"OPTIMIZATION OF BINARY MIXES FOR ULTRA HIGH STRENGTH CONCRETE BY PUNTKE METHOD"

A PROJECT REPORT

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

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IN

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Under the supervision of

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HIMACHAL PRADESH, INDIA

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CERTIFICATE

This is to certify that the work which is being presented in the project title**"OPTIMIZATION OF BINARY MIXES FOR ULTRA HIGH STRENGTH CONCRETE BY PUNTKE METHOD"**in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology submitted in Civil Engineering Department, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Tarun Gaur & Rishab Attri** during a period from August 2016 to May 2017 under the supervision of Mr. **Abhilash Shukla,** Assistant Professor, Civil Engineering Department, Jaypee University of Information Technology, Waknaghat.

Theabovestatementmadeiscorrecttothebestofmyknowledge.

Date:

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Abstract

Ultra-high-strength concrete is a progression of high-strength concrete in concrete technology. It groups compressive strength of 150MPa or above. Since UHSC is another kind of solid, it has not been broadly utilized by the designers. Because of absence of research, it has just been utilized as a part of some reinforced concrete members and few large and precise structures. Research are been led to discover mechanical properties of UHSC utilizing distinctive mineral and synthetic admixtures.

In our test, we centered to discover the ideal extent of mineral admixture with cement to accomplish most extreme packing density and make a mix design based on the obtained results. We have utilized five mineral admixtures as a pozzolanic material in cement. The mineral admixtures utilized were Quartz powder, Fly ash, Metakaolin, Ultra-fine slag and Rice-husk ash. A third generation superplasticizer was additionally utilized ito set up the mix design with a specific end goal to minimize the water necessity for cement hydration.

The trial work is done in two stages. The main stage incorporates finding of different properties of materials like speceific gravity and water retention.The second stage incorporates optimization of binary blend by accomplishing greatest packing density utilizing strategy given by Puntke. After the analyses utilizing diverse materials, graphical portrayal was done to acquire the advanced extent. After the experiments using different materials, graphical representation was done to obtain the optimized proportion.

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ABBREVIATIONS

RPC	*Reactive Powder Concrete*
UHSC	*Ultra-High Strength Concrete*
HSC	*High Strength Concrete*
HPC	*High Performance Concrete*
OC	*Ordinary Concrete*
HPFRCC	*High performance fiber reinforced cementitious composites*
GGBS	*Ground granulated blast furnace slag*
UFS	*Ultra-fine slag*
MK	*Metakaolin*
AF	*Ultra-Fine Slag*
QP	*Quartz Powder*
FA	*Fly Ash*
W/S	*Volumetric ratio of water wrt. solids*
RHA	*Rice Husk Ash*

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CHAPTER 1

Introduction

1.1 General Introduction

Ultra-High Strength cement is a rising innovation that gives another measurement to the expression "High performance concrete". It has a lot of potential in construction development industry. It has great mechanical properties and durability properties when contrasted with the traditional cement. It can likewise substitute basic steel in a few applications by joining fiber support. It can also substitute structural steel in some applications bycombining fiber reinforcement.

Essential standards like packing density, micro structural improvement can be used to to accomplish Ultra-High Strength concrete. The advantage like water resistance and strength are likewise given by UHSC. It can be a decent substitute for mechanical and atomic waste storerooms. Different examination of the UHSC and HSC have been performed for assurance of mechanical and durability properties. The outcomes demonstrates that Ultra-High Strength concrete have more prominent compressive and flexural strength and a decreased water penetrability. The most extreme compressive strength is between 120-150 MPa.

Once in a while strength may likewise reach upto 200MPa. At such a high compressive strength the coarse aggregates are the weakest part in concrete. The concrete is liable to fail from coarse aggregates.

To accomplish a compressive quality we can remove the coarse totals and accomplish consistency and homogeneity in the blend. The pozzolanic properties of materials like silca fume, fly ash and so forth are utilized to accomplish high density and strength. UHSC incorporates bond of higher grade (for the most part OPC 53), quartz sand. quartz powder, steel aggregates and silica fume, steel fibers and a superplasticizer (III generation). We likewise utilize superplasticizers so as to decline water-cement ratio with extra advantage of getting great workability.

A packed matrix is accomplished by changing the granular packing of the dry fine powders. This compactness gives the concrete, ultra-high strength and durability. Ultra-High Strength concrete have compressive strengths around 150 MPa.

1.2Purpose of study :

Our test meant to discover the ideal extent of mineral admixture with concrete to discover the most extreme packing density. Extreme or correctly speaking the maximum packing density implies that the voids between the concrete particles are least and a large portion of the volume is possessed by the solids. By diminishing the air content in solid, its strength upgraded,. We add mineral admixtures in order to maximize silica content in the blend as silica substance diminishes the measure of free lime exhibit after hydration of bouge mixes. As the particle size of these mineral admixtures is smaller than that of cement, they fill the cement voids and decrease the capillary pores in concrete. When the capillary pores are are diminished, the penetrability of outside material, for example, chloride, water and other destructive mixes is additionally diminished and it along these lines increases the durability of concrete.

