EFFECT OF COLLOIDAL NANO SILICA (CNS) ON HIGH STRENGTH RICE HUSK ASH CONCRETE

Submitted in partial fulfillment of the requirements

for the degree of

Bachelor of Engineering

By

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This is to certify that the project entitled ***"Effect Of Colloidal Nano Silica (CNS) On High Strength Rice Husk Ash Concrete"*** is a bonafide work of ***Gupta Vinay Vedmani (12CE19), Gupta Vipin Vedmani (12CE20), Khan Abdul Samad Abdul Mannan (12CE26), Sayed Khalil Husen (13CE68)*** submitted to the University of Mumbai in partial fulfilment of the requirement for the award of the degree of "Bachelor of Engineering" in Department of Civil Engineering.

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Declaration

We declare that this written submission represents our ideas in our own words and where others ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Abstract

Now a day mineral admixtures are use as replacement for cement in concrete because it reduces CO_2 emission during hydration of cement. These mineral admixtures reacts with calcium hydroxide forms during cement hydration and this is called as pozzolanic action. The pozzolanic action of mineral admixture like Rice Husk Ash (RHA) would come into play at later stages. The Colloidal Nano Silica (CNS) which is nano material use in cement for accelerating pozzolanic action. In the present study, the mineral admixture RHA was used as 5, 10,15% replacement for OPC in M60 grade of concrete. The 10% RHA was taken as optimum dose on the basis of workability and compressive strength. To this 10% RHA concrete, effect of 1, 2, 4, 6% CNS addition were study by workability, compressive strength and split tensile strength. The workability decreases as CNS doses increases in 10% RHA replacement mix. The compressive strength of 2% CNS addition in 10% RHA replacement mix was increased by 8.44%, 9.5%, 13.21% at 3, 7, 28 days with respect to 10% RHA replacement mix without CNS. The split tensile strength of 2% CNS addition in 10% RHA replacement mix was decreased by 8.13%, 8.06%, 1.93% at 3, 7, 28 days with respect to 10% RHA replacement mix without CNS.

Keyword: Pozzolanic action, Rice Husk Ash (RHA), Colloidal Nano Sillica (CNS), Ordinary Portland Cement (OPC), Workability, Compressive Strength, Split Tensile Strength.

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List of Nomenclatures/Abbreviations

C_3S	Tricalcium Silicate
CH	Calcium Hydroxide
CM	Conventional Mix
CNS	Colloidal Nano Silica
C-S-H	Calcium Silicate Hydrate
FA	Fly Ash
FST	Final Setting Time
HPC	High Performance Concrete
HSC	High Strength Concrete
IST	Initial Setting Time
ITZ	Interfacial Transition Zone
NS	Nano Silica
OPC	Ordinary Portland Cement
R10C1M	10% RHA replacement with 1% CNS addition Mix
R10C2M	10% RHA replacement with 2% CNS addition Mix
R10C4M	10% RHA replacement with 4% CNS addition Mix
R10C6M	10% RHA replacement with 6% CNS addition Mix
R10M	10% RHA replacement Mix
R15M	15% RHA replacement Mix
R5M	5% RHA replacement Mix
RHA	Rice Husk Ash
SCC	Self Compacting Concrete
SF	Silica Fume

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Chapter 1

Introduction

1.1 General

Concrete is a highly heterogeneous material produced by mixture of finely powdered cement, aggregates of various sizes and water with inherent physical, chemical and mechanical properties. A reaction between the cement and water yields calcium silicate hydrate, which gives concrete strength and other mechanical properties of concrete, as well as some by-products including calcium hydroxide (CH), 'gel pores' etc. Cement hydration as per the following chemical equations.

$$C_3S + 6H \longrightarrow C_3S_2H_3 + 3CH$$

$$2C_2S + 4H \longrightarrow C_3S_2H_3 + CH$$

(Cement chemistry notation: C = CaO; S = SiO_2; H = H_2O).

With reference to the above equations, it is learnt that the C-S-H is the strength phase, whereas the by-product CH is not having any cementitious properties, easily be leached out, prone to chemical attack. With the addition of suitable cementitious materials, mostly siliceous or aluminous with cement which will react with excess CH and produce additional C-S-H with the replacement of porous CH and refines the pore structure and reduces permeability of gases and water in concrete (Maheswaran et al, 2013).

Human activities on the Earth produce solid waste in considerable quantities of over 2500 MT per year, including industrial wastes, agricultural wastes and wastes from rural and urban societies. Amongst the solid wastes, the most prominent ones are fly ash, blast furnace slag, rice husk, silica fume and demolished construction materials. Rice milling generates a by-product known as husk. This surrounds the paddy grain. During the milling of paddy about 78 % of weight is received as rice, broken rice and bran. The rest 22 % of the weight of paddy is received as husk. This husk is used as fuel in the rice mills to generate steam for the parboiling process. This husk contains about 75 % organic volatile matter which burns up and the balance 25 % of the weight of this husk is converted into ash during the firing process, which is known as rice husk ash (RHA). Rice husk was burnt approximately 48 hours under uncontrolled combustion process. The burning temperature was within the range of 600 to 850 degrees. The ash obtained was ground in a ball mill for 30 minutes and its color was seen as grey.This RHA in turn contains around 85 %-90 % amorphous silica. So for every 1000 kg of paddy milled, about 220 kg (22%) of husk is produced, and when this husk is burnt in the boilers, about 55kg (25%) of RHA is generated (Rao et al, 2014).

India is a major rice producing country, and the husk generated during milling is mostly used as a fuel in the boilers for processing paddy, producing energy through direct combustion and /or by gasification. About 20 million tons of RHA is produced annually. This RHA is a great environment threat causing damage to the land and the surrounding area in which it is dumped. Lots of ways are being thought of for disposing it by making commercial use of this RHA (Rao et al, 2014). In this present study, Ordinary Portland Cement (OPC) was replaced by Rice Husk Ash (RHA) at various percentages so as to arrive at optimum dose of RHA.

Nanoscience and technology is a new field of emergence in materials science and engineering, which forms the basis for evolution of novel technological materials. Nano technology finds application in various fields of science and technology (Maheswaran et al, 2013).

Nano technology has been introduced to cement and concrete research because it can achieve a stronger and more durable concrete. As the most widely used nano material for cement/concrete-engineering, nanoSiO_2 has been studied intensively. It has been widely reported that nanoSiO_2 addition can greatly improve properties of cementitious materials (Hou et al, 2013).

The performance enhancing properties of nano silica are achieved through two mechanisms. The ultrafine particles are able to fill the microscopic voids between the cement particles improving ‘‘packing’’ and creating a less permeable structure. In the curing process, the nano silica also reacts with the $Ca(OH)_2$ produced with the cement paste to form additional calcium silicate hydrate .Furthermore, the well-dispersed nanoparticles could act as centers of nucleation for cement hydrates, a fact which would accelerate the hydration. The mechanism of this working principle is related to the high surface area of nano silica, which works as nucleation site for the precipitation of CSH-gel. The nanoparticles favor the formation of small-sized crystals (such as calcium hydroxide and AFm) and small sized uniform clusters of C–S–H. Finally, they could improve the structure of the aggregate contact zone, which results in a better bond between aggregates and cement paste. Due to results of the filling effect (reduced porosity) and the pozzolanic reaction (consuming of calcium hydroxides for CSH formation), the nano silica could be used as admixtures for producing HPC with enhancing strength and abrasion resistance along with reducing permeability and dry shrinkage (Kontoleontos et al, 2012).

However, the compressive strength of ordinary Portland cement increases with the increase of the amount of nano silica, until it reaches an optimal amount of (approx. 0.5%) and then drops to lower values, at higher addition. Because Nano silica presents high specific surface areas with high surface energies, agglomeration has been observed in higher substitution, a fact that prevents uniform distribution of the nano-SiO_2 particles within the mortar. Thus, the enhancement of the compressive strength (and pore structure) is subjected to a certain limit. Furthermore, when nano silica is incorporated into the mortar in the fresh state it has a direct influence on the water amount required in the mixture, a fact that could lead to a considerable decrease of setting times and the reduction of mortar flow, due to the gain in cohesiveness of the paste (Kontoleontos et al, 2012).

