INFLUENCE OF NANO SILICA AND NANO ALUMINA ON PACKING DENSITY OF CEMENT PASTE

A

THESIS

Submitted in partial fulfillment of the requirements for the award of the degree

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Under the supervision

of

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by

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to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

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HIMACHAL PRADESH, INDIA

May- 2019

STUDENT'S DECLARATION

I hereby declare that the work presented in the Project report entitles **"Influence of Nano Silica and Nano Alumina on Packing Density of Cement Paste"** submitted for partial fulfilment of the requirements for the Master of Technology in Civil Engineering (Structural Engineering) at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Mr. Abhilash Shukla.** This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project.

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May, 2019

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"Influence of Nano Silica and Nano Alumina on Packing Density of Cement Paste"**in the partial fulfilment of the requirements for the award of the degree of Masters of Technology in Civil Engineering (Structural Engineering) submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Bharat Bhushan (172654)** during the period from July 2018 to may 2019 under the supervision of **Mr. Abhilash Shukla**, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

Date…………….

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ABSTRACT

The nano silica and nano alumina is superfine filler materials. The superfine nano element is higher fineness then OPC. To maximize the particle packing density of cement paste, the particles may be selected in a form that they able to fill up the voids between large particles with smaller particles. The obtained paste is dense and stiff particle structure. As compare to normal cement past the effect of superfine elements on packing of cement is directly measure by wet pecking method and the water film thickness of cement paste. Packing density of cementations materials determined on the basis of amount of voids filled with water. Higher the packing density would demand less water to fill the void. The experimental work is dividing into three parts. Initially the influence of nano silica and nano alumina on particle packing density will be measured individual later the combined influence of both (nano silica and nano alumina) will be measured. Graph between compressive strength vs water cement ratio at curing of 7days and 28 days will also be plotted.

Keywords: Bulk density, voids ratio, packing density and plotting**.**

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List of abbreviations And Symbols

CNA Cement Nano Alumina

CNS Cement Nano Silica

CNSA Cement Nano Silica Alumina

CSF Condensed Silica Fume

CTM Compression Testing Machine

FA Fly AshFAM Fly Ash Microsphere

NA Nano Alumina

NS Nano Silica

OPC43 Ordinary Portland cement 43 grade

PFA Pulverized Fuel Ash

SF Silica Fume

SFC Superfine cement

SP Super plasticizer

UHSC ultra high strength concrete

w/b Water to Binder Ratio

w/c Water to Cement Ratio

Chapter 1

Introduction

1.1 General

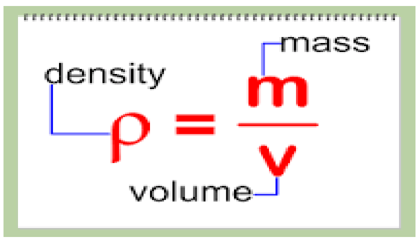
The packing particle density of cementitious is an significant part of engineering and materials sciences. Particle packing of cementitious mix is depends on few parameters such as size ratio, huge particle volume proportion and combined effect of vibration frequency on packing density of binary and ternary spherical mixtures.

1.2 Density

The particle packing density of cement paste is defined as the ratio of the mass of the cement per unit volume of the cement. It is denoted by symbol ρ(rho). The SI unit of density is kg/m^3. Density is basically following type's bulk density, relative density.

1.2.1 Bulk Density

Bulk density or mass density is the ratio of the mass per unit volume. It is not a fundamental property of substance; bulk density is change depending on how the material is handled.



Density of cement is 3150 kg/m^3. Different materials generally have different densities, so density is a most important idea concerning particle packing density. Bulk density of cement could be around 1.14. This means the bulk of cement has a density of about 1140kg/m^3 which is equal to 1.14grms/ml or 1.14g/cm^3. The bulk density of materials varies with pressure, temperature. Increases the pressure on a substance decreases the volume of the substance and therefore increases its density. The reciprocal of the density of a matter is knows as its specific volume. It is denoted by ρv and its unit is m^3/kg.

1.2.2 Relative Density

Relative density is ratio of the density of an objects to density of a given reference material. It is denoted by RD or SG. Specific gravity is a dimensionless quantity. It is used to find out the density of an unknown material from the known density of another material. The value of the specific gravity of cement is determined by using Le Chatelier Flask method.

1.3 Particle Packing

Particle packing indicates the packing of voids between cement grains. Generally there is large number of voids in between the cement particle. Now for filling those voids particle packing is required. The voids in the cement grain can be filled with the help of fine mineral, filler materials, admixture such as Nano Alumina and Nano Silica etc. In particle packing include the selections of suitable size shape and properties of materials to get suitable combinations for optimal packing. Optimum particle packing is key for manipulative a dense, strong and durable cement paste materials. Particle packing optimization of cement paste provides positive influence for fresh and hardened cement paste. Addition of fine particle helps filling the voids in the particle structure and leave minimum space for water. There are several numbers of Indian standard methods for determining the packing density, such as wet and dry packing method, relative density methods, bulk density methods and Puntke methods. In this research work Puntke methods was used for determining the particle packing density.

1.3.1 Puntke method

Puntke (2002) developed a procedure to find out the water demand of dry particle materials. The water demand of dry particle structure is used to finding out the packing density of cementitious mixture. The basic principle of Puntke method is to fill the exact amount of water demand between the grains.

Packing density Φ was calculated by using:

$$\phi = 1 - \frac{Vw}{Vw + V_p}$$

Where Vp: Volume of powder

Vw: Volume of water

1.4 Performance benefits

- Long term mechanical properties
- Fill up the voids between large particles with smaller particles
- Increases strength without increases in the volume
- Durability against freezing and thawing
- Toughness
- Volume stability
- Longer life is several environmental
- Reduce maintenance and repair cost

Chapter 2
Literature Review

2.1 General

Reviews of authors or (Literature review) is simple summary of the source, which discusses available information in a particular area, subject within a certain period. Literature review is a scholarly researcher paper, which includes the current knowledge substantive finding. Literature review is the secondary source for finding new research work. The purpose of literature review, give a new understanding of old materials.

2.1 Reviews of authors

Hettiarchchi et al. (2018) [1] The researcher are examine the studies of particle size ratio, shape, vibration frequency, and large particle size division on particle packing of ternary spherical mixture. The packing density is depends upon the following parameter such as particle size ratio, vibration frequency, and large/smaller particle volume. When all these parameter are increases the packing density increases at optimal value further increases these parameter the packing density of spherical mix is decreases. Vibration frequency is 110 Red/s mixture tends to maximum packing density sooner. The initial study was done by Mc Geary in 1961. The researcher found that the sphere-shaped metal beds were packed in glass containers by automatic shaking. The researcher creates out the solo element packed in an orthorhombic collection with the particle density of 62%. The researcher found that there is three main effect of this study such that wall effect is due to large particle fraction, loosing effect is due to large particle fraction and wedging effect is due to small particle fraction.

Helmi.M et. al, (2016) [2] Examine the effect of optimal pressure and temperature curing on RPC microstructure formation. Applied pressure was 8MPa and curing temperature 240^0 C. It was seen that the pozzolonic reaction were fast and also seen that capillary pores were increased due to high pressure.

Li.H&Liu.G (2016) [3] researcher works on the tensile strength and flexural strength of hybrid fiber reinforced reactive powder was increased when exposed to elevated temperature. Temperature decreases 700^0, the steel fiber worked effectively and toughness of reactive powder concrete was improved.

Foroodetal. (2016) [4] the researcher examines the influence of nano silica on compressive strength and durability of concrete with different w/b ratio. Researcher works on addition of different amount of silica dosage with respect to cement. The results show that the compressive strength increases in case of w/b is o.65.

Leo et al. (2015)[5] researcher studies about the effect of super plasticizers type on packing density water film thickness and flow ability of cementitious paste. Super plasticizer is important ingredient for production of cementitious materials. Super plasticizer materials are increases the particle packing density, improving strength and reduce water demand of the cementitious material. In this investigation adding two type of super plasticizer Naphthalene based SP and Polycarboxylate based SP. This testing is done by wet packing method. In this test three cementitious materials mixes is used OPC PFA and CSF. The different amount of both super plasticizers is adding in the cementitious materials. The result of this objective was found Polycarboxylate based SP is high packing density than Naphthalene based SP. Adding 3% dosage of Naphthalene based SP increases packing density 11.5% and Polycarboxylate based SP increases packing density 13%.

Mehta. D et. al, (2015) [6] the researcher are examine the effect of SP dosage and w/c demand on compressive strength and workability. Researcher is found that there had no direct relation SP with compressive strength. The strength of cementitious materials and water cement demand are inversely related to each other.

