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AN EXPERIMENTAL STUDY ON MECHANICAL PROPERTIES OF JUTE FIBER REINFORCED CONCRETE BEAMS

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***Abstract*--Conventional concrete improved by applying nanotechnology aims at developing a novel, smart and environment- friendly construction material towards the green structure. In today's life, though utilization of cement based materials plays a vital role in the infrastructure development, it is polluting the environment by emitting CO_2. Based on this view, going to an alternate material towards a green and sustainable solution. The aim of this study is to determine the properties of High Performance Concrete (HPC) with partial replacement of nano silica with cement. In this study, 7th and 28th day Compressive strength of concrete & slump values for different trial mix proportions are determined. Based on the compressive strength & slump value of trial mixes, mix proportions are fixed. By using this result, specimens are cast for different mixtures with different amounts of nano-silica as partial replacement of cement with a constant water to binder ratio (w/b= 0.30) and this specimens are kept for curing. The main objective of this study is to investigate the effect of Nano silica on the mechanical and durability properties of High performance concrete. In this study, Mechanical properties like compressive strength, split tensile, flexural strength, modulus of elasticity and durability-related properties such as chloride penetration, water absorption, abrasion and impact resistance, acid and sea water resistance of high performance concrete containing nano silica have been investigated. For this purpose, different trail mixtures were designed with different amounts of nano silica admixtures. Portland cement was partially replaced by 1%, 1.5%, 2%, 3% of nano silica were replaced by 5%, 7.5%, and 10%. The results confirmed that nano silica performs better than the conventional concrete in mechanical and durability properties. Owing to the size of nano silica, it shows better results.**

Keywords: Nano Silica, High Performance Concrete, Mechanical and Durability Properties.

I. INTRODUCTION

Portland cement and supplementary cementitious materials are cheapest binders which maintain and enhance the performance of concrete. However, out of these binders, production of Portland cement is very energy exhaustive along with CO_2 production. About 1 tone of CO_2 is produced in manufacturing of each tone of Portland cement (PC).Concrete is the most widely used construction material in India with annual consumption exceeding 100 million cubic meters. It is well known that conventional concrete designed on the basis of compressive strength does not meet many functional requirements such as impermeability, resistance to environment exposure, resistance to frost, thermal cracking adequately. As a result, innovations of supplementary materials and composites have been developed. Due to enhance mechanical properties and durability, high performance concrete (HPC) has gained wider acceptance in the construction of tall buildings, bridges and marine structures. For the past few decades, HPC has undergone many developments based on the influence of cement type, type and proportions of mineral admixtures, type of superplasticiser and the mineralogical composition of coarse and fine aggregates. For producing HPC, it is well recognized that the use of supplementary cementitious materials (SCM), such as nano silica (NS), ground granulated glass blast-furnace slag (GGBS) and fly ash (FA), are necessary. These materials, when used as mineral admixtures in HPC, can improve either or both the strength and durability properties of concrete.

1.1 High Performance Concrete

HPC is an engineered concrete possessing the most desirable properties during fresh as well as hardened concrete stages. While high strength concrete, aims at enhancing strength and consequent advantages owing to improved strength, the term high-performance concrete (HPC) is used to refer to concrete of required performance for the majority of construction applications.

As per ACI, High performance concrete (HPC) is defined as "a concrete meeting special combination of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practices". In the other words a high performance concrete is a concrete in which certain characteristics are developed for a particular application and environment, so that it will give excellent performance in the structure in which it will be placed, in the environment to which it will be exposed, and with the loads to which it will be subjected during its design life. The superiority may lie in one or more of several attributes, such as strength stiffness, freeze thaw, durability, resistance to chemical attack**.** High performance concrete is the term used for concrete mixes which possess invariably high dimensional stability, reasonable workability and high durability. The American Concrete Committee on HPC includes the following six criteria for material selections, mixing, placing, and curing procedures for concrete.