Colloidal silica (CS) denotes small particles consisting of an amorphous SiO_2 core with a hydroxylated surface, which are insoluble in water. The size of the particles can be varied between 1 and 500 nm, hence they are small enough to remain suspended in a fluid medium without settling. Parameters such as specific surface area, size and size distribution can be controlled by the synthesis technique (Kontoleontos et al, 2012). In this present study, also the effect of various doses of Colloidal Nano Silica (CNS) on workability, compressive and tensile strength of high strength rice husk ash concrete were study.

1.2 Aim of Project

To study the effect of Colloidal Nano Silica (CNS) on High Strength Rice Husk Ash Concrete.

1.3 Application of Colloidal Nano Silica (CNS)

Following are the applications of CNS

1) Colloidal silica works as a stabilizer, a durability enhancer, an accelerator and a strength developer in concrete.

2) It produces extremely stable, bleed-free cement slurries without free water. Additionally, at lower temperatures in deep to ultra-deep well cementing applications, colloidal silica enhances early compressive strength and shortens setting times and well drilling activities usually can resume more quickly, saving time and money. Additionally, the low specific gravity of colloidal silica produces lightweight slurries that can be injected more controllably.

3) Colloidal particles interact with the free lime ($Ca(OH)_2$) created during cement hydration to create calcium silicate binders which produce a cohesive gel structure that enhances cement-paste density, reinforces the structure between cement grains, and eliminates free water.

4) When added to self-compacting concrete, it control segregation of aggregates and prevent bleeding, making the mix more stable and workable.

1.4 Objectives of the Present Study

The primary aim is to study the effect of CNS on High Strength Rice Husk Ash Concrete. The objectives of the present study are:

1) To produce 60 MPa High Strength Concrete using 0,5,10, and 15 % of Rice Husk Ash (RHA) as a mineral admixture.
2) To determine the optimum percentage of RHA as a partial Replacement of cement to produce HSC.
3) To study effect of 0,1,2,4 and 6 % of CNS on Mechanical properties such as compressive strength, splitting tensile strength, and modulus of rupture of High Strength Rice Husk Ash Concrete.

1.5 Expected Outcome

To arrive at optimum dose of CNS at which property of concrete will improve.

1.6 Methodology

Following methodology adopted in this present study

1) Study the material properties such as cement, sand, coarse aggregate and admixtures.
2) Design of RHA concrete mix from 60 MPa grade Concrete.
3) To achieve the target strength by making trial mixes and finalizing the mix proportions by different trial mixes.
4) Addition of different doses of CNS in rice husk concrete.

5) Casting of cube specimens (150mmx150mmx150mm) for testing under compression.
6) Casting of cylindrical specimens (150mm dia x 300mm height) for testing under split tensile strength.

Chapter 2

Review of Literature

2.1 General

In this chapter, literatures on Rice Husk Ash (RHA) and Colloidal Nano Silica (CNS) were presented. From literature review it was observed that there are many literatures in which RHA was used as replacement for cement and studied the properties of RHA concrete. Also there are many literatures in which effect of CNS on cement paste was studied.But there are few literatures in which effect of nano silica in powder form was studied in concrete and there is no literature in which effect of nano silica in liquid form was studied in high strength RHA concrete.

The detail discussion of literatures of RHA and CNS are given in following sections.

2.2 Literature review of Rice Husk Ash

Following are the literatures related to RHA

Akeke et al (2012) investigated the effects of introducing Rice Husk Ash (RHA) as a Partial Replacement of Ordinary Portland Cement (OPC) on the Structural Properties of Concrete. They found compressive strength ranging from 33-38.4 N/mm^2 at replacement percentages of 10-25% in a mix of 1:1.5:3. According to them, there is no substantial increase in tensile strength due to the addition of RHA while there is a marginal improvement in flexural strength with 10 to 25% RHA replacement levels. They concluded that RHA is good for structural concrete at 10% replacement level.

Marthong (2012) used three grades of Ordinary Portland Cement (OPC) namely; 33, 43 and 53 as classified by Bureau of Indian Standard (BIS) and percentage replacement of OPC with RHA was 0, 10, 20, 30 and 40% respectively. He found that mixes containing RHA will required higher water content than the corresponding conventional mixes therefore the workability decreased upon the inclusion of RHA and also RHA concrete can attain the same order of strength as conventional concrete at longer curing periods.

He also found that shrinkage of RHA concrete is similar to the pure cement concrete in all grades of OPC, water absorption of RHA concrete up to 20% replacement decreased with the increased in grades of OPC and inclusion of RHA as partial replacement of cement slightly improves the durability when exposed to sulphate environment. He suggested the use of RHA as partial replacement of cement upto a maximum of 10% by volume in all grades of cement, having good compressive strength performance and durability (Marthong, 2012).

Muthadhi et al (2013) prepared four concrete mixtures to identify the effect of RHA (added as partial replacement of Ordinary Portland Cement from 10 to 30%) on performance characteristics of the concrete. They found that the durability of RHA concrete was on the higher side for all doses compared with the reference mixtures and at the 30% RHA level, the mixtures attained strength comparable to that of respective reference mixtures. They conclude linear relationship exists between measured permeability properties of RHA-blended concrete irrespective of water binder ratio, age and cement content. Then by considering the maximum strength, cost effectiveness, and performance characteristics, 20% replacement of cement by RHA addition was concluded as optimum dosage in concrete making.

Nair et al (2013) concluded that incorporation of RHA in concretes results in improved compressive strength and flexural strength. A slight increase in bond strength was also reported. RHA-High strength concrete showed a reduction in density compared with conventional concrete. Hence this study promotes the use of RHA in high strength concrete as a sustainable cement replacement material.

Pande et al (2013) tested samples with dimensions of 15 X 15 X 15 cm , with 12.5, 25& 37.5% of RHA, replacing in mass of the cement. They found that replacement of 12.5 % of cement with rice husk ash in matrix causes reduction in utilization of cement and expenditures and also their results indicate that pozzolanic reactions of rice husk ash in the matrix composite were low in early ages, but by aging the specimens to 90 days, considerable effect have been seen in strength. According to their study, addition of pozzolans like rice husk ash to the concrete, can improve the mechanical properties of specimens.

Rajput et al (2013) experimentaly studies on strength characteristics of cement mortar in which Rice Husk Ash (RHA) is used as partial replacement (5% to 30% by weight of cement) of Ordinary Portland Cement (OPC). From the test results they concluded that if approximately 10% of cement is replaced by equal amount of RHA, there is not any significant depreciation in the compressive strength and thus the RHA can be used as partial replacement of cement in the regions where the material is locally available.

Khatri et al (2014) show the impact of Admixtures and Rice husk ash on concrete structures by conducting an experimental study in the laboratory to improve the cubic strength of concrete structures. Super plasticizer Conplast 430: G-8 as an admixture is added in concrete mix design (M-20 grade). Their results shows that compressive strength of concrete increases about 30% at 7days and 50% at 28 days by inclusion of admixture as compared to without admixture. Also increment of about 19.5% and 27.3% at 7 and 28 days has been observed respectively with 5% RHA as compared to without RHA and increment of about 35.5% and 52.5% at 7 and 28 days respectively with 15% RHA as compared to without RHA. They also observed that at 15% RHA compressive strength of concrete cubes increase about 13.38% at 7 days and about 19.78% at 28 days with respect to 5% RHA.

Kulkarni et al (2014) studied the suitability of the rice husk ash as a pozzolanic material for cement replacement in concrete. They found that the bulk density of RHA concrete is reducing with increase in RHA content. They observed that early strength gain is slightly increasing with addition of 10%, 20% & 30% RHA in normal concrete at 7 days. But in 28 days tests results they found that with addition of 20% RHA in normal concrete, strength is running parallel or more than of normal concrete. Thus 20% RHA they consider as optimum content for getting nearly equal strength at 28 days. Also they observed as replacement of cement by RHA in concrete increases, the workability of concrete decreases.

They concluded that the pozzolonic activity of rice husk ash is not only effective in enhance the concrete strength, but also in improving the impermeability characteristics of concrete. They concluded optimum replacement level of Rice Husk Ash is to be 0 to 20% for M30 grade of concrete (Kulkarni et al, 2014).

Obilade (2014) studied the properties of Rice Husk Ash (RHA) when used as partial replacement (0%, 5%, 10%, 15%, 20% and 25%) for Ordinary Portland Cement (OPC) in concrete. They found that the compacting factor decreased as the percentage replacement of OPC with RHA increased. Also the compressive strength of the hardened concrete decreased with increasing OPC replacement with RHA and the bulk densities of concrete reduced as the percentage RHA replacement increased. He concluded optimum addition of RHA as partial replacement for cement is in the range 0-20%.

