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An Experimental Investigation of Partial Replacement of Nano Cement with Polypropylene Fibre in Concrete

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ABSTRACT –

Nano technology has contributed a number of materials that have excellent properties and a lot of research has been put into effect in order to create nano particles which could be infused into cement paste in order to improve their performance. Although cementitious construction materials are mainly used in a large scale and in huge quantities, fundamental properties such as strength, ductility, creep, shrinkage, and fracture behavior depend, to a great extent, on structural elements and phenomena which are effective at the micro and nanoscale. Although concrete offers many advantages regarding mechanical characteristics and economic aspects of the construction, the brittle behavior of the material remains a larger handicap for the seismic and other applications where flexible behavior is essentially required. Recently, however the development of polypropylene fiber- reinforced concrete (PFRC) has provided a technical basis for improving these deficiencies. This project presents an overview of the effect of polypropylene (PP) fibers on various properties of concrete in fresh and hardened state such as compressive strength, tensile strength, flexural strength, workability, bond strength, fracture properties, creep strain, impact. The role of fibers in crack prevention has also been discussed. So in this project, an attempt has been made to assess the suitability of providing 30% of Nano cement to Ordinary Portland Cement with an incorporation of 1% of Polypropylene fiber reinforced concrete to increase the strength by the survey of the literature and the tests were experimentally conducted and the results have been found.

1. INTRODUCTION

Concrete is considered to be very durable material that requires little or no maintenance. Concrete is a mixture of cement, fine aggregate, coarse aggregate and water. Concrete plays a vital role in the development of infrastructure viz., buildings, industrial structures, bridges and highways etc., leading to utilization of large quantity of cement and fine aggregate. Portland cement, already being a very expensive material constitutes a substantial part of the total construction cost of any project and the situation has further been aggravated by the energy crisis, which has further increased the cost of production of Portland cement. Therefore, it is of current important for a country to explore and develop alternate cementing materials cheaper than the Portland cement. Cement is the most important constituent of the concrete and occupies about 20% of the volume of concrete. The demand for concrete is an ever increasing scale, leading to higher cement production. But the production of cement releases equal amount of CO2 in to the atmosphere leading to global warming. Concrete modification by using polymeric materials has been studied for the past four decades. In general, the reinforcement of brittle building materials with fibers has been known from ancient period such as putting straw into the mud for housing walls or reinforcing mortar using animal hair etc. Many materials like jute, bamboo, coconut, rice husk, cane bagasse, and sawdust as well as synthetic materials such as polyvinyl alcohol, polypropylene (PP), polyethylene, polyamides etc., have also been used for reinforcing the concrete. Research and development into new fiber reinforced concrete is going on today as well. Polypropylene fibers were first suggested as an admixture to concrete in 1965 for the construction of blast resistant buildings for the US Corps of Engineers. The fiber has subsequently been improved further and at present it is used either as short discontinuous fibrillated material for production of fiber reinforced concrete or a continuous mat for production of thin sheet component.

2. OBJECTIVES

The main objective of this project is to harden the monolithic concrete,to occupy and fill free spaces inside the concrete. As a result of chemical reactions taking place, the concrete gets super- hydrated. They fill capillaries, pores and micro- gaps thus bonding free limestone present in concretes into non-soluble solid bodies and to use for controlling shrinkage & temperature cracking to reduce the crack in concrete. Practically and economically advantages of Nano-Cement Technology molecular concretes and mortars drastically decreases execution period and investment costs yet maintaining top quality and ecologic standards. Due to enhance performances and effective cost-benefit ratio, the use of polypropylene fibers is often recommended for concrete structures recently. PFRC is easy to place, compact, finish, pump and it reduces the rebound effect in sprayed concrete applications by increasing cohesiveness of wet concrete. The use of PFRC provides a safer working environment and improves abrasion resistance in concrete floors by *controlling the bleeding while the concrete is in plastic stage. The possibility of increased tensile strength and impact resistance offers potential reductions in the weight and thickness of structural components and should also reduce the damage resulting from shipping and handling.*

3. METHODOLOGY

Consistency test on Cement, Initial & Final Setting time of cement

Consistency test on Nano Cement, Initial & Final Setting time of Nano-cement.

Specific gravity of Coarse aggregate Specific gravity of Fine aggregate Sieve analysis of Coarse aggregate Sieve analysis of Fine aggregate

Compression test on concrete cubes to obtain the strength of cubes at 7,14 & 28 days using Ordinary Portland Cement.