- Ease of placement
- Long term mechanical properties
- Early-age strength
- Toughness
- Life in severe environments
- Volumetric stability

1.2 Nanotechnology in High Performance Concrete

Nanotechnology is a very active research field and has applications in a number of areas. Nowadays nanomaterials are used in construction along with the traditional building materials. A small quantity of nano material is sufficient to enhance the performance of nano-composites. In cement composites, inclusion of nano particles such as nano SiO_2, Al_2O_3, TiO_2, quartz are used to make High Strength (HSC), High Performance (HPC) and Self Compacting concrete (SCC). Nowadays researchers are looking for ultra high performance concrete with the improved mechanical properties. Basically cementitious materials are quasi-brittle materials with low tensile strength and low strain capacity. It has opened a new pathway for evolving "nano-engineered ultra high performance material" and to create a new generation of a "crack free material". This type of concrete has many advantages including low-environmental impact, high strength and light structures with low CO_2 emissions, also enhances mechanical property, vibration damping capacity, air void content, low permeability,

1.3 Objectives

The objective of the present investigation is to study the mechanical and durability properties of M60 grade of high performance concrete for the replacement of 1%, 1.5%, 2% and 3% of the mass of cement by NS at a constant water-binder ratio. The present investigation also aimed to find the optimum percentage of NS for the cement replacement which will give the superior mechanical and durability characteristics of high performance concrete.

II. MATERIALS USED IN HIGH PERFORMANCE CONCRETE

2.1 Cement

Concrete is made from a properly proportioned mixture of cement, water, fine and coarse aggregates, and often, chemical or mineral admixtures. The most common cement used in construction today is portland cement. Portland cement is a finely ground grey powder chemically formed by combining raw materials containing calcium oxide (CaO), silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3), heating this mixture to a high temperature, and then grinding the resulting material, called clinker, with a small quantity of calcium sulfate ($CaSO_4$). The properties of hydraulic cement are determined, for the most part; by the way each cement compound reacts with water, a process known as hydration.

2.2 Nano Silica

Nano silica fume (NSF) is synthetic product with spherical particles in the range of 1-100 nanometers in Figure 4.2. It act as a viscosity modifying agent in combination with super plasticizers in order to produce high performance concrete. The performance of these Cementitious based materials is strongly dependent on nano-sized solid particles, such as particles of calcium–silicate–hydrates (C–S–H), or nano-sized porosity at the interfacial transition zone between cement and aggregate particles. Typical properties affected by nano-sized particles or voids are strength, durability, shrinkage and steel-bond.

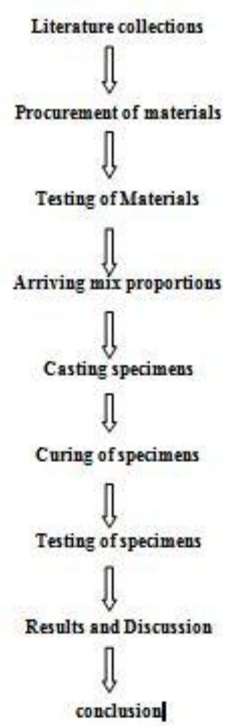
2.3 Experimental Procedure

This chapter presents the details of the trail mix proportions and experimental investigations carried out on the test specimens to study the mechanical and durability properties of high performance concrete containing nano silica.

Experimental investigations have been carried out on the HPC test specimens to ascertain the workability related properties like slump, vee-bee consistometer, etc., mechanical properties like compressive strength, flexural strength, etc., for the designed M60 grade of concrete. Minimum three specimens were cast and tested for each trail mix, also all the tests conducted as per the specifications.