Priya and Vinutha (2014)presents a laboratory studies on the preparation of rice husk ash by burning at 700^{0}C for 3hrs. Consequently, silica content obtained after heat treatment is 90.3%.SEM results shows that 2.5N NAOH for 3hrs provided agglomerate particles with dimension 5-10nm. Accoding to them the burning process strongly affects the pozzolanic activity of produced RHA, in some cases RHA concretes suffer low initial strength. So they integrated NS with RHA in concrete to overcome this problem. However, they made an effort to investigate the effect of Nano Silica (NS) in improving the properties of RHA concrete. Accordingly they incorporated 0.5%, 0.75%, 1% NS into RHA concrete.

They found that nano silica and rice husk ash incorporated concrete had showed higher strength compare to that of concrete without nano silica, the workability of fresh concrete remains almost the same for normal as well as NS+ RHA concrete and incorporating 1% NS into 20% RHA concrete caused an increase in compressive and flexure strength. They found that disadvantages of rice husk ash had overcome by adding nano silica particles up to maximum limit of 1% with the average particle size of 10 nm (Priya and Vinutha, 2014).

Rego et al (2015) investigated the pozzolanic activity of residual RHA A and residual RHA B, with high and low contents of amorphous silica respectively, showing different particle size distributions. They concluded that the effect of increase in the external specific surface area with decrease in the particle size along with an increase in the amorphous silica content can justify the increased reactivity of RHA B. Also the reduction of particle size seems to have little effect on the consumption of $Ca(OH)_2$ in the case of RHA A with a high amorphous silica content, while RHA B with low content of amorphous silica increases the consumption of calcium hydroxide when its particle size decreases.

2.3 Literature review of Colloidal Nano Silica

Following are the literatures related to CNS

Hou et al (2012) investigated the influences of colloidal nanoSiO_2 (CNS) addition on fly ash hydration and microstructure development of cement–fly ash pastes. They concluded that the early age strength gain of a CNS added FA-cement paste is probably due to the acceleration effect of nanoSiO_2on both cement and fly ash hydration. They also concluded that CNS can enhance the pozzolanic reaction of fly ash by increasing the alkalinity of solution in the early age, its later age hydration may be adversely affected and there is a dense coating around FA particles in the CNS added pastes, which, with a low Ca/Si ratio may result from the reactive CNS hydration at the early age and act as a barrier that hinders ion penetration and consequently the fly ash hydration at the later age.

Kontoleontos et al (2012) investigated the influence of colloidal nano silica addition on an ultrafine cement in terms of physicomechanical and microstructure properties. They were carried out primarily experiments to produce an ultrafine cement (UF) with a Blaine specific surface area greater than 10.500 cm^2/g. Then nano silica was added in amounts of 2% and 4% on UF cement basis.

They concluded that colloidal nano silica behaved not only as a filler to improve cement micro-structure (porosity decrease), but also as a promoter of pozzolanic reaction. Among four ages and three sets of mix proportions, they consider optimal mix proportion is the set of 4% NS addition, which presented the highest compressive strength of 78.9 MPa, after 28 days of curing. They also concluded that at early ages, the main hydration component was C_3S, whereas silica nanoparticles provided nucleating sites for the precipitation of hydration products (especially $Ca(OH)_2$) & colloidal nano silica slightly increased the strength of the ultra fine cement, mainly because of the packing effect and at later ages, nano silica modified the internal structure of the C–S–H gel, increasing the average chain length of the silicate chains, leading to a denser structure & $Ca(OH)_2$ evolution was diminished due to the pozzolanic reaction, whereas the large pores were partially or completely filled with hydration products (especially secondary C–S–H) and thus the enhancement of the compressive strength at later ages was due to the consuming of $Ca(OH)_2$ by nano silica (Kontoleontos et al, 2012).

According to them the cements with nano silica presented a denser microstructure. Both the total porosity and the average pore diameter, deducted by mercury intrusion porosimetry also confirm a denser micro-structure for the hardened cement paste with nano silica. Also the pore size refinement at later ages, as a result of the pozzalanic reaction, also led to a significant enhancement of the compressive strengths (Kontoleontos et al, 2012).

Quercia et al (2012) applied two different types of nano-silica in self-compacting concrete (SCC), both having similar particle size distributions (PSD) but produced in two different processes (fumed powder silica and precipitated silica in colloidal suspension). From the results of the fresh state behavior of SCC they found that concrete with addition of 3.8% of nano-silica (based on the mass of cement) shows similar flowing and viscosity behavior as the reference mix without nano-silica. They also found small differences in the reactivity at early age for both types of nano-silica while colloidal type shown more reactivity at early age, which influenced all the final SCC properties.

They also gets, improved compressive and tensile splitting strengths of SCC by the addition of both types of nano-silica though highest compressive strength was found for the colloidal nano silica SCC, meanwhile the highest splitting tensile strength was found for the powder type nano-silica SCC. Also when nano-silica is added, the SCC mixes become almost impermeable to the penetration of water under pressure. All durability indicators of the SCC studied (conductivity, chloride migration, chloride diffusion, and freeze-thaw resistance) were improved with the additions of 3.8% of both types of the nano-silica. Moreover the SCC with colloidal nano-silica showed slightly better properties than the SCC with powder nano-silica additions (Quercia et al, 2012).

From the microstructural analysis of the hardened SCC they observed that the additions of nano-silica particles produced a homogeneous microstructure, characterized by compact and small sized C-S-H gel and consequently, a denser ITZ was produced. They also observed that the high reactivity and faster pozzolanic behaviour of the colloidal nano-silica particles at early ages produced a more refined microstructure than the SCC with powder nano-silica (Quercia et al, 2012).

Hou et al (2013) investigated the combined effects of Colloidal Nano Silica (CNS) and fly ash on the properties of cement based materials. The fresh and hardened properties of mixtures with CNS of 10 nm size and two Class F fly ashes were evaluated. They found that a paste with 40% fly ash replacement and 5% CNS addition exhibited comparable initial and final setting times as plain cement paste. Also the incorporation of fly ash and CNS each increase the viscosity of cement paste however, there exists a threshold value for the CNS dosage above which the viscosities of fly ash–cement pastes become equal to or less than those of cement pastes without fly ash and the incorporation of fly ash offsets the decrease in flowability of mortars caused by CNS.

They also found that the early-age compressive strength of fly ash–cement mortars can be greatly improved by the addition of CNS: the higher the dosage, the greater the improvement however, CNS adversely affects strength gain at later ages: the higher the dosage, the greater the reduction in rate of strength gain. They concluded that calcium hydroxide consumption by the CNS at early ages and the hydration hindrance effect of CNS on cement at later ages are contributing factors to the gradual decrease in rate of strength gain exhibited by fly ash–cement systems at later ages (Hou et al, 2013).

Hou et al (2013) investigated the effects of Colloidal NanoSiO_2 (CNS) on cement hydration and gel properties in the early and later age, hydration heat, calcium morphology, hydroxide content, non-evaporable water (NEW) content and nano scale mechanical properties were measured. They concluded that the acceleration of cement hydration and maturation of gel structure in CNS-added paste is achieved through an acceleration of the dissolution of cement particles and a preferred hydration and hydrates precipitation on CNS particle surface although CNS can accelerate cement hydration to a great extent in the early age, the later hydration of cement is hindered. They also concluded the NEW content of CNS-added paste experiences a higher rate of increase initially, but gradually becomes smaller than that of the control paste due to changes in the gel structure, making NEW content an unsuitable method for monitoring the hydration of CNS-added paste.

Rathi et al (2014) investigated the influence of Colloidal Nano SiO_2 (CNS) addition along with P-100 grade of fly ash on hydration of cement paste and compressive strength of cement mortar. From the result they reveal that fly ash hydration is accelerated by CNS at early age thus enhancing the early age strength of materials. They concluded that initial and final setting time of cement paste goes on decreasing, which indicates the accelerating effect of CNS on cement hydration, when CNS is added the IST and FST of cement + fly ash paste were significantly shortened although fly ash delays the hardening of paste, the addition of CNS can greatly offset this effect.