Compression test on concrete cubes to obtain the strength of cubes at 7,14 & 28 days using 1% of Polypropylene Fibre in Ordinary Portland Cement

Compression test on concrete cubes to obtain the strength of cubes at 7,14 & 28 days using 30% of Nano Cement in Ordinary Portland Cement.(30% nano –cement & 70% Orinary Portland cement+ 1% of PFC)

Split tensile strength & Flexural strength at 28 days

Initial nominal mix batch will be 100% of Ordinary Portland cement.

Second batch will be adding 1% of Polypropylene Fibers in 100% Ordinary Portland cement in different aspect ratios.

Third batch will be 30% of Nano-Cement & 70% of Ordinary Portland Cement with the addition of 1% of Polypropylene Fibers.

Cubes,cylinder & beams are casted and tested for their strength values.

Comparison results will be differentiated using graph.

Cost comparison will be differentiated.

IV. MATERIALS CEMENT

Cement is a binding material used in the preparation of concrete. It bends the coarse aggregates and fine aggregates with help of water, to a monolithic matter and also it fills the voids in the concrete. There are two requirements for any cement in the concrete mix design. That is compressive strength development with time attainment of appropriate rheological characteristic, type and production of cement. OPC 53 Grade sample was tested to obtain the following characteristic as per IS12269-1987:

Specific gravity Standard consistency Initial setting time Fineness Modulus

FINE AGGREGATE

The fine aggregate used in the manufacturing of concrete should be free from debris, fungi and chemical attack. It plays a vital role in concrete, so it should durable,angular and sharp edges then only it gives a rich mix concrete and workability. In this present investigation, the river sand which was available near Karur,was used as fine aggregate and the following tests, carried out on sand as per IS:2386-1963 PART (I),(III)&(IV)

Specific gravity

Sieve analysis and fineness modulus Bulk density

COARSE AGGREGATE

Aggregate are the important constituents in concrete. They give body to the concrete, reduces shrinkage and effect economy. Earlier, aggregates were considered as chemically insert materials but now it has been recognized that some of aggregates are chemically active and also that certain aggregate exhibit chemical bond at the interface of aggregate and paste. The more aggregates occupy 70 – 80 percentage of concrete; their impact on various characteristics and properties of concrete is undoubtedly considerable. In this present investigation, locally available crushed blue stone aggregate ofsize 20mm and down was used and the various tests carried out on the aggregates are given below as per IS: 2386-1963(1V)

Specific gravity

Sieve analysis and fineness modulus Water absorption

Bulk density Crushing strength Impact strength ***WATER***

Water is an important ingredient of concrete as it actively participates in the chemical reactions with cement. The strength of cement concrete mainly from binding action of the hydration of cement get the requirement of water should be reduced that required chemical reaction of un-hydrated cement as the excess water would end up in only formation undesirable voids (or) capillaries in the hardened cement paste in concrete. It is important to have the compatibly between the given cement and the chemical material admixtures along with the water used for mixing. It is generally stated in the concrete *codes and also in the literature that the water fit for making concrete. This may not be true always. The limits of the content of water have to be determined from the following consideration. High content of cement is susceptible to a rapid loss of workability on account of higher amount of heat of hydration generated. The salt in water would not interface with the development of strength of later ages. Apart from the strength consideration, the durability characteristics such as porosity, degree of resistance to diffusion of Co2, CaSo4 moisture, air oxygen, etc, should also be investigated after specified curing period.*

NANO CEMENT

Nanotechnology has the potential to enhance the desirable properties of concrete while helping to address some of the challenges facing the construction industry. The concrete construction industry is not the only industry looking at using nanoscience and technology to enhance their products. Cement is one of the most widely used materials in construction industry. In2011, the expected total worldwide production of cement was 3,400 million tonnes. China is the largest producer accounting for 2 billion tonnes in production with India in second position (210 million tonnes) followed by the USA (68 million tonnes). Despite being widely used, cement-based materials have poor mechanical properties and are highly permeable to water and other aggressive chemicals, which reduces their durability. Moreover, the cement industry is one of the significant sources of CO2 emissions, which accounts for 5-6% of global man-made CO2 emission annually. However, the increasing demand for high performance structural materials and components has led to the rapid development of new classes of materials. Nanotechnology can play a significant role in the construction industry and stands at eighth position in terms of most significant areas of applications in nanotechnology. Nanoengineering of cement-based materials can result in outstanding or smart properties. Introduction of nanotechnology in cement industry hasthe potential to address some of the challenges such as CO2 emissions, poor crack resistance, long curing time, low tensile strength, high water absorption, low ductility andmany other mechanical performances.