Canbaz.M (2014) [7]researcher are works on effect of reactive powder concrete at high temperature. Sample contains resources such as cement, quartz powder, super plasticizer and steel wire. It was seen that compressive strength decreased at 100^0 C and increased at 200^0 C to 500^0C. Above 600^0C compressive strength also again decreased.

Singh et al. (2013) [8] studies about nano materials are used in construction sector in the terms of smart and sustainable features. Nano materials such as Nano silica, nano titania, nano alumina and carbon nano tubes. Nano silica has been used most extensively. Researcher are containing improves the sustainability and durability of cement paste. The researcher summarizes the effect of nano silica and nano alumina addition of hydration kinetics, fresh/hardened properties of cement concrete.

Kwan et al. (2013) [9] the researcher is examine the effect of fly ash microsphere in cement paste. FAM improves the flow ability, strength of cement motar and particle packing density. FAM materials are finer than cement particle. FAM is spherical in shape and particle size is nanometer/micrometer scale. The function of the FAM is reducing the cement consumption, reduces the w\c ration, air content and increases the particle packing. The value of packing density is depends on size distribution, particle shape vibration frequency. Packing density is cement paste is 0.60. The fillings the voids and the minimum water cement ratio may be evaluate 0.67by volume or 0.22 by mass. The research done experimental work two part, in the 1st part was measured the packing density with adding different quantity of FAM and 2nd part measured flow rate, flow spread, and cube strength of cementitious materials specimen contain different amount of FAM at different w\c ratio. Generally water demend increase the solid concentration 1st increases to optimal value; after certain points it decreases.

Kwan et al. (2012) [10] the researcher was studies about FAM,FAM is improving the flow ability, strength of cementitious materials and particle packing. FAM particle sphere shaped and size is micro-meter scale. The function of the FAM is reducing the cement consumption, reduces the w\c ratio. The value of particle packing is depends on particle size distribution. Packing density is cement paste is 0.60. The fillings the voids and the minimum water cement ratio may be evaluate 0.67by volume or 0.22 by mass. The experiment program is done by two part, in the 1st part was measured the particle packing of cementitious materials with adding different FAM quantity and 2nd part considered flow spread, flow rate and cube strength of cementitious materials sample containing different amount of FAM at different W\C ratio. Generally water content increase the solid concentration 1st increases to optimal value and then certain time it decreases.

Chen et al. (2012) [11] the main purpose of this study was improving the strength, rheology and packing density of cement past by adding superfine cement. The superfine cement is filler materials. The superfine cement is higher fineness then OPC. The effect of superfine cement on particle packing of cement is directly measure by water film thickness of cement paste and wet pecking method. Particle packing of cement paste which calculates the quantity of voids packed with water. Higher the packing density laser water demand to fill the voids. Generally OPC packing density is 0.60 minimum w/c ratios for filling voids. If the water cement ratio smaller than 0.22 the cement paste will have air voids entrapped. Lower w/c ratio higher the packing density. Without adding SFC the packing density was measured 0.637 and void ratio 0.570. Adding 10%, 20% and 20 to 30% of SFC the packing density was measured 0.659, 0.697 and 0.678 and the voids ratio was measured 0.517, 0.473 and 0.475 respectively. The result of this purpose is higher the packing density is lower the voids ratio.

Ltifi et al. (2011) [12] the researcher has analyzedthe properties of cement mortar with NS. The glassy silica or amorphous is one of major components of pozzolana, react with the calcium hydroxide produced from calcium silicate. The Pozzolonic rate of reaction is directly proportional to the quantity of surface region. The objective of this study determined the influence of addition nanoparticles on the performance of cement mortar with nano particle of silica power were included at range of 3.5 and 10 % by its weight. . The compressive strengths of different mortars increased with the increase in quantity of nano silica. The effect of nano silica on consistency and setting time are significantly different.

Senff et al. (2009) [13] studied about addition of nano silica particle 0 to 2.5 % by weight in cement paste, and analysis the effect of nano silica in fresh cement paste. The researcher shows the rheological tests after 75min from mixing start, the mortar having 2.5%nano silica shows insufficient flow ability of cement paste. The addition of nano silica 2.5% results shows density decreased 2.4% and air content increased 79%.

Peng et al. (2009) [14] The researcher works on packing properties of minerals admixture in cementitious materials. In this investigation were studies about the effect of ulta fine fly ash, silica fume and steel slag on packing density of concrete. The function of the addition of admixture in cement paste increases the particle packing density and decreases the w\c ratio. De larrard and Sedron 1994 investigation the packing density of admixture containing cement lime stone filler and silica fume by using a linear modal. Zhang et al (1996) was investigation packing density in cement paste of binary system. Aim and Goff (1968) determine quantitatively the packing density effect of UFFA of cement paste. The dense packing methods were done by using relative density of paste packing density of power.

Yazici.H (2009) [15] researcher investigated compressive strength of the reactive powder concrete containing high volume of GGBFS. Mix contained OPC, aggregate, brass coated steel fiber, quartz sand and polycarboxylate based super plasticizer. The replacement of GGBFS varied from 20%, 40% and 60%. The compressive strength determined after three types of curing was done. In autoclave curing results shows maximum compressive strength.

Wong et al. (2008) [16] works on dry and wet packing method of cementitious materials. Dry packing is known as direct methods and wet methods are known as indirect methods. The bulk density of power is dependent on the compaction phenomena. In dry method the main problem is decreasing particle size increasing adhesion phenomena. Bulk particle packing is not applicable for grain size smaller than 100um. Indirect methods required minimum water content. Minimum water content achieves maximum packing density. Simplest method for determining the water demand is standard consistence test.

Kwan et al. (2008) [17] the main purpose of this study was to calculate particle packing of cementations materials, flow ability and flow rate of OPC +CSF+PFA. The direct measurement of packing density is done by dry condition and indirect measurement of the packing density is done by wet conditions. In this experiment two type of super plasticizer is used polycarboxylate based and naphthalene based. In 1st part cementitious materials with and without super plasticizer was compares. In this case the maximum packing density calculated PFA with policarboxylate based super plastersizer was 0.646. And maximum voids 0.547. In 2nd part was used OPC PFA CSF in different amount tested. The maximum packing density 0.752 was calculated adding OPC 25%, PFA 45% and CSF 30%. In this investigation researcher found the maximum packing density was calculated by increasing PFA .Improving the packing density would reduce the water content and voids content.

Nanthagopalan P. et al, (2008) [18] examine the flow properties were dependent on plastic viscosity and yield value. With the help of Puntke methods particle packing density of cement+ silica fume and cement +fly ash was analysis.

Wan jo et al. (2007) [19] The main objective of this study was characteristics of cement mortar with nana silica parcels. Nano is a new scitific technology due to particle size in 10^{-9}m scale. The silica is the main components of a pozzolana which mixed with calcium hydroxide formed calcium silicate hydrate. The silica content is main components is hydration process of cement paste. Nano particle is more valuable of packing density and compressive strength of cementitious materials. Nano silica is like as filler materials and also more activator to promote the pozzaolanic reactions.

Quig et al. (2007) [20] examine thereaction of Nano silica on the properties of hardened concrete as compare with the SF has been calculated through capacity of compressive strength and bond strength of HPC. The result indicates that the influence of Nano silica and silica fume on consistency. Adding different amount of NS and SF. increasing the NS and SF increases the strength after certain amount of addition of NS and SF the strength starts decreasing. The results suggest that with a small quantity of Nano Silica crystals at the interface between aggregate and hardened cement paste at early age may be successfully absorbed in high performance concrete.

Tao ji et al. (2005) [21] the researcherexamine the water permeability opposing actions and microstructure of cementitious materials with NS were experimentally determined. The water permeability experiment shows the cement similar 28-days strength; the absorption of NS can recover the resistance of water penetration of concrete. An environmental scanning electron microscope test reveals that the microstructure of concrete with NS is more homogeneous and dense than that of conventitional concrete. Analysis about the effect of NS on concrete and cement paste is described.

Abdullahet al. [22] the researcher is investigate the bulk specific volume of in homogeneity binary and ternary power mixture with a large size ratio. When two different size powder large ratio is mixed the specific volume of mix is generally less than the either of the individual powders. The basic phenomenon was determined theoretical by Furnas using space filling argument. Furnas prediction do not gives expect experimental measurement of specific volume of mixture when compositional inhomogenities exist. Furnas modal is inadequate. After this a methodology was presented that make possible calculation for specific volume of mixture when the compositional inhomogenities exits. The methodology is done by one dimensional packing and three dimensional packing.