They observed that the standard consistency of fly ash based cement paste after addition of CNS in various percentages does not vary much more. They also observed that average compressive strength of cement mortar at 3, 7 and 28 days goes on increasing up to 4 % addition of CNS and there after goes on decreasing and when 0 % fly ash is added the strength of fly ash based cement mortar is less as compare to 10 %, 20%, 30% replacement of cement by P-100 grade of fly ash. Also standard consistency decreases as % of P-100 grade of fly ash is increases (Rathi et al, 2014).

Chapter 3

Concrete Making Materials and its Mix Proportion

3.1 General

Concrete is obtained by mixing cementing materials , water and aggregates and sometimes admixtures in required proportions.The mixture when placed in forms and allowed to cure , hardens into a rock-like mass known as concrete. The hardening is caused by chemical reaction between water and cement and it continues for a long time and consequently the concrete grows stronger with age. The hardened concrete may also be considered as an artificial stone in which the voids of larger particles (coarse aggregate) are filled by the smaller particles (fine aggregate) and the voids of fine aggregates are filled with cement. In a concrete mixture the cementing material and water form a paste called cement-water paste which in addition to filling the voids of fine aggregate, coats the surface of fine and coarse aggregates and binds them together as it cures , thereby cementing the particles of the aggregates together in a compact mass (Gambhir, 2009).

The strength, durability and other characteristics of concrete depend upon the properties of its ingredients, on the proportions of mix, the method compaction and other controls during placing, compaction and curing. The popularity of the concrete is due to the fact that from the common ingredients, it is possible to tailor the properties of concrete to meet the demands of any particular situation(Gambhir,2009).

3.2 Materials used in the present study

In the view of present study, cement, coarse & fine aggregates, water, supreplasticizer, mineral admixture and colloidal nano silica were used as ingrident of concrete. This materials are discuss in detail below.

3.2.1 Cement

Cement is a well-known building material and has occupied an indispensable place in construction works. There are a variety of cements available in the market and each type is used under certain conditions due to its special properties. Although all materials that go into a concrete mixture are essential, cement is by far the most important constituent because it is usually the delicate link in the chain. The function of cement is, first to bind the sand and coarse aggregates together, and second to fill the voids in between sand and coarse aggregate particles to form a compact mass (Gambhir, 2009).

In the present study, Ordinary Portland Cement of grade 53 (manufacture by Ultra Tech Cement Ltd.) was used having properties shown in Table 3.1.

Table 3.1 Properties of Cement

Normal Consistency (IS:4031 Part IV)	
Required Water for Normal Consistency	110ml
% of Normal Consistency	27.5%
Setting Time (IS:4031 Part V)	
Initial Setting Time	150 Min (Minimum 30 Min)
Final Setting Time	225 Min (Maximum 600 Min)
Specific Gravity	
Specific Gravity	3.14
Specific Surface (Fineness) (IS:4031 Part II)	
Fineness	310.83 m^2/kg (Minimum 225 m^2/kg)
Compressive Strength	
3 Days	27 MPa
7 Days	37 MPa
28 Days	53 MPa

3.2.2 Aggregate

The aggregates provide about 75% of the body of the concrete and hence its influence is extremely important. Aggregates are generally cheaper than cement and impart greater volume stability and durability to concrete. The aggregate is used primarily for the purpose of providing bulk to the concrete. To increase the density of the resulting mix, the aggregate is frequently used in two or more sizes. The most important function of the fine aggregate is to assist in producing workability and uniformity in mixture. The fine aggregate also assists the cement paste to hold the coarse aggregate particles in suspension. This action promotes plasticity in the mixture and prevents the possible segregation of paste and coarse aggregate, particularly when it is necessary to transport the concrete some distance from the mixing plant to point of placement (Gambhir, 2009).

In the present study, coarse and fine aggregates of properties shown in Table 3.2 and Table 3.3 were used.

Table 3.2 Properties of Coarse Aggregate

Sr. No.	**Particulars**	**C.A. 20mm down**	**C.A. 10mm down**
1.	Maximum size(mm)	20	10
2.	Specific gravity	2.61	2.56
3.	Dry LooseBulk Density(Kg/m3)	1314.44	1235.53
4.	Water Absorption (%)	3.3 %	4.7%
5.	Fineness Modulus	2.74	2.25
Sieve analysis of C.A. 20mm down			
Sieves	%Weight Retained	Cumulative% Retained	Cumulative % Passing
40mm	0	0	100
20mm	8.91	8.91	91.09
16mm	57.1	66.01	33.99
10mm	33	99.01	0.99
4.75mm	0.99	100	0
2.36mm	0	0	0
Sieve analysis of C.A. 10mm down			
Sieves	% Weight Retained	Cumulative % Retained	Cumulative % Passing
20mm	0	0	100
16mm	0.8	0.8	99.2
10mm	24.2	25	75
4.75mm	73.85	98.85	1.15
2.36mm	1.1	99.95	0.05
Pan	0.05	100	0
Quarry Location: J.M. Mhatre quarry , Uran-Panvel road, Panvel, Navi Mumbai.			

Table 3.3 Properties of Fine Aggregate

Sr. No.	Particulars		Test result
1.	Grading zone		I
2.	Specific gravity		2.07
3.	Dry Loose Bulk Density		1401.34 kg/m3
4.	Water absorption		0.81 %
5.	Moisture content		0 %
6.	Silt content		2.76 %
7.	Fineness modulus		3.14
Sieve analysis of Sand			
Sieves	% Weight Retained	Cumulative % Retained	Cumulative % Passing
4.75mm	0	0	100
2.36mm	0.98	0.98	99.02
1.18mm	37.07	38.05	61.95
600 micron	40	78.05	21.95
300 micron	19.51	97.56	2.44
150 micron	1.95	99.51	0.49
Pan	0.49	100	0
Brand : Gujrat sand			

3.2.3 Water

Water is the most important and least expensive ingredient of concrete. A part of mixing water is utilize in the hydration of cement to form the building matrix in which the inert aggregates are held in suspension until the matrix has hardened. The remaining water serves as a lubricant between the fine and coarse aggregates and makes concrete workable, i.e. readily placeable in forms (Gambhir, 2009).

3.2.4 Superplasticizer

For high strength concrete, w/b ratio will be very low so use of superplasticizer or high range water reducer is essential. In the present study, MasterGlenium SKY 8233 is an admixture of a new generation based on modified polycarboxylic ether was used having properties shown in Table 3.4.

Table 3.4 Properties of MasterGlenium SKY 8233

Sr. No.	Particulars	Values
1.	Chemical content	Poly Carboxylic Ether
2.	Aspect	Light brown liquid
3.	Specific gravity	1.08
4.	Chloride content	< 0.2%
5.	Recommended dosage	500-1500 ml per 100 kg cement
6.	Solid content	30% by weight
7.	Compatibility	All types of cement
8.	pH	> 6
9.	Reference specification	IS 9103:1999
10.	**Manufacturer:** BASF India Ltd., Turbhe.	

3.2.5 Mineral admixture

The mineral additives also called supplementary cementing materials (pozzolana) are finely ground siliceous materials which as such do not possess cementing property in themselves, but react chemically with calcium hydroxide released from the hydration of Portland cement at normal temperature to form compounds of low solubility having cementing properties. The action is termed pozzolanic action (Gambhir, 2009).

The pozzolanic materials can be divided into two groups namely, natural pozzolanas and artificial pozzolanas. The typical examples of natural pozzolana are clay, shales, opaline cherts, diatomaceous earth, volacanic tuffs and pumicites. The commonly used artificial pozzolanas are fly ash, blast-furnace-slag, silica fume, rice husk ash, metakaoline and surkhi (Gambhir, 2009).

In the present study, rice husk ash was used as mineral admixture having properties shown in Table 3.5.

Table 3.5 Properties of Rice Husk Ash

Sr.No.	Properties	Value
1	Physical state	Solid , Non-Hazardous
2	Appearance	Very fine powder
3	Particle size	25 μ (mean size)
4	Colour	Grey
5	Odour	Odourless
6	Specific Gravity	2.30

7	Loss on Ignition (%)						2.33		
8	Moisture (%)						1.08		
9	**Chemical Composition (%):**								
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	Carbon	Others
	90.36	3.24	0.70	1.67	0.80	0.18	1.30	2.25	1.75
10	**Particle Size Distribution:**								
	Particle size		45μ	45-	20-10μ	10-05μ		05-02μ	< 02μ
	%		0.43	17.41	29.20	31.15		14.55	7.25
11	**Manufacturer:** N. K. Enterprises, Jharsuguda – 768201, Orissa State.								