1.3How will UHSC prove useful to construction industry?

The concrete possessing mighty compressive strength of over 150MPa can find various uses in construction industry such as. :

1. Because of high compressive compressive strength, the structural members cast from UHSC will be slender as compared to the structural members cast using ordinary concrete for taking up the same amount of load. The material prerequisite will be significantly lessened which will at last make the concrete economical. Likewise because of decline in size of basic individuals, the dead load will be incredibly decreased.

2. Casting of UHSC uses various mineral and chemical admixtures. These admixtures fills up the voids of cement and decrease the permeability of concrete. Because of this, the penetrability of outside material, for example, chloride and moisture is diminished. This makes the solid impervious to different corrosive assaults and warmth. In this manner, the durability of concrete is increment
3. UHSC can locate its noteworthy application in pre-cast industry. This concrete can be used to cast bridge girders and various structural members of very high strength.

Accelerated curing of this concrete can give very high early strength within 3 days of curing. Researchers have presumed that around 200MPa of compressive quality can be accomplished via autoclave curing of cement at 90°C for 3 days. These structural members can be utilized when the work must be done in less time..

4. UHSC discovers its real application when it is utilized with fibers. Different sort of fibers can be added to UHSC to enhance its ductility and toughness. Incorporation of fiber reinforcement in UHSC can eliminate the structural steel completely. Various foot-over bridges constructed using fiber reinforcement and UHSC have indicated great serviceability and durability. High compressive strength of UHSC makes it a reasonable material for establishment of tall structures, underground shelters and different other auxiliary portions.

1.4Composition of Ultra-High Strength concrete

Ultra-High Strength concrete is made out of cement, sand, quartz powder and silica fume, steel fibers and superplasticizer. The superplasticizer, utilized at its ideal dose, diminishes the water to cement ratio and enhance workability of the concrete. A very dense matrix is accomplished by optimizing the granular packing of the dry fine powders. This compactness gives this concrete ultra-high strength and durability. Reactive Powder Concretes have compressive strengths going around 200 MPa. The mixture design Ultra-High Strength concrete principally includes the formation of a thick granular skeleton. Optimization of the granular mixture can be accomplished either by the utilization of packing models or by open source programming, for example, EMMA

1.5Scope of study:

- With use of ultra-high strength concrete, the structures made can be put to service earlier, like opening the pavements with 2-3 days.
- The cross sectional members of large structures can be reduced and structures can be made aestheticaly good.
- Large and durable structures can be made in no time as compared to the conventional methods of concrete industry. Specialized mechanical properties can be satisfied .e.g long durability, high compressive and flexural strength etc.

These improved properties will let us make dams. Foundations, heavy and large structures more efficiently and economically.

1.6 Advantages:

1. The structures made will be sooner available for us.

2. The cross section of columns and beams of large structures are reduced.

3. We get highly durable structures with the use of ultra high strength concrete.

Concrete with any desirable mechanical properties can be made.

1.7Limitations

1. Extra care is required while placing High Strength Concrete which may not be requied while using conventional concrete.
2. Good quality control is required while making ultra high strength concrete.
3. The cost will be increased because in use of UHSC we need to do test at site as well.
4. The mix of concrete may require some special special materials and skilled labour as well

1.8MATERIAL INTRODUCTION

A. OPC 53 Grade cement:

The basic criteria while grading the concrete is strength. The grade of the concrete let us know that what will be the of concrete after 28 days of curing.

Higher the grade of concrete will let us do the construction at a faster pace and the high initial strength can be achieved .The 7 day strength of the OPC 53 grade concrete will be around 27MPa. This grade of cement is used in higher grade RCC and prestressed concrete, cement grouts. 53 grade cements is on the costlier side as compared to other grades of concrete. Brands available in India are Birla Cement, Ultratech Cement, ACC Cement etc.

Specific gravity of cement is around 3.15 .

B. Fly-Ash:

After burning of coal in thermal electric stations the by product which we get is known as Fly ash. It is a very fine powder. Fly ash is a pozzolan highly rich in silica content. Pozzolanic substances are those substances which contain aluminous and siliceous material which when mixed with water forms like a cement like properties.

Pozzolanic materials like fly ash when get mixed with lime and water inhibits a binding property same as of other cementitious materials. The fly ash is a very good material and can be used for partial replacement in cement. During the formation of mosaic tiles and other small or large structures the quality of fly ash entirely depends upon the type of coal which is burnt..

The mineral composition of fly ash may vary but all types of fly ash will include silicon dioxide both in