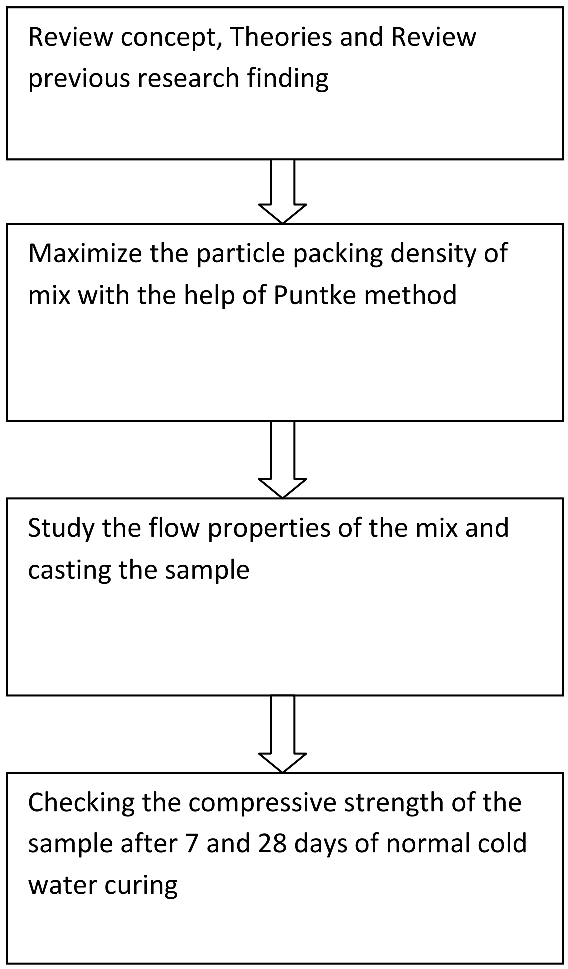
2.3 Research gap

With the increases in the number of finer nano particle added to cement past the packing density increases and studies up to binary blends no one studied about mechanical properties and ternary bland with nano particles.

2.4 Research Objectives

1. Assessment of particle packing density on Nano silica and Nano alumina added cement paste.
2. Influence particle packing density on mechanical properties of cement mortar paste.

2.3.1 Flowchart for objective



Chapter 3

Materials and Research Methodology

3.1 General

The whole research work is divided into three parts. In the 1st part of research work several basic test of OPC were performed for finding the properties of materials. The basic test of OPC is such as IST, FST, fineness, tensile strength, and compressive strength, Normal consistency of cement and specific gravity of cement. In the 2nd stage the optimal packing density was finding with the addition of different amount of nano silica and nano alumina. In 3rd stage several cement motar cube were prepared, to evaluate compressive strength at 7days and 28 days.

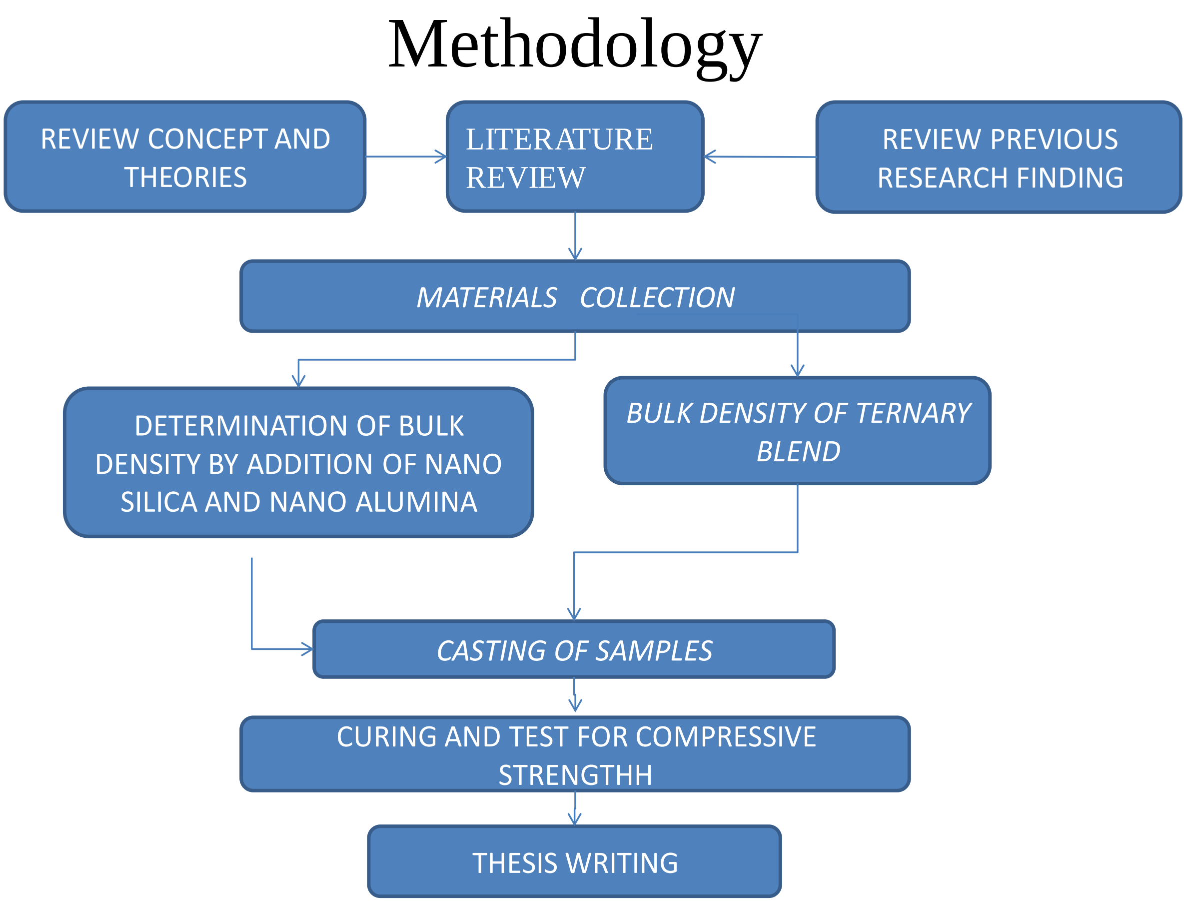


Fig. 3.1 Methodology of project

3.2 Materials used

Table 3.1 Ingredients used to prepare cement paste

Components	Function	Particle size	Type
Cement	Binding material	15 µm To 90 µm	OPC 43grade
Sand	Inert material	150 µm To 600 µm	Natural crushed
Nano silica	Fills the voids , Enhance rheology Improve strength	0.2 µm to 0.3 µm	Powder
Nano alumina	Fills the voids , Enhance rheology Improve strength	0.1 µm to 0.2 µm	Powder

3.2.1 OPC 43 Grade: it was procured from Ambuja Cement Darlaghat Solan, Himachal Pradesh conforming to IS: 8112-1989.

Fig. 3.2 OPC 43

3.2.2 Sand – Fine aggregate is obtained after crushing of hard stone. Size of crushed sand is less than 4.75mm. It is procured locally from Solan, Himachal Pradesh. Range of fine aggregate is 150μm To 600 μm.

Fig. 3.3 Crushed sand

3.2.3 Nano silica –Silicon dioxide is known as silica. The chemical formula of silicon is SiO_2. Silica is the 2nd largest amount cement ingredients which s about 17 to 23%. It can be collect from argillaceous rock. Sufficient amount of silica in cement helps for imparts strength. The properties of nano silica is

1. Increases strength
2. Workability
3. Flexibility
4. Increases viscosity of fluid phase
5. Durability

Nano silica is procured Adinath Industries from Rajasthan. Nano particle size ranges from 0.2µm to 0.3µm.

Fig. 3.4 Nano silica

3.2.4 Nano Alumina–it is the chemical compound of aluminum and oxygen. Alumina is 3rd largest amount cement ingredients which s about 3to8%.

The properties of nano alumina is

1. High specific surface area.
2. Increases the setting time of cement.
3. Materials surface coating.

Nano alumina is procured Nanopar Tech Industries from Panchkula, Chandigarh. Nano particle size ranges from 0.1 μm to 0.2μm

Fig. 3.5 Nano alumina

3.3 Oxide Composition and particle side distribution of materials

The oxide compositions are shows the percentages of different compounds in the materials. Oxide compositions of OPC 43, NS and NA were checked by XRD. Particle size of all the materials is an important element for the expansion of High Strength concrete. Proper particle size of all the materials should be known for optimum mix proportioning.

Table 3.2 Oxide composition

Materials	CaO	SiO_2	Al_2O_2	$Fe_2 O_3$	MgO	SO_2	K_2O+ Na_2O
OPC 43	63	20	6	3	2	1.5	1
NS	<0.003	99.5	<0.004	<0.001	<0.002	-	-
NA	<0.002	,0.003	98.5	<0.001	<0.003	-	<0.001

3.4 Indian standard used for experiments performance

The whole experimental works for this research work are corresponding to IS codes.

Table 3.3 List of IS code used during experimental study of research work.