3.2.6 Colloidal Nano Silica (CNS)

Colloidal silica denotes small particles consisting of an amorphous SiO_2 core with a hydroxylated surface, which are insoluble in water. The size of the particles can be varied between 1 and 500 nm, hence they are small enough to remain suspended in a fluid medium without settling. The performance enhancing properties of nano silica are achieved through two mechanisms. The ultrafine particles are able to fill the microscopic voids between the cement particles improving ‘‘packing’’ and creating a less permeable structure. In the curing process, the nano silica also reacts with the $Ca(OH)_2$ produced with the cement paste to form additional calcium silicate hydrate .Furthermore, the well-dispersed nanoparticles could act as centers of nucleation for cement hydrates, a fact which would accelerate the hydration (Kontoleontos et al, 2012).

In the present study, CNS of following properties as shown in Table 3.6 was used.

Table 3.6 Properties of Colloidal Nano Silica

Colour	**Specific gravity**	**pH value**	**Solid content**	**Particle size**	**SiO_2 content**
White	1.12	10.11	39%	8-20nm	99.1%
Manufacturer: Bee Chems, Kanpur-208022, U.P.					

3.3 Mix proportion of materials

Concrete of different qualities can be obtained by using its constituents namely, cement, water, fine and coarse aggregates, and mineral additives, in different proportions.

In the present study, following mix proportion as shown in Table 3.7 was used.

Table 3.7 Mix proportion for M60

W/C	Cement (kg/m^3)	C.A. (kg/m^3)	F.A. (kg/m^3)	Supreplasticizer
0.35	457	1158	700.19	1%

Materials used in the present study are shown in following figures.

Fig. 3.1 shows Ordinary Portland Cement of 53 grade manufacture by Ultra Tech Cement Ltd.

Fig. 3.2 shows mineral admixture Rice Husk Ash manufacture by N. K. Enterprises, Jharsuguda, Orissa.

Fig. 3.3 shows blending of some percentage of Rice Husk Ash in Ordinary Portland Cement.

Fig. 3.1 OPC 53 grade

Fig. 3.2 Rice Husk Ash (RHA)

Fig. 3.3 OPC+RHA

Fig. 3.4 shows Gujrat brand of sand which was used as fine aggregate.

Fig. 3.5 shows 10 mm (on left side) and 20 mm (on right side) coarse aggregates procure from J.M. Mhatre quarry , Uran-Panvel road, Panvel, Navi Mumbai.

Fig. 3.4 Sand

Fig. 3.5 10mm and 20mm Coarse Aggregate

Fig. 3.6 shows superplasticizer MasterGlenium Sky 8233 manufacture by BASF India Ltd., Turbhe.

Fig. 3.7 shows Colloidal Nano Silica manufacture by Bee Chems, Kanpur-208022, U.P.

Fig. 3.8 shows potable water used for making concrete.

Fig. 3.6 MasterGlenium Sky 8233

Fig. 3.7 Colloidl Nano Silica (CNS)

Fig. 3.8 Water

Fig. 3.9 shows mixture of Superplasticizer with some portion of mixing water.

Fig. 3.10 shows mixture of Colloidal Nano Silica with remaining portion of water.

Fig. 3.9 Water + Superplasticizer

Fig. 3.10 Water + CNS

Chapter 4

Casting and Testing of Concrete Specimens

4.1 Introduction

The design of a satisfactory mix proportion is by itself no guarantee of having achieved the objective of quality concrete work. The batching, mixing, transportation, placing, compaction, finishing and curing are very complimentary operations to obtain desired good quality concrete. Good quality concrete is a homogeneous mixture of water, cement, aggregates and other admixtures. It is not just a matter of mixing these ingredients to obtain some kind of plastic mass, but it is a scientific process which is based on some well-established principles and governs the properties of concrete mixes in fresh as well as in hardened state (Gambhir, 2009).

The strength of concrete assumes a greater significance because the strength is related to the structure of harden cement paste and gives an overall picture of the quality of concrete. The strength of concrete at a given age under given curing conditions is assumed to depend mainly on water-cement ratio and degree of compaction (Gambhir, 2009).

4.2 Casting of Test Specimens

Casting of specimens done in following steps

1) Quantity of concrete and ingredients of mix was calculated.
2) Required moulds (Cube, Cylinders) confirming to were assembled and thinly coated with mould oil to prevent adhesion of the concrete.
3) Moulds were kept on vibrating table so that concrete can be poured immediately after mixing.

4) The laboratory concrete mixer was cleaned and dried. The Mixer used in the work is tilting drum mixer.
5) The ingredients were poured in the following sequence –
   (20mm CA +10 mm CA) → (Cement +RHA)
6) The material was dry mixed for 3 minutes.
7) Some portion of water taken and sprinkled on top of materials. (Note: When CNS was used then it is mix with mixing water and sprinkled on top of materials.)
8) While keeping the mixer in running condition remaining portion of water + Superplasticizer solution was sprayed in the mixer. The care was taken that the liquid should not fall at one place in mixer so that maximum surface area will be covered.
9) The mixer was run until the concrete appears to be homogenous and has the desired consistency.
10) The mixer in running condition and concrete was collected in a tray.
11) The concrete was filled into the mould in layers. In placing each scoopful of concrete, the scoop was moved around the top edge of the mould as the concrete slides from it, in order to ensure a symmetrical distribution of the concrete within the mould. Each layer was compacted by vibration. After the top layer has been compacted, the surface of the concrete was finished level with the top of the mould, using a trowel.
12) Moulds were transferred to leveled surface.
13) After 24 hrs of setting the specimens were demoulded without harming the edges.
14) Each specimen was marked with Identification mark.
15) The entire specimens were transferred in curing tank.

4.3 Observations while Mixing and Demoulding

Following points were observed while mixing and demoulding

1) The mix prepared was very homogenous and consistent.
2) Excess slurry was not formed.
3) The colour of mix without RHA was grey in colour while with RHA it was pale black to dark black depending upon RHA percentage.
4) The conventional mix was found to have more slump than mix with RHA and CNS. Also mix with CNS was found to have more slump than mix with RHA.
5) Mix with CNS sets faster than conventional mix & mix with RHA.
6) More wastage of concrete observed with increasing the replacement of OPC with RHA at constant volume.

7) After demoulding, specimens were having smooth surface and sharp edges.

4.4 Properties of Fresh Concrete

Freshly prepare concrete which can be moulded in any shape has property such as workability which is discuss below.

4.4.1 Workability

IS:6461 (Part-VII)-1973 defines workability as that property of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, compacted and finished.

4.4.1.1 Measurement of workability

The empirical tests widely used for measurement of workability are

1) Slump test
2) Compacting factor test
3) Vee-Bee consistence test
4) Flow test

In the present study, the workability was measured with slump cone test.

The slump test is perhaps the most widely used, primarily because of the simplicity of the apparatus required and the test procedure.The slump test indicates the behavior of a compacted concrete cone under the action of gravitational forces.The test is carried out with a mould called the slump cone.The slump cone is placed on a horizontal and non-absorbent surface and filled in three equal layers of fresh concrete, each layer being tamped 25 times with a standard tamping rod. The top layer is struck off level and the mould is lifted vertically without disturbing the concrete cone.The subsidence of concrete in millimeters is termed the slump.The concrete after the test when slumps evenly all around is called true slump. In the case of very lean concrete, one –half of the cone may slide down the other which is called a shear slump; or it may collapse in the case of very wet concretes. The slump test is essentially a measure of consistency or the wetness of the mix (Gambhir, 2009).

4.5 Properties of Hardened Concrete

Hardened concrete has properties such as compressive strength, split tensile strength, flextural strength and durability etc. Out of which only compressive strength and split tensile strength have been discuss.

4.5.1 Compressive strength

Compressive test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength.

The compressive test is carried out on specimens cubical or cylindrical in shape. Prism is also sometimes used, but it is not common in our country. Sometimes, the compressive strength of concrete is determined using parts of a beam tested in flexure. The end parts of the beam are left intact after failure in flexure and, because the beam is usually of square cross section, this part of the beam could be used to find out the compressive strength.

4.5.1.1 Cube strength

The cube specimen is of the size 150 X 150 X 150 mm. If the largest nominal size of the aggregate does not exceed 20 mm, 100 mm size cubes may also be used as an alternative. The rate of loading as per IS: 516-1959 is 315 KN/min (14 N/mm^2/ min).