III. METHODOLOGY

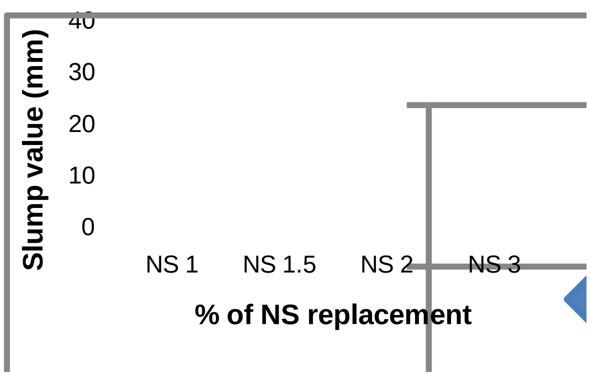
Fig.1 Flow chart of methodology



IV. RESULTS AND DISCUSSION

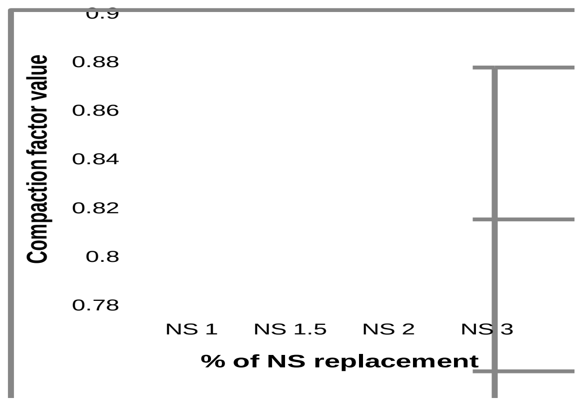
4.1 Slump Test

The apparatus for conducting the slump test essentially consists of a frustum of a cone having the bottom diameter of 20 cm, top diameter of 10 cm and height of 30 cm. For slump test, tamping rod of steel 16 mm in diameter, 0.6 m long and rounded at one end is used for compaction. The internal surface of the slump cone shall be thoroughly cleaned and should be free from any set concrete before commencing the test. The mould should be placed on smooth horizontal, rigid and non – absorbent surface such as carefully leveled metal plate. The mould should be filled in 4 layers each approximately one quarter of the height of mould. Each layer shall be tamped with 25 blows. For the 2^{nd} and subsequent layers tamping rod should penetrate into underlying layer. The bottom layer should be tamped throughout its depth. After the top layer has been rodded the concrete shall be struck off level with trowel or rod. The mould shall be removed from concrete immediately by raising it slowly and carefully in vertical direction. This will allow the concrete to subside and the slump shall be measured immediately by determining the difference between height of mould and that of highest point of slumped concrete specimen



4.2 Compaction Factor Test

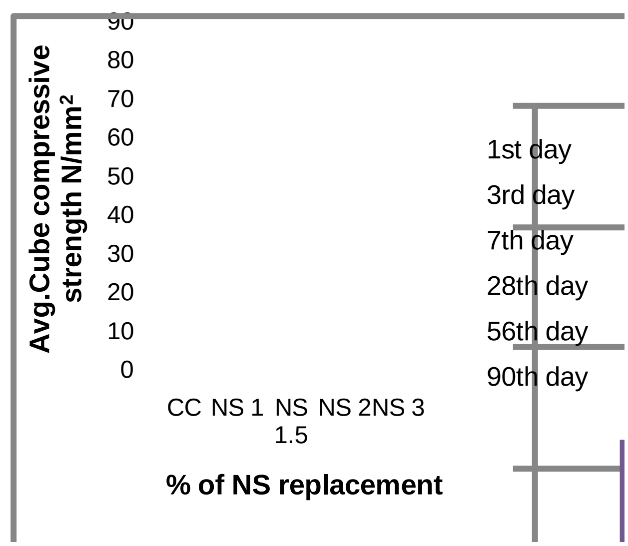
BS 1881 stated that compacting factor test as one of the test to determine the workability of the concrete. This test is usually being carried out in the lab and in specific condition i.e. construction site. It was a sensitive and more accurate test compared to the slump test and suitable for low workability of concrete mixture. Nevertheless the accuracy of the result will be reduced with the increased of the aggregate size (size exceed 20mm). The sample of concrete is placed in the upper hopper up to the brim in. The trap-door is opened so that the concrete falls into the lower hopper. The trap-door of the lower hopper is opened and the concrete is allowed to fall into the cylinder. The excess concrete remaining above the top level of the cylinder is then cut off with the help of plane blades. The concrete in the cylinder is weighed. This is known as weight of partially compacted concrete. The cylinder is filled with a fresh sample of concrete and vibrated to obtain full compaction. The concrete in the cylinder is weighed again. This weight is known as the weight of fully compacted concrete. It should normally be stated to the nearest second decimal place.