Code No.	**Description**
IS 8112-1989	Ordinary Portland cement 43 grade
IS 4031-1988 (part 4)	Normal consistency
IS 4031-1988 (part -5)	IST and FST of cement
IS 4041-1988 (part-3)	Soundness
IS 4041-1988 (part-1)	Fineness
IS 4041-1988 (part-11)	Specific gravity of cement
IS 5513-1996	Vicat’s apparatus
IS 4041-1988 (part-6)	Compressive strength
IS 1458-2000	CTM
IS 383-1970	Zoning of sand
IS 2386-1963 (part-1)	Specification of aggregate

3.5 Testing

The experimental work has been separated into three stages. Every part of experimental works includes preparation of samples.

Stage 1 Cement and fine aggregate test.

Stage 2 Measure the packing density of Nano silica and Nano alumina in cementations materials.

Stage3 Measure the packing density of ternary blends (Cement+Nano Silica + Nano Alumina)

Stage I:- Basic cement test

3.5.1Normal consistency

It is the general experiment of cement. It is used to calculate accurate quantity of water for complete hydration which to acquire optimal strength. Optimal quantities of water are required for best result. Vicat's equipment is used to finding the optimal amount of water. The needle used vicat's equipment is 10mm diameter and 50mm length. To find out the normal constancy of cement the needle should be penetrate 5mm to 7mm.

Fig. 3.6 Vicat's apparatus

For finding the consistency of cement, initially take 400g of dry, lump free cement. The normal consistency of cement ranges from 25% to 34% by its weight.

3.5.2 Initial and final setting time of cement

- IST of cement is the time elapsed between the moments that the water added to the cement to the time that paste starts losing its plasticity.
- FST of cement is the time elapsed between the moment that the water added to the cement and the time when the paste has completely lost its plasticity and has attained sufficient fineness to resist definite pressure.

3.5.3 Soundness of cement

The soundness of the cement is caused by expansion of a little its constituents some time after setting. The large modify in volume additional expansion results in disintegrate and cracking.

Fig. 3.7 Le Chatelier apparatus

3.5.4 Fineness of cement

The fineness is the measurement of particle grain of cement powder and fineness is expressed in the terms of the specific surface of the cement. It can be calculated from size distribution. Fineness isimportant factor for finding the size of gain of strength and standardized of quantity. The fineness of the cement calculated with the help of 90µm sieve.

Fig. 3.8 Sieve 90 micron

3.5.5 Specific gravity of cement

Specific gravity of solid particles is the ratio of the mass of volume of solid to the mass of equal volume of the water. Generally water is used as reference materials but we used kerosene oil, kerosene oil not reacts with cement and its specific gravity is 0.79.

3.5.6 Compressive strength of cement mortar

Compressive strength is the one of the basic and important test of cement. Compressive strength is the ability of structure or material to carry the load on its surface without ant deflection and crack. The compressive strength is calculated by following formula.

Compressive strength = load /cross sectional area

Fig. 3.9 cement mortar casted cube

3.5.7 Tensile strength of cement motar

Tensile strength is an important property of cement motar. The capacity of a material of withstanding tensile load is known as tensile strength. It is measured to achieve several suggestion of the cohesion between the particles.

Fig. 3.10 Preparation of briquette specimen

Stage 2:- Measurement the packing density of nano silica in cementitious materials by using Puntke test

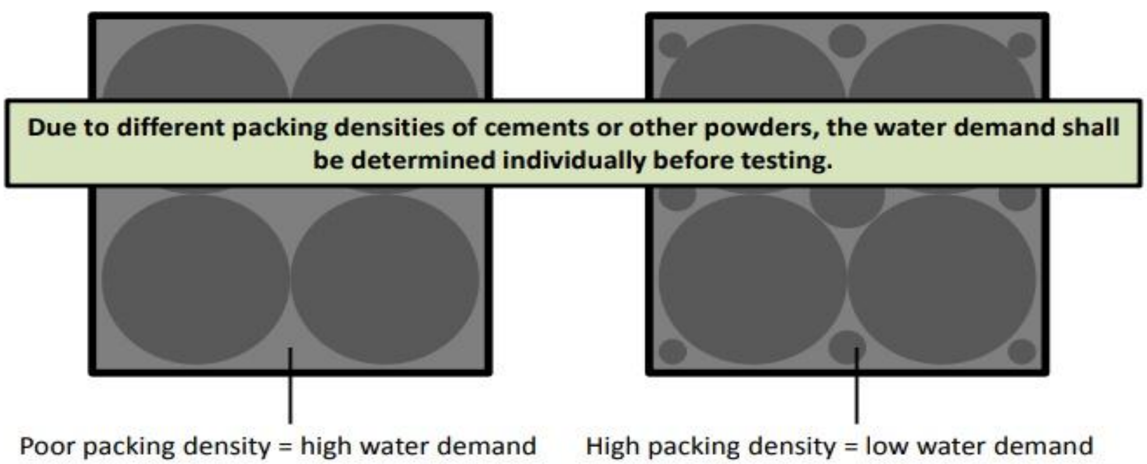
3.5.8 The specific gravity of the materials is

Table 3.4 Specific Gravity of materials

Material	Specific Gravity
Cement	3.21
Nano silica	2.20
Nano alumina	2.42

3.5.9 Puntke Method:

The basic principle of Puntke methods is water fills the voids in between the grains. The water which is in excess after completely filling with the voids, appears at the surface of the mix. Puntke methods is easy handle, easy to perform, requires simple apparatus.



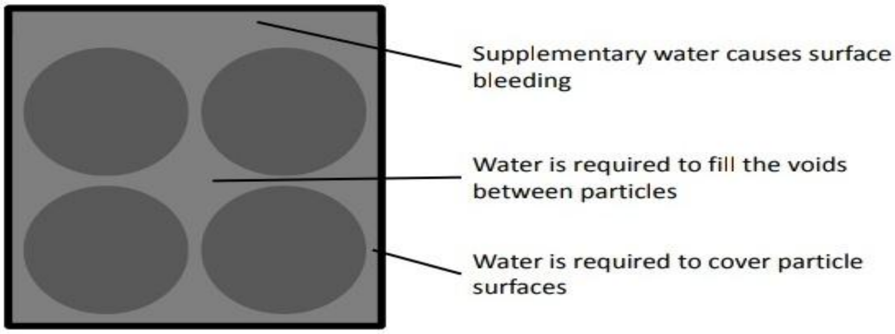


Fig. 3.11 Mix proportioning of Puntke methods

Experimental Procedure:

1) Total weight of 100 gm of cementitious material (Cement + Mineral admixtures) was taken in a beaker of round straight walls.

2) Initially done dry mixing for homogenization.

3) Water was added gradually, Mixing was done with the help of a stirrer till it got a closed surface. Continuous tapping was done to obtain closed surface.

4) After that water was added drop by drop till the mix obtained a glossy surface.

5) Then above procedure was repeated two more time to get minimum water required to attain saturation.

6) The time taken for each mix was approximately 10- 15 minutes.

Packing density Φ was calculated by using:

$$\phi = 1 - \frac{Vw}{Vw + V_p}$$

Where Vp: Volume of powder

Vw: Volume of water

Weights were converted into volumes by dividing them with each material's specific gravity of all materials

$$Vp = \frac{Mc}{Sc} + \frac{M1}{S1} + \frac{M2}{S2}$$

Mc, M1, M2 are the weights of cement and other two mineral admixture

Sc, S1, S2 are the specific gravity of cement and other two mineral admixture

3.6 Mix proportion

Mix proportion is a most important part for getting the optimum quantity of material which will provide desired strength. In this research work we have selected binary and ternary mix. A large no. of nano silica and nano alumina combinations were tried to get maximum particle packing density. Total 100 gm of cement is taken; replacement of cement was done from 0.5% to 4.0 % in step of 0.5% with mineral admixture.