The specimens casted are demoulded after 24 hours of casting and tested after 3,7 and 28 days. The cube compressive strength of concrete which is given by equation (i) are recorded after crushing cube under the compression testing machine (3000 KN Capacity).

$$\text{Compressive strength} = \frac{\text{Ultimate crushing load}}{\text{Area of loading}} \text{ in N/mm}^2. \qquad \text{-------} \text{ (i)}$$

4.5.2 Tensile strength of concrete

Concrete is relatively strong in compression and weak in tension. In reinforced concrete members, little dependence is placed on the tensile strength of concrete since reinforcement is provided to resist all tensile forces. However, tensile stresses are likely to develop in concrete due to drying shrinkage, rusting of reinforcement, temperature gradients and many other reasons. Therefore, the knowledge of tensile strength of concrete is of importance.

Tensile strength of concrete is determined by the following two tests.

1. Split tensile strength test and
2. Modulus of rupture strength test

In the present study, the tensile strength was determined by split tensile strength.

4.5.2.1 Split tensile strength

It is also called as indirect tension test method. This also sometimes referred as, "Brazilian Test". This test was developed in Brazil in 1943. At about the same time this was also independently developed in Japan.

This test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load is applied until failure of the cylinder, along the vertical diameter.

When the load is applied along the generatrix, an element on the vertical diameter of the cylinder is subjected to a vertical compressive stress and horizontal stress which are given by equations (ii) and (iii) respectively.

Vertical compressive stress $= \frac{2P}{\pi LD}\left[\frac{D^2}{r(D-r)}-1\right]$ ------- (ii)

Horizontal stress $= \frac{2P}{\pi LD}$ ------- (iii)

where, P is the compressive load on the cylinder

L is the length of cylinder

D is its diameter

The main advantage of this method is that the same type of specimen and the same testing machine as are for the compression test can be employed for this test. That is why this test is gaining popularity. The splitting test is simple to perform and gives more uniform results than other tension tests. Strength determined in the splitting test is believed to be closer to the true tensile strength of concrete, than the modulus of rupture. Tensile splitting strength is an important property that greatly affected the extent and size of cracking in structures under shear and torsion.

Mixing of various ingredients of concrete in mixer, filling of fresh concrete in moulds and testing of concrete samples are shown in following figures.

Fig. 4.1 shows mixing of various ingredients of concrete in tilting drum mixer.

Fig. 4.2 shows pouring of fresh workable concrete on tray.

Fig. 4.3 shows slump cone test perform on fresh concrete.

Fig. 4.1 Mixing

Fig. 4.2 Workable Mix

Fig. 4.3 Slump Cone Test

Fig. 4.4 shows filling of fresh concrete in cube moulds which are placed on vibrating table.

Fig. 4.5 shows filling of fresh concrete in cylinderical moulds which are placed on vibrating table.

Fig. 4.6 shows samples which are demoulded after harding of concrete.

Fig. 4.4 Flling of Cube Mould

Fig. 4.5 Flling of Cylinderical Moulds

Fig. 4.6 Samples after Demoulding

Fig. 4.7 shows placing of demoulded samples in curing tank.

Fig. 4.8 shows samples which are ready for testing.

Fig. 4.7 Samples in Curing Tank

Fig. 4.8 Samples Ready for Testing

Fig. 4.9 shows testing of cube sample in compression testing machine.

Fig. 4.10 shows testing of cylindrical sample.

Fig. 4.11 shows tested cube samples.

Fig. 4.9 Testing of Cube Sample

Fig. 4.10 Testing of Cylinderical Sample

Fig. 4.11 Tested Cube Sample

Fig. 4.12 shows tested 10% RHA, 10% RHA+2% CNS, 10% RHA+4% CNS, 10% RHA+6% CNS cylinderical samples at 28 days curing from left to right respectively.

Fig. 4.12 Tested Cylinderical Samples

Chapter 5

Results and Discussion

5.1 General

In this chapter, the various tests which were conducted on fresh concrete like workability and on harden concrete like compressive strength test & split tensile strength test results have been presented and discuss in brief.

5.2 Workability

The Table 5.1 gives the workability by slump cone test of conventional mix, mix with 5, 10 and 15% RHA replacement & mix with 10% RHA replacement with addition of 1,2,4,6% CNS. The workability results are shown graphically in Fig.5.1.

Table 5.1 Workability by Slump Cone Test

Sr.No.	Description	Various Mixes	Slump (mm)
1.	Conventional Mix	CM	290
2.	RHA Mix	R5M	100
		R10M	85
		R15M	0
3.	RHA+CNS Mix	R10C1M	180
		R10C2M	140
		R10C4M	122
		R10C6M	118

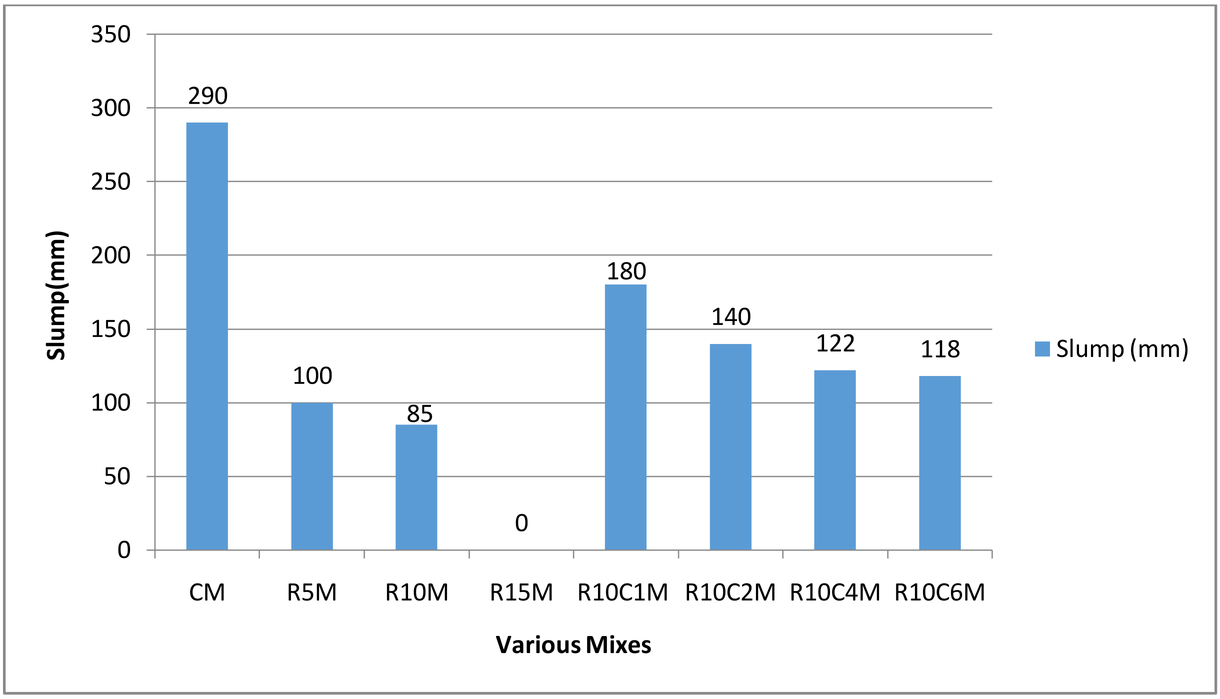

Fig. 5.1 Workability of different mixes

With the 5 and 10% RHA replacement, the slump was decreased by 65.52% and 70.69% with respect to conventional mix.15% RHA replacement gives zero slump.

In present study, workability was considered as one of the factor for deciding the optimum dose of RHA.Therefore, from above workability result we consider 10% RHA as optimum dose.

Further the slumps were more for 1,2, 4, 6% CNS addition on 10% RHA replacement mix with respect to 10% RHA mix without CNS but slump decreases as CNS addition increases.

5.3 Cube Compressive Strength

The Table 5.2 gives the cube compressive strength of conventional mix, mix with 5, 10 and 15% RHA replacement & mix with 10% RHA replacement with addition of 1,2,4,6% CNS at 3,7 and 28 days curing.The results are shown graphically in Fig.5.2.

