was carried on mechanical properties of concrete containing nano silica. Basedon the results of the study, the following conclusions were drawn.

1. The strength of concrete started increasing till 2.5% of nanomaterial, but after that itstarted declining.

2. The compressive strength observed for 2.5% of nanomaterial is 47.14 N/mm^2.

3.The optimum percentage of maximum compressive strength improvement in M30 grade concrete is 20.01 % in NS5 (i.e., 2.5% nano silica replacement in cement).

4.The split tensile strength observed for 2.5% of nanomaterial is 4.28 N/mm^2.

5.The split tensile strength at 28 days of NS5 increases by 21.59 % than CC.

6.The flexural strength observed for 2.5% of nanomaterial is 5.96 N/mm^2.

7.The average flexural strength at 28 days of NS5 increases by 8.20 % than CC.

8.When compared to CC, NS1, NS2, NS3, NS4, NS5 and NS6 shows better performance in all aspects.

9. The optimum percentage of Nano Silica is 2.5%

FUTURE SCOPE

The research work may be protracted for future scope of the study by considering thefollowing perspectives:

i. Investigation of nano silica concrete should be further expanded to other durability properties i.e., shrinkage, creep and acid test.

ii. Comparing the mechanical properties of concrete with partial replacement of nano silica with other types of additives such as fly ash, slag, and metakaolin.

iii. Investigating the effect of nano silica on the workability and setting time of concrete.

iv. Application in other construction materials: The use of Nano Silica in concrete can alsobe extended to other construction materials such as mortar, bricks, and tiles. Therefore, a future scope of this project is to investigate the effects of Nano Silica on the strength properties of these materials.

v. Examining the cost-effectiveness of using nano silica as a partial replacement for cement in concrete production.

vi. Environmental impact: The production of cement is a major contributor to greenhouse gas emissions. Therefore, a future scope of this project is to investigate the environmental impact of using Nano Silica as a partial replacement of cement material and compare it with traditional concrete production methods.

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