For binary blends, the combinations are

OPC 43+Nano Silica

OPC43+ Nano Alumina

For ternary blends, the combinations are

OPC 43 +Nano Silica + Nano Alumina

Table 3.5 Combination trial (OPC +Nano Silica)

Combination No.	**Combination ratio** (Cement +Nano silica) grams
CNS1	100:00
CNS2	99.5:0.5
CNS3	99:01
CNS4	98.5:1.5
CNS5	98:02
CNS6	97.5:2.5
CNS7	97:03
CNS8	96.5:3.5
CNS9	96:04

Table 3.6 Combination trial (OPC 43+ Nano Alumina)

Combination No.	**Combination ratio** (Cement + Nano Alumina) grams
CNA1	100:00
CNA2	99.5:0.5
CNA3	99:01
CNA4	98.5:1.5
CNA5	98:02
CNA6	97.5:2.5
CNA7	97:03
CNA8	96.5:3.5
CNA9	96:04

Table 3.7 Combination trial (OPC43 +Nano Silica +Nano Alumina)

Combination No.	**Combination ratio (Cement +Nano Silica +Nano Alumina) grams**
CNSA1	100:00:00
CNSA2	99.5:0.5:00
CNSA3	99.5: 00:05
CNSA4	99:01:00
CNSA5	99:00:01
CNSA6	99:0.5:0.5
CNSA7	98.5:01:0.5
CNSA8	98.5:0.5:1.0
CNSA9	98.5:1.5:00
CNSA10	98.5:00:1.5
CNSA11	98:01:01
CNSA12	98:02:00
CNSA13	98:00:02
CNSA14	98:1.5:0.5
CNSA15	98:0.5:1.5
CNSA16	97.5:00:2.5
CNSA17	97.5:0.5:02
CNSA18	97.5:01:1.5
CNSA19	97.5:1.5:01
CNSA20	97.5:02:0.5
CNSA21	97.5:2.5:00

CNSA22	97:03:00
CNSA23	97:2.5:05
CNSA24	97:02:01
CNSA25	97:1.5:1.5
CNSA26	97:01:02
CNSA27	97:0.5:2.5
CNSA28	97:00:03
CNSA29	96.5:3.5:00
CNSA30	96.5:03:0.5
CNSA31	96.5:2.5:01
CNSA32	96.5:02:1.5
CNSA33	96.5:1.5:02
CNSA34	96.5:01:2.5
CNSA35	96.5:0.5:03
CNSA36	96.5:00:3.5
CNSA37	96:00:04
CNSA38	96:0.5:3.5
CNSA39	96:01:03
CNSA40	96:1.5:2.5
CNSA41	96:02:02
CNSA42	96:2.5:1.5
CNSA43	96:03:01
CNSA44	96:3.5:0.5
CNSA45	96:04:00

Fig. 3.12 Puntke Method materials and Apparatus

Fig. 3.13 Dry mix of materials

Fig. 3.14 Wet mix at 0.25 w/c ratio

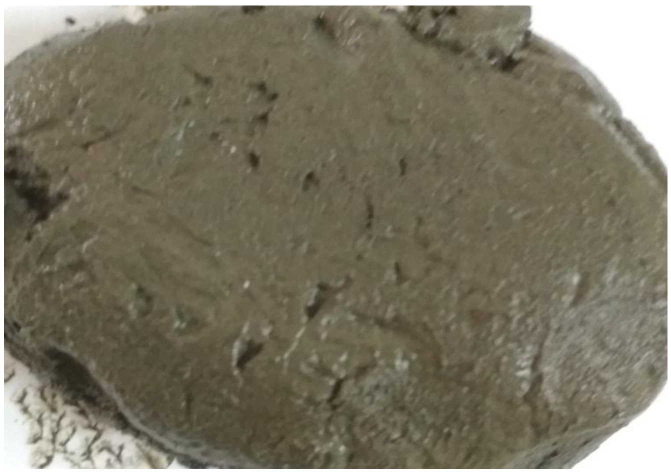


Fig. 3.15 Wet mix at 0.26w/c ratio

3.7 Test for compressive strength

Compressive strength is the ability of materials or structure to bear the maximum loads in its surface without any deflection or cracks. The following formula is used to find out the compressive strength.

- Compressive Strength = Load / Cross-sectional Area

For checks the compressive strength 7.06cm* 7.06cm cube were casted. Before the casting of the cubes specimen were properly tightened, cleaned and oiled properly. The experiments procedure for this research work is according to Indian Standards IS 4031(part 6):1988.

- Cement and Admixture were weighted on weighing machine.
- Then dry mixing was done in hand mixing for 3minutes
- After that calculated water was added in the mix and was mixed for 3 to 5 minutes
- Then three moulds were filled for each combination with the paste and compaction was done on vibration table.
- Cubes were kept in water basin for curing for 7dads and 28 days for curing. Total 27 cubes were casted.
- After 28 days of normal curing done cubes were place out from water basin and tested for compressive strength.
- Cubes were tested for compressive strength in CTM of capacity 2000KN and loading rate of CTM is 1.2KN/mm^2/min.

Fig 3.16 Dry mix of solid

Fig 3.17 Wet mix of solid

Fig. 3.18 Casting of cube

3.8 Curing

Curing acts an important role in the progress of microstructure and strength of cement mortar. Curing increases the hydration process, increases the durability and controls cracks development. After 24 hours from casting of cube demoulds and placed in water basin for 7days and 28 days at normal room temperature

CHAPTER 4

Result and Discussion

4.1 Stage-1 Test results of OPC 43 grade

4.1 Basic cement test results

Experiment name	Experimental results	Results as per IS codes
Normal consistency	32%	26 % to 33%
IST	110 minutes	< 30 minutes
FST	290 minutes	> 600 minutes
fineness of cement	2.7 %	Less than 5%
Specific gravity of cement.	3..20	3.15
Compressive strength	7 days -28.44MPa	33 MPa
	28 days 39.78 MPa	43 MPa
Tensile strength	7 days 2.41 MPa	2.5Mpa
	28days 3.03 MPa	3.5 MPa

4.2 Stage 2

4.2.1 Measurement the packing density of nano silica in cementitious materials by using puntke test

Table 4.2 shows the result for packing density of different combinations

Table 4.2 Packing density of different combinations of nano silica

OPC 43 (%)	Nano silica (%)	*Sample 1 Vw1*	*Sample 2 Vw2*	*Sample 3 Vw3*	Average value Vw	*Packing density (Φ)*
100	0	29.85	29.85	29.85	29.85	0.510
99.5	0.5	29.30	29.20	29.30	29.27	0.516
99	1.0	28.70	28.70	28.65	28.68	0.521
98.5	1.5	28.10	28.15	28.10	28.12	0.527
98	2.0	27.45	27.40	27.55	27.47	0.533
97.5	2.5	26.95	26.95	27.00	26.97	0.538
97	3.0	26.50	25.55	26.50	26.52	0.543
96.5	3.5	25.95	25.95	26.00	25.97	0.549
96	4	26.30	26.30	26.25	26.28	0.546

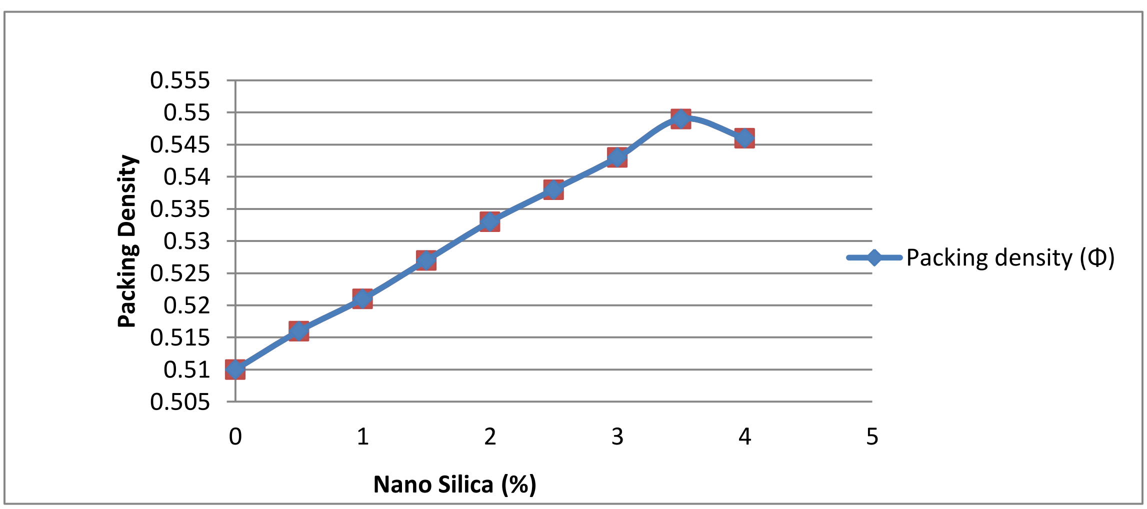


Fig 4.1 Change in packing density with the variation in amount of nano silica

4.2.2 Measurement the packing density of nano alumina in cementitious materials by using puntke test

Table 4.3 shows the result for packing density of different combinations

Table 4.3 Packing density of different combinations of nano alumina

OPC 43 (%)	Nano alumina (%)	*Sample 1 Vw1*	*Sample 2 Vw2*	*Sample 3 Vw3*	Average value Vw	*Packing density (Φ)*
100	0	29.85	29.85	29.85	29.85	0.510
99.5	0.5	29.00	29.10	29.00	29.03	0.518
99	1.0	28.30	28.25	28.25	28.27	0.525
98.5	1.5	27.45	27.40	27.45	27.43	0.532
98	2.0	27.05	27.00	26.95	27.00	0.537
97.5	2.5	27.30	27.35	27.35	27.33	0.534
97	3.0	27.80	27.80	27.70	27.57	0.532
96.5	3.5	28.20	28.15	28.10	28.15	0.528
96	4	28.65	28.65	28.55	28.62	0.524