Table 5.2 Cube Compressive Strength

Various Mixes	3 Days (MPa)	7 Days (MPa)	28 Days (MPa)
CM	51.55	53.35	65.9
R5M	47.7	53.16	71.26
R10M	42.86	50.8	62.06
R15M	38.93	51.66	65.13
R10C1M	38.36	47.16	62.96

R10C2M	46.48	55.63	70.26
R10C4M	40.8	41.83	58.1
R10C6M	36.7	38.83	43.13

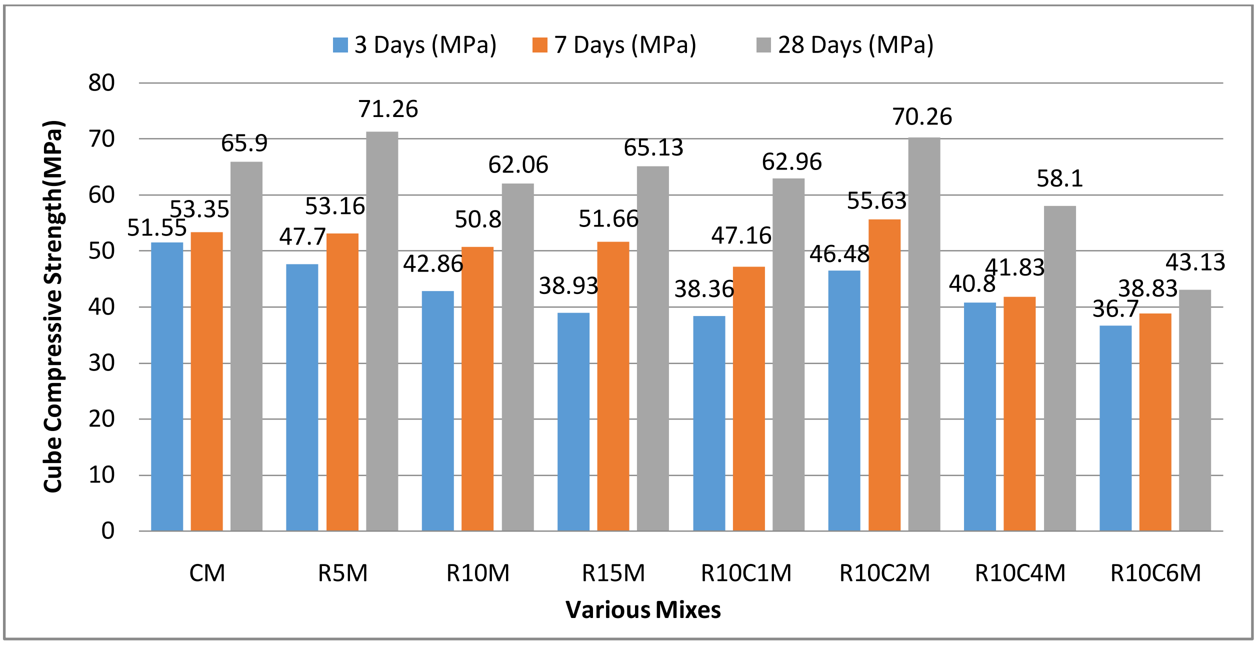

Fig. 5.2 Variation in cube compressive strength at various ages

At 3days, the compressive strength of 5, 10 and 15% RHA replacement mix were decreased by 7.47%, 16.86% and 24.48% with respect to convectional mix.

At 7 days, the compressive strength of 5, 10 and 15% RHA replacement mix were decreased by 0.36%, 4.78% and 3.17% with respect to convectional mix.

At 28 days, the compressive strength of 5% RHA replacement mix was increased by 8.13% while it was decreased by 5.83%, 1.17% for 10,15% RHA replacement mix with respect to convectional mix.

In present study, the compressive strength was considered as second factor for deciding the optimum dose of RHA.Therefore, from above graph, it was observe that 10% RHA replacement gives compressive strength slightly more than 60MPa at 28 days. So, we consider 10% RHA as optimum dose.

At 3days, the compressive strength of 2% CNS addition in 10% RHA replacement mix was increased by 8.44% while it was decreased by 10.49%,4.81%,14.37% for 1,4,6% CNS addition in 10% RHA replacement mix with respect to 10% RHA replacement without CNS.

At 7 days, the compressive strength of 2% CNS addition in 10% RHA replacement mix was increased by 9.5% while it was decreased by 7.17%,17.66%,23.56% for 1,4,6% CNS addition in 10% RHA replacement mix with respect to 10% RHA replaced mix without CNS.

At 28 days, the compressive strength of 1,2% CNS addition in 10% RHA replacement mix was increased by 1.45%,13.21% while it was decreased by 6.38%,30.5% for 4,6% CNS addition in 10% RHA replacement mix with respect to 10% RHA replaced mix without CNS.

5.4 Split Tensile Strength

The Table 5.3 gives the split tensile strength of conventional mix, mix with 10% RHA replacement with addition of 1,2,4,6% CNS at 3,7 and 28 days curing.The results are shown graphically in Fig.5.3.

Table 5.3 Split Tensile Strength

Various Mixes	3 Days (MPa)	7 Days (MPa)	28 Days (MPa)
R10M	3.2	3.97	4.67
R10C1M	3.23	3.51	5.57
R10C2M	2.94	3.65	4.58
R10C4M	2.83	3.54	4.39
R10C6M	2.66	3.57	4.43

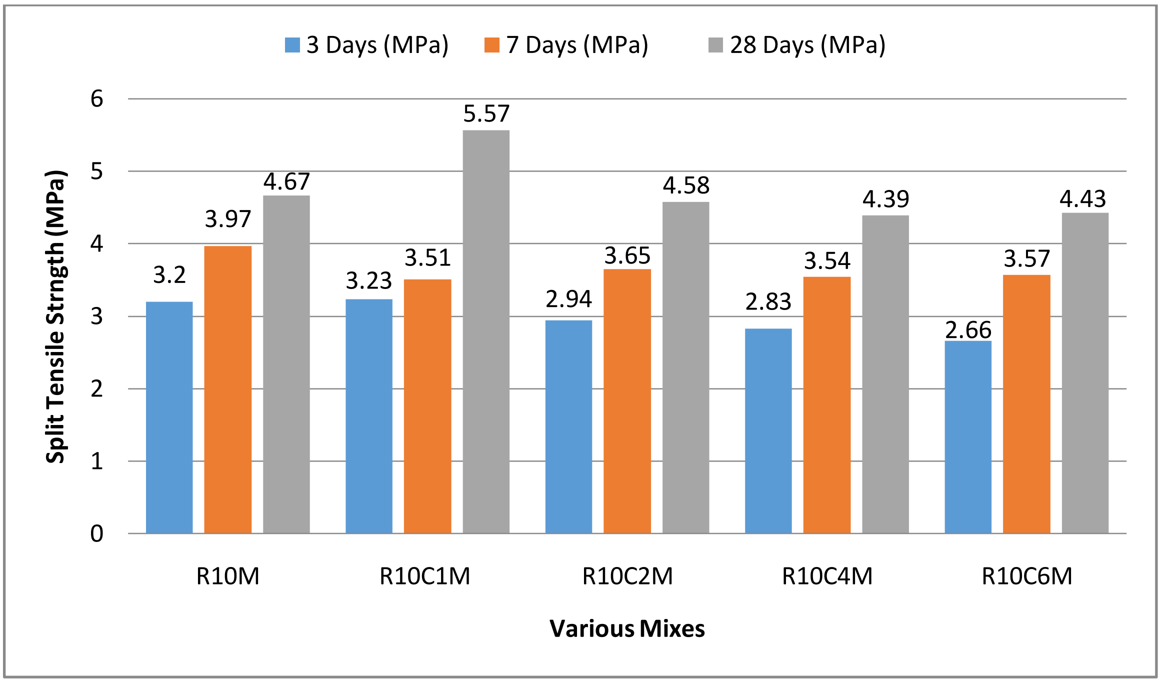

Fig. 5.3 Variation in split tensile strength at various ages

At 3 days, the split tensile strength of 1% CNS addition in 10% RHA replacement mix was increased by 0.93% while it was decreased by 8.13%,11.56%,16.88% for 2,4, 6% CNS addition in 10% RHA replacement mix with respect to 10% RHA replacement mix without CNS.

At 7 days, the split tensile strength was decreased by 11.59%,8.06%,10.83%,10.08% for 1,2,4, 6% CNS addition in 10% RHA replacement mix with respect to 10% RHA replacement mix without CNS.