POLYPROPYLENE FIBER

The use of these fibers has increased tremendously in construction of structures because addition of fibers in concrete improves the toughness, flexural strength, tensile strength and impact strength as well as failure mode of concrete. Polypropylene twine is cheap, abundantly available, and like all manmade fibers of a consistent quality. The raw material of polypropylene is derived from monomeric C3H6 which is purely hydrocarbon. Its mode of polymerization, its high molecular weight and the way it is processed into fibers combine to give polypropylene fibers very useful properties. Good FRC mixes usually contain a high mortar volume as compared to conventional concrete mixes. The aspect ratio for the fibers are usually restricted between 100 and 200 since fibers which are too long tend to "ball" in the mix and create workability problems. As a rule, fibers are generally randomly distributed in the concrete; however, placing of concrete should be in such a manner that the fibers become aligned in the direction of applied stress which will result in even greater tensile and flexural strengths.

5. MIX DESIGN FOR M20 CONCRETE

According to IS 456 : 2000 it was mixed in the ratio of 1:1.5:3.

The mix was designed for the characteristic compressive strength of 20 N/mm^2 as per IS guidelines and proportion by weight and volumes were arrived. All the materials were weighed and used. No additive was added.

The concrete mix details are furnished below.

PROPORTIONING

Grade designation : M20

Type of cement : Ordinary Portland cement Maximum size of aggregate : 20mm Maximum Water cement ratio : 0.4

Minimum cement content : 300kg/m^3 Workability : 50-100 mm

Exposure condition : Mild

Method of concrete placing : Hand placing Degree of supervision : Good

TEST DATA FOR MATERIAL

Cement used :	*OPC*
Specific gravity of cement :	*3.15*
Specific gravity of CA :	*2.868*
Specific gravity of FA :	*2.59*

TARGET MEAN STRENGTH

Fck : fck +1.65s

= 20+1.65x4

= 26.6 N/mm²

***SELECTION OF WATER CEMENT RATIO**:*

Maximum Water cement ratio : 0.45 SELECTION OF WATER CONTENT

From table 2,

Maximum Water content : 197litre (100mm slump)

CALCULATION OF CEMENT CONTENT

Water cement ratio : 0.45

Cement content : 197/0.45 = 437. 77kg/m³ 437.77kg/m³ > 300kg/m³

Hence ok

VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE

Volume of CA for w/c ratio of 0.45 = 0.63 Volume of FA = 1 – 0.63 = 0.37

MIX CALCULATIONS

Volume of concrete : 1 m³

Volume of cement = (mass of cement/specific gravity ofcement) x (1/1000)

= (437.77/3.16) x (1/1000)

= 0.138 m³

Volume of water = (197/1) x (1/1000

= 0.197 m³

Volume of aggregate (CA&FA) = 1-(0.138+0.197)

= 0.665 m³

Mass of CA = 0.665X0.63X2.86X1000

= 1198.19 kg

Mass of FA = 0.665x0.37x2.59x1000

= 637.26 kg

MIX PROPORTIONS

Cement : 437.77 kg/m³

Fine ***aggregate :*** *637.26 kg/m³ Coarse* ***aggregate :*** *1198.19 kg/m³* ***Water :*** *197 lit**res***

Cement : FA : CA = 1 : 1.46 : 2.7

CONCRETE MIX & CURING

6. TEST ON BEAM

Reinforced concrete beams were cast for each mix. All beams have same concrete dimensions,(100 X 200 X 2000 mm).The beam consist of two numbers of 10 mm dia bars for tension zone and compression zone. Two legged 8 mm dia stirrups at a spacing of 100 mm were provided throughout the span. After casting the beam curing process was done by using wet gunny bags. After the required period of curing, all the beams were tested in a loading frame ofcapacity 2000 kN. The test beams were simply supported over two rigid supports. Two points were applied to all the beams and were increased until failure. Load and deflection at first crack and at failure were recorded. Test setup of the beam shown in fig below.

TEST ON BEAM

7. SUMMARY

There is wide scope for the use of nanotechnology including nano ingredients for harnessing improved mechanical and electrical properties such as higher strength, toughness, flexibility, stability, conductivity, besides self-cleaning property of cement-based composites. Current studies are mostly confined to laboratory stage. Therefore, a lot more extensive studies are required before the application of nanotechnology becomes viable and economical way for enhancing the important properties of cement-based materials. PFRC is easy to place, compact, finish, pump and it reduces the rebound effect in sprayed concrete applications by increasing cohesiveness of wet concrete.Hence an experimental test has been made with the incorporation of 1% polypropylene fibre with 30% nano cement replacement and the results have been found. It is to be said that the strength is more in the incorporation of polypropylene fibre & Nano cement comparing with the conventional concrete & can be applied for building constructions but the cost is ineffective & reliable a higher cost comparing with the conventional concrete. The Nano cement can be analyzed in the future for its cost & thus it might be applied for future Economic constructions as the rate of polypropylene fibre is lower.

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