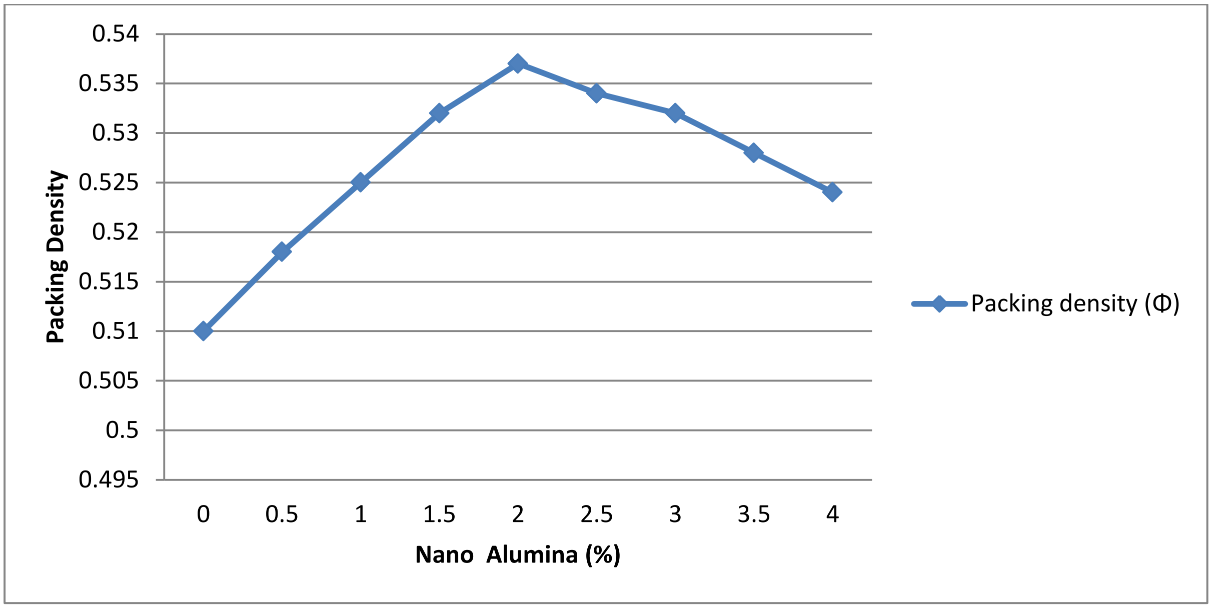


Fig no 4.2 Change in packing density with the variation in amount of nano alumina

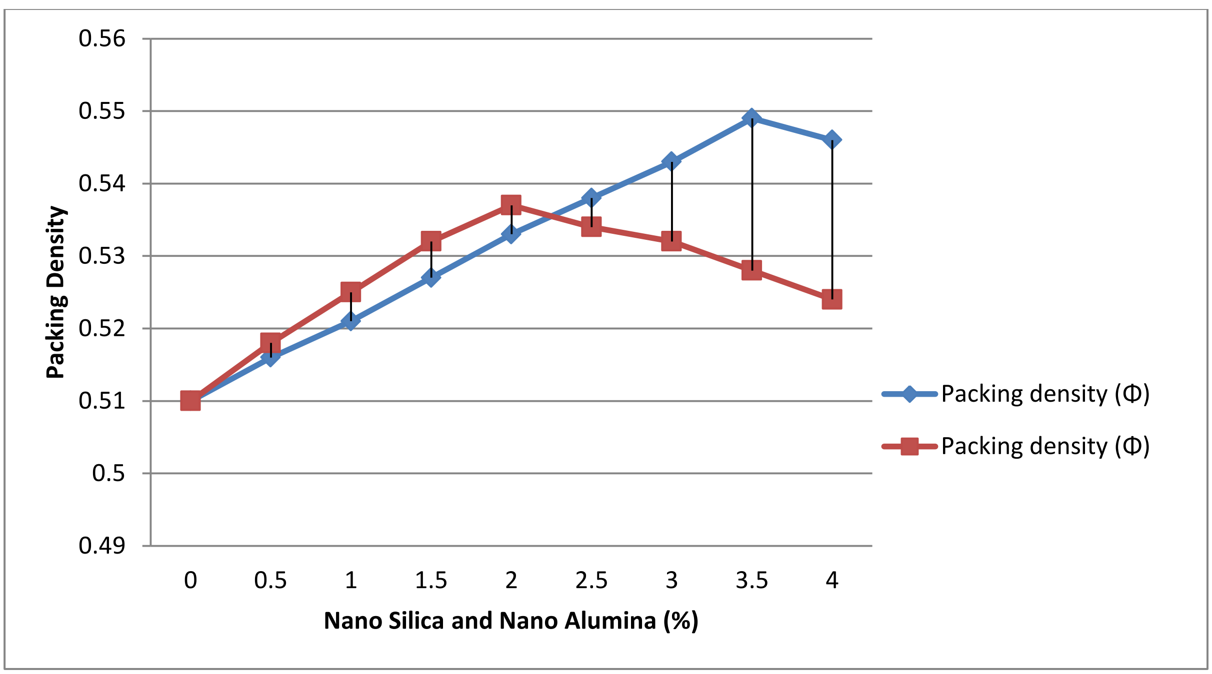


Fig 4.3 Change in packing density with the variation in amount of nano silica and nano alumina

4.2.3 Measurement the packing density of nano silica and nano alumina in cementitious materials by using Puntke test

Table 4.4 Packing density of different combinations of nano silica and nano alumina

OPC 43 (%)	*Nano silica (%)*	*Nano alumina (%)*	*Sample 1 Vw1*	*Sample 2 Vw2*	*Sample 3 Vw3*	Average value Vw	*Packing density (Φ)*
100	0	0	29.85	29.85	29.85	29.85	0.510
99.5	0.5	0	29.30	29.20	29.30	29.27	0.516
99.5	0	0.5	29.00	29.10	29.00	29.03	0.518
99	1	0	28.70	28.70	28.65	28.68	0.521
99	0	1	28.30	28.25	28.25	28.27	0.525
99	0.5	0.5	29.15	29.15	29.20	29.16	0.517
98.5	1	0.5	28.65	28.60	28.60	28.61	0.522
98.5	0.5	1	28.85	28.80	28.85	28.83	0.520
98.5	1.5	0	28.10	28.15	28.10	28.12	0.527
98.5	0	1.5	27.45	27.40	27.45	27.43	0.532
98	1	1	28.60	28.50	28.50	28.53	0.523
98	2	0	27.45	27.40	27.55	27.47	0.533
98	0	2	27.05	27.00	26.95	27.00	0.537
98	1.5	0.5	28.40	28.35	28.35	28.36	0.525
98	0.5	1.5	27.90	27.85	27.90	27.88	0.529
97.5	2.5	0	26.95	26.95	27.00	26.97	0.538
97.5	2.0	0.5	27.25	27.20	27.30	27.25	0.536
97.5	1.5	1.0	28.20	28.15	28.15	28.16	0.527
97.5	1.0	1.5	27.90	27.85	27.85	27.86	0.530
97.5	0.5	2.0	28.00	27.95	27.95	26.96	0.538

97.5	0	2.5	27.30	27.35	27.35	27.33	0.534
97	3.0	0	26.50	25.55	26.50	26.52	0.543
97	2.5	0.5	27.90	27.95	27.90	27.91	0.530
97	2.0	1.0	27.90	27.85	27.90	27.88	0.532
97	1.5	1.5	27.70	27.60	27.70	27.66	0.532
97	1.0	2.0	27.30	27.20	27.20	27.23	0.536
97	0.5	2.5	27.50	27.45	27.55	27.50	0.533
97	0	3.0	27.80	27.80	27.70	27.57	0.532
96.5	3.5	0	25.95	25.95	26.00	25.97	0.549
96.5	3.0	0.5	26.50	26.50	26.45	26.48	0.544
96.5	2.5	1.0	27.90	27.90	27.95	27.91	0.531
96.5	2.0	1.5	27.00	27.05	27.00	27.01	0.539
96.5	1.5	2.0	28.40	28.50	28.50	28.46	0.525
96.5	1.0	2.5	27.60	27.50	27.60	27.56	0.533
96.5	0.5	3.0	27.80	27.70	27.70	27.73	0.532
96.5	0	3.5	28.20	28.15	28.10	28.15	0.528
96	4.0	0	26.30	26.30	26.25	26.28	0.546
96	3.5	0.5	26.10	26.10	26.20	26.13	0.548
96	3.0	1.0	26.20	26.20	26.10	26.16	0.547
96	2.5	1.5	27.10	27.05	27.10	27.08	0.539
96	2.0	2.0	27.25	27.25	27.20	27.23	0.537
96	1.5	2.5	27.10	27.15	27.05	27.10	0.538
96	1.0	3.0	27.90	28.00	28.00	27.96	0.530
96	0.5	3.5	28.05	28.00	28.00	28.01	0.527
96	0	4.0	28.65	28.65	28.55	28.62	0.524