At 28 days, the split tensile strength of 1% CNS addition in 10% RHA replacement mix was increased by 19.27% while it was decreased by 1.93%,6%,5.14% for 2,4, 6% CNS addition in 10% RHA replacement mix with respect to 10% RHA replacement mix without CNS.

Chapter 6

Investigation on Result Obtain

6.1 General

The results obtained in the present study are presented tabularly & graphically and discuss briefly in terms of percentage increased or decreased with respect to reference mix in previous chapter. In this chapter an attempt is done to give probable reasons for results obtain on the basis of literature review and experiment.

6.2 Investigation on workability of RHA concrete

As discuss in chapter 5, with increase in replacement of OPC with RHA, the workability decrease. This is due to high specific surface area of RHA which would increase the water demand (Pande et al, 2013).

6.3 Investigation on early strength of RHA concrete

As discuss in chapter 5, the early strength (i.e. at 3 days) of RHA mix was less than conventional mix because RHA results in reduction in the rate of development of strength (Gambhir, 2009).

6.4 Investigation on workability of RHA concrete with CNS

As discuss in chapter 5, with increase in addition of CNS, the workability decrease. This is because as the nano silica is finer than the cement , the specific surface increases as the nano silica content increases. When particle size gets finer it needs more water to facilitate the movement of particles on each other (Kontoleontos et al, 2012).

6.5 Investigation on strength of RHA concrete with CNS

As discuss in chapter 5 the compressive strength of 2% CNS addition in 10% RHA replacement mix was increased at 3,7,28 days with respect to 10% RHA replacement mix without CNS.This improvement is due to three reasons (1) the acceleration effect of CNS on cement hydration, (2) pozzolanic reaction of CNS, and (3) improved particle packing of the matrix (Hou et al, 2013).

6.6 Investigation on setting time of CNS

As discuss in chapter 4, mix with CNS sets faster than conventional mix & mix with RHA.This is because CNS accelerate cement hydration (Hou et al, 2013) and this is investigated through Vicat Test (for determining initial and final setting time of cement) experiment whose result is shown in Table6.1 and it shown graphically in Fig.6.1.

Table 6.1 Observation table for Vicat Test

Time in minutes	Penetration depth in mm measuring from bottom of mould for		
	OPC(53 grade)	OPC+10% RHA	OPC+10% RHA+2% CNS
0	0	0	0
62	0	0	1
66	0	0	1.5
82	0	1	1.5
86	0	1	4
92	0	2	5
104	0	2	25
106	0	5	25
110	0	23	25
112	0	23.5	25
122	2	23.5	25
128	5	23.5	
130	21	24	
132	22	24	
134	23	24	
138	23	25	
164	24	25	

200	25		

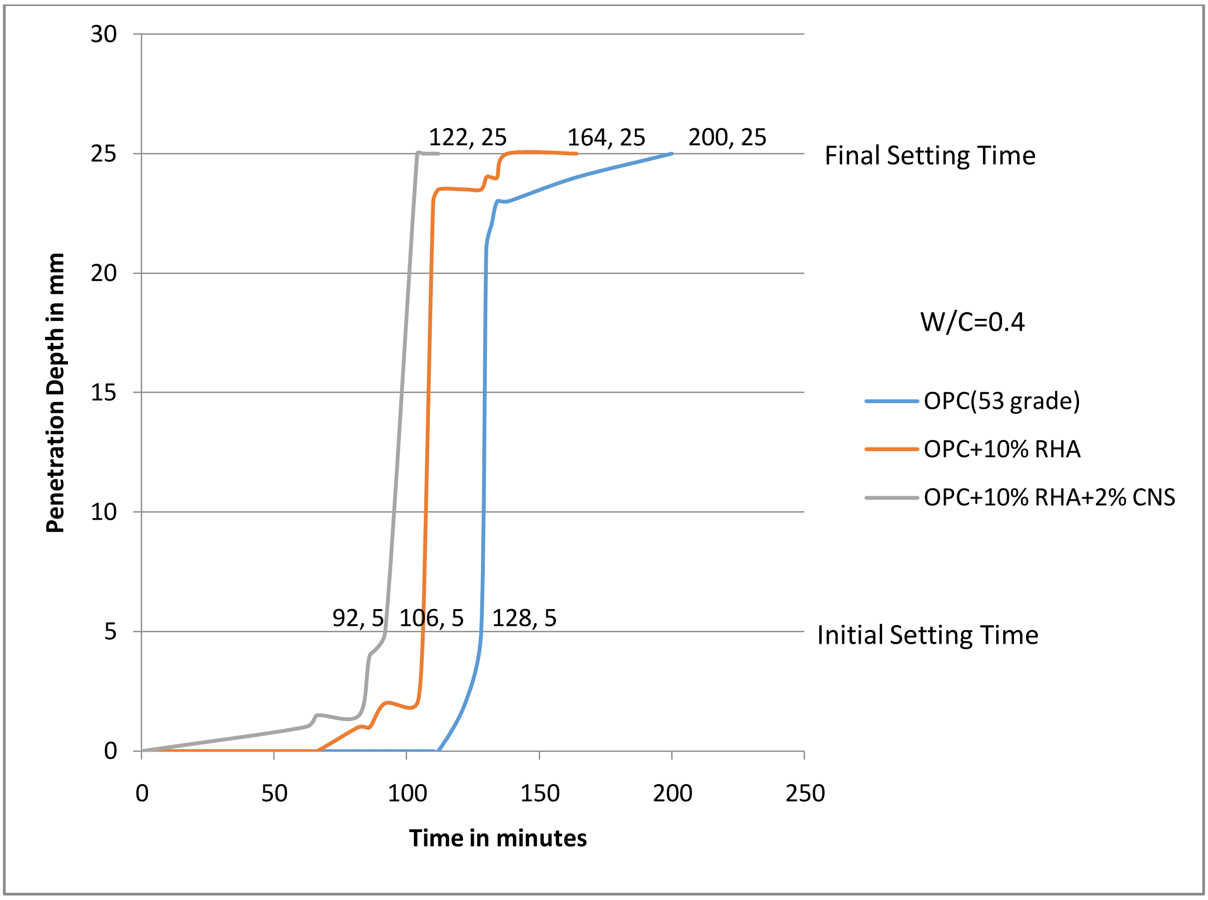

Fig. 6.1 Graph of Penetration verses Time

From the graph following points are observed which are shown in Table 6.2.

Table 6.2 Initial and Final Setting Time

Setting time	OPC(53 grade)	OPC+10% RHA	OPC+10% RHA+2% CNS
Initial (min.)	128	106	92
Final (min.)	200	164	122

Fig. 6.1 shows experimental setup for Vicat Test with three different samples.

Fig. 6.2 shows testing samples in vicat apparatus.

Fig. 6.3 shows Conventional (OPC 53), OPC+10% RHA and OPC+10% RHA+2% CNS samples after test.

Fig. 6.1 Arrangement for Vicat Test

Fig. 6.2 Testing of Samples

Fig. 6.3 Samples after Test

Chapter 7

Conclusion

From result obtain it can be concluded that

1) As replacement of OPC with RHA increases, workability goes on decreases.
2) 10% RHA replacement gives compressive strength slightly more than 60MPa at 28 days. So, 10% RHA was consider as optimum dose on basis of workability and strength.
3) The workability were more for 1, 2, 4, 6% CNS addition in 10% RHA replacement mix with respect to 10% RHA mix without CNS but workability decreases as CNS addition increases.
4) 4)The compressive strength of 2% CNS addition in 10% RHA replacement mix was increased by 8.44%, 9.5%, and 13.21% at 3,7,28 days with respect to 10% RHA replacement mix without CNS.
5) The split tensile strength of 1% CNS addition in 10% RHA replacement mix was increased by 0.93%,19.27% at 3, 28 days but decrease by 11.59% at 7 days while for 2% CNS addition it was decreased by8.13%,8.06%, 1.93% at 3, 7 and 28 days with respect to 10% RHA replacement mix without CNS.
6) Mix with CNS sets faster than conventional mix & mix with RHA.

Chapter 8

Recommendation for Future Study

The further study can be done such as

1) Study of water absorption, chloride penetration, durability etc.
2) Study of effect of CNS on RHA concrete of other grades.
3) Study of effect of CNS on concrete containing other mineral admixture such as GGBS, Fly Ash, Silica Fume or combination of these mineral admixture.

Chapter 9

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