4.3 Cube Compressive Strength

For the compression strength test of concrete 100 x 100 mm cubes are used and it's tested as per BIS: 516-1959. For each trail mix combination, three cubes were tested at the age of 3, 7, 28, 56 and 90 days of curing using 3000KN capacity AIMIL compression testing machine the specimens shall be tested with the moulded sides in contact with the plates. The load shall be applied without shock and increased continuously at a rate of approximately 140 kg/sq cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The compressive strength is determined by following formula:

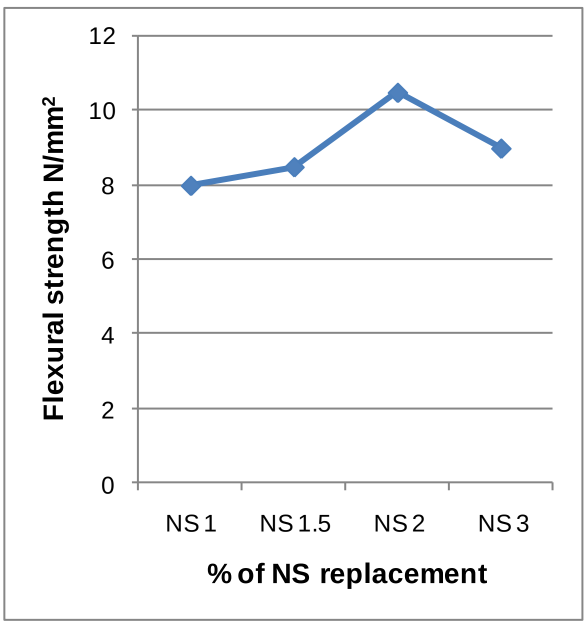
$$Fck = \frac{ultimate\ load}{area\ of\ specimen}$$



4.4 Flexural Strength Test

The Flexural strength of concrete is determined as per BIS: 516-1959 at the age of 28 days using 100 x 100 x 500 mm prisms. For each trail mix three prisms were tested to determine the flexural strength of concrete. The bearing surfaces of the supporting and loading rollers shall be wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers. The specimen shall then be placed in the machine in such a manner that the load shall be applied to the uppermost surface as cast in the mould, along two lines spaced 20.0 or 13.3 cm apart in Figure 5.8. The axis of the specimen shall be carefully aligned with the axis of the loading device. No packing shall be used between the bearing surfaces of the specimen and the rollers. The load shall be applied without shock and increasing continuously at a rate such that the extreme fibre stress increases at approximately 7 kg/sq cm/min, that is, at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens. The load shall be increased until the specimen fails, and the maximum load applied to the specimen during the test shall be recorded. The appearance of the fractured faces of concrete and any unusual features in the type of failure shall be noted. The flexural strength of the specimen shall be expressed as the modulus of rupture *f*b, which, if '*a*' equals the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen, in cm, shall be calculated to the nearest 0.5 kg/sq cm as follows:

$$F_b = \frac{PL}{BD^2}$$



V. CONCLUSIONS

The following conclusions are drawn from the obtained experimental results:

- ✓ Due to the particle size and specific surface area of nano silica and silica fume, water demand for the HPC mixes are higher. In order to achieve the required workability super plasticizer dosage is increased from 0.4 to 0.8 % by weight of cement.
- ✓ The average cube compressive strength at 28th day for the mix containing 1%, 1.5%, 2% and 3% of NS are increased by 1.41%, 1.8%, 2.2% and 2% respectively. Also, there is increasing of cube compressive strength at 56th and 90th day.
- ✓ The flexural strength for the mix containing 1%, 1.5%, 2% and 3% of NS are increasing up to 2% of NS The trail mixes with the NS replacement shows less water absorption, porosity and sorptivity .This indicates that the particle size of NS plays an vital role to make the concrete impermeable.
- ✓ The concrete mixes contain NS shows better resistance against chloride penetration, abrasion, acid and sea water attack and impact.

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