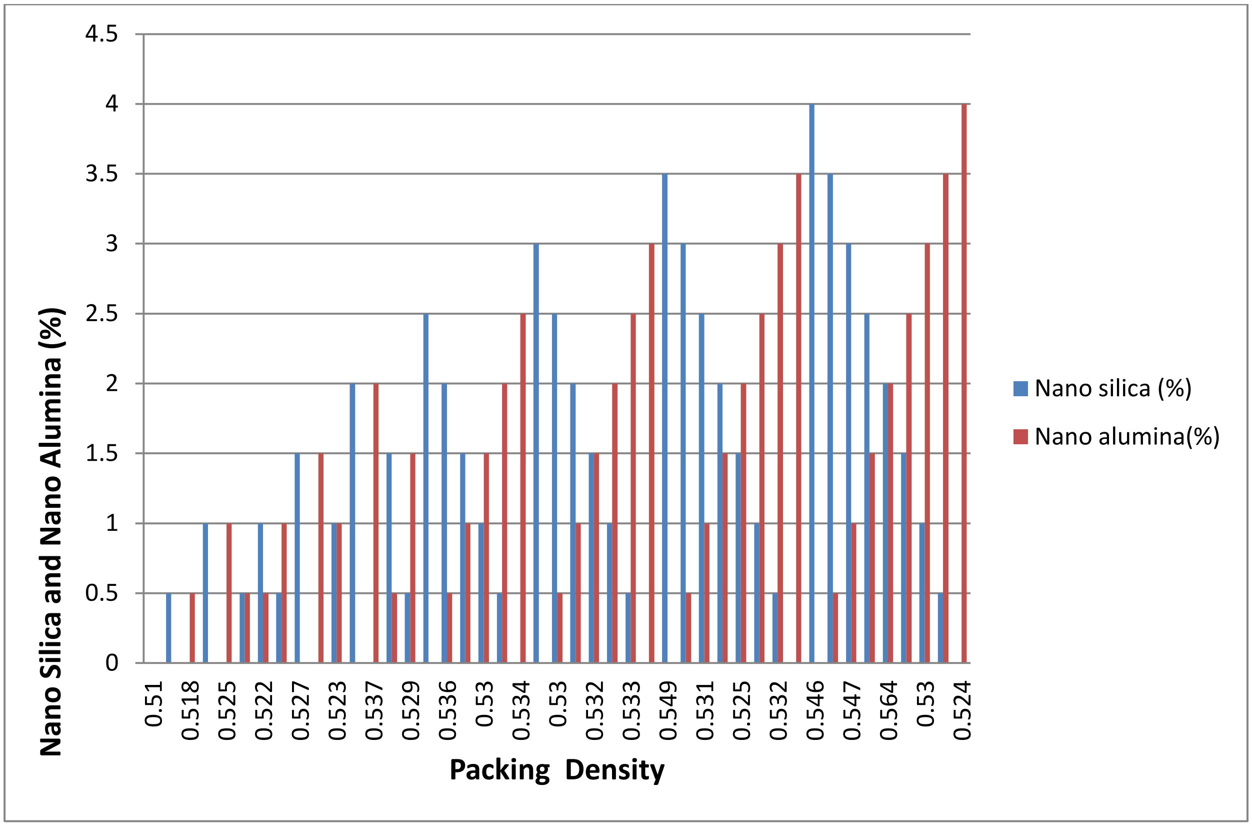


Fig 4.4 Change in packing density with the variation in amount of [nano silica + nano alumina]

4.3 Discussion on packing density

After trying 135 combinations it was observed that packing density varied from 0.510 to 0.549. Maximum particle packing density of 0.549 was obtained in the mix combination of OPC 43 + 3.5 % Nano silica by weight. It was seen that as the fine content increased, packing density increased up to certain percentage and then it decreased gradually. It was due to the increased surface area and as a result of that water demand increased and therefore packing density decreased. The mix combinations which gave maximum particle packing density in different combinations are

- Cement (96.5 %) + (Nano Silica 3.5%) give maximum packing density of 0.549
- Cement (98%) + Nano Alumina (2%) give maximum packing density 0.537
- Cement (96 %) + Nano Silica (3.5 %) + Nano Alumina (0.5%) give maximum packing density 0.54

Whole mix combination following three was selected for optimization and cube casting so that effect of all mineral admixture on the compressive strength can be studies.

- CNS8: Cement (96.5%) + Nano Silica (3.5%)
- CNA5 Cement (98%) +Nano Alumina (2%)
- CNSA: Cement (96%)+ Nano Silica (3.5%) + Nano Alumina(0.5%)

4.4 Testing of the cubes:

Compressive strength of concrete and cement mortar is measured by breaking concrete and cement mortar specimen in a CTM and UTM machine. The compressive strength is measured from failure load divided cross-sectional area. Compressive strength is basically is a compressive stress concrete can withstand. After 7 and 28 days of normal cold water curing, cubes were tested for compressive strength in CTM of capacity 2000KN and loading rate is 2.5KN/mm^2/min.

Fig 4.5 Testing of cubes in CTM

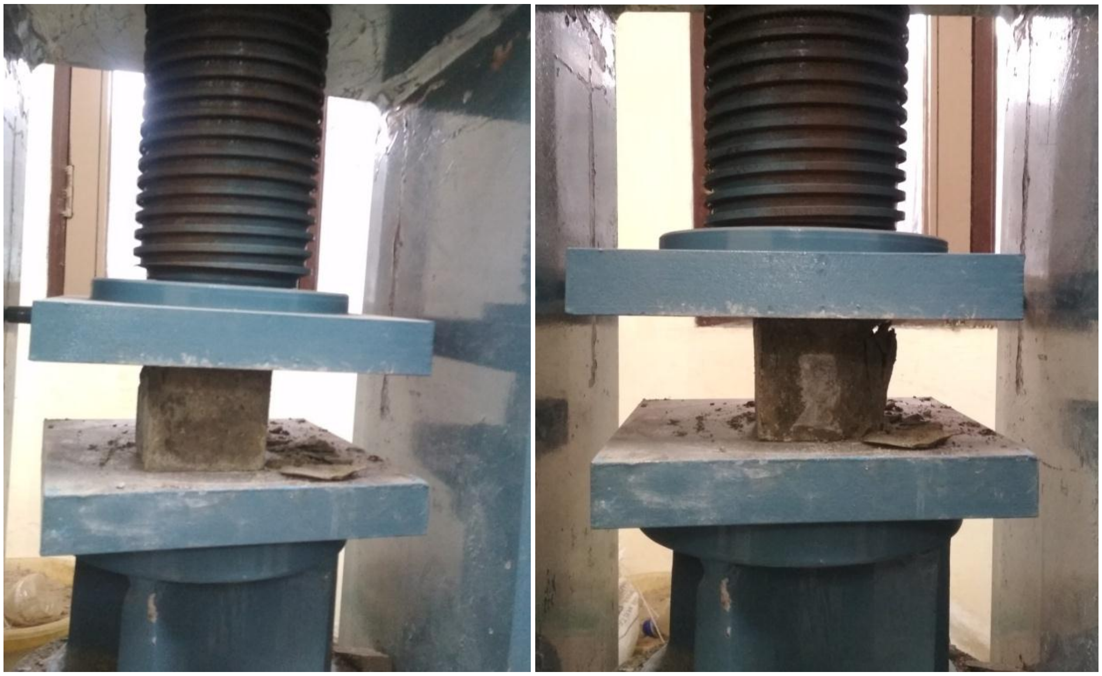


Fig 4.6 Testing of sample

Fig 4.7 Casted cube ternary blend

Table 4.5 Compressive strength result for [cement +nano silica]

Sample Name	Days of testing	Load(KN)	Area (mm^2)	Stress (MPa)	Avg. stress (MPa)
C11	7	133	49.84	26.68	
C12	7	149	49.84	29.89	
C13	7	141	49.84	28.29	28.28
CNS8	7	179	49.84	35.91	
CNS8	7	163	49.84	32.70	
CNS8	7	172	49.84	34.51	34.37
C21	28	203	49.84	40.73	
C22	28	192	49.84	38.52	
C23	28	208	49.84	41.73	40.32
CNS8	28	236	49.84	47.35	
CNS8	28	249	49.84	49.95	
CNS8	28	225	49.84	45.14	47.75

Table 4.6 Compressive strength result for [Cement +Nano Alumina]

Sample Name	Days of testing	Load(KN)	Area (mm^2)	Stress (MPa)	Avg. stress (MPa)
C11	7	133	49.84	26.68	
C12	7	149	49.84	29.89	
C13	7	141	49.84	28.29	28.28
CNA5	7	157	49.84	31.50	
CNA5	7	170	49.84	34.10	
CNA5	7	166	49.84	33.30	32.96
C21	28	203	49.84	40.73	
C22	28	192	49.84	38.52	40.32
C23	28	208	49.84	41.73	
CNA5	28	230	49.84	46.14	
CNA5	28	221	49.84	44.34	
CNA5	28	226	49.84	45.34	45.27

Table 4.7 Compressive strength result for [Cement +Nano Silica +Nano Alumina]

Sample Name	Days of testing	Load(KN)	Area (mm^2)	Stress (MPa)	Avg. stress (MPa)
C11	7	133	49.84	26.68	
C12	7	149	49.84	29.89	
C13	7	141	49.84	28.29	28.28
CNSA44	7	168	49.84	33.70	
CNSA44	7	173	49.84	34.71	
CNSA44	7	160	49.84	32.10	33.50
C21	28	203	49.84	40.73	
C22	28	192	49.84	38.52	
C23	28	208	49.84	41.73	40.32
CNSA44	28	234	49.84	46.95	
CNSA44	28	227	49.84	45.54	
CNSA44	28	235	49.84	46.74	46.41

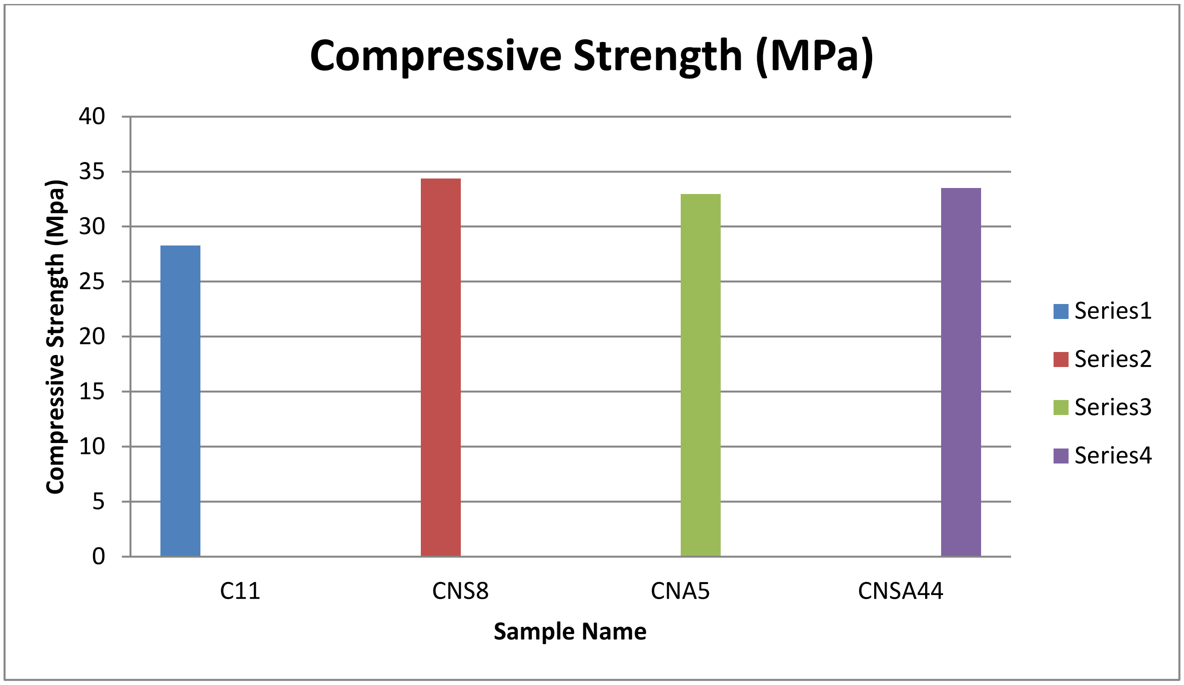


Fig.4.8 7days Compressive strength of different samples

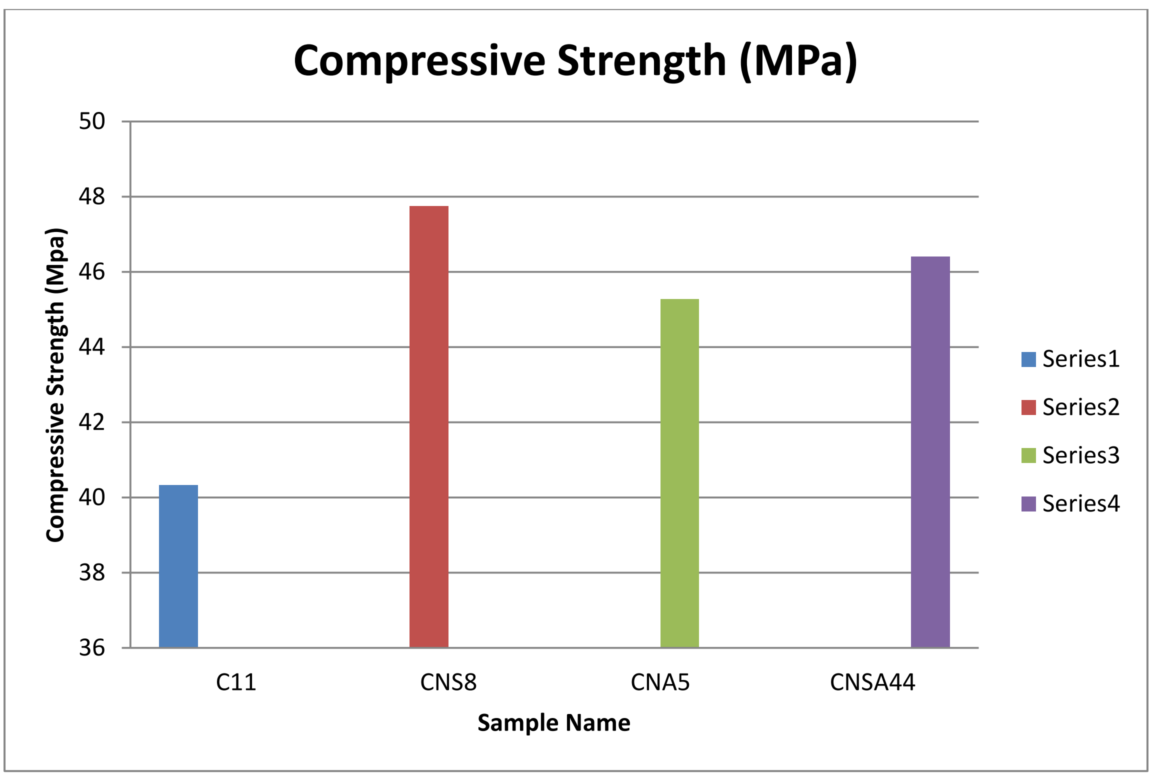


Fig 4.9 28 days Compressive strength of different samples

4.4.1 Discussion

Whole mix combination following three was selected for optimization and cube casting so that effect of all mineral admixtures on the compressive strength can be studies. The following compressive strength is gives the nano particle.

- CNS8: Cement (96.5%) + Nano Silica (3.5%) gives maximum strength 47.75MPa
- CNA5 Cement (98%) +Nano Alumina (2%) gives maximum strength 45.27MPa
- CNSA: Cement (96%)+ Nano Silica (3.5%) + Nano Alumina(0.5%) gives maximum strength 47.41MPa
- Imperfection dimension of mould can be one reason for less compressive strength.
- Normal cold water curing was done for 7days and 28 days.

CHAPTER 5

Conclusions

As the demand of high strength concrete is increasing day by day for long span, high rise structure and heavy construction. Our researcher was aimed to achieve optimal compressive strength for binary and ternary blends using for Puntke method. After using two types of mineral admixture Nano Silica and nano Alumina for cement replacement. It can be conclude that as cement replacement increases packing density also increases.

After trying 135 combinations it was observed that packing density varied from 0.510 to 0.549. Maximum particle packing density of 0.549 was obtained in the mix combination of OPC 43 + 3.5 % Nano silica by weight. It was seen that as the fine content increased, packing density increased up to certain percentage and then it decreased gradually. It was due to the increased surface area and as a result of that water demand increased and therefore packing density decreased.. The mix combinations which gave maximum particle packing density in different combinations are

- Cement (96.5 %) + (Nano Silica 3.5%) give maximum packing density of 0.549
- Cement (98%) + Nano Alumina (2%) give maximum packing density 0.537
- Cement (96 %) + Nano Silica (3.5 %) + Nano Alumina (2%) give maximum packing density 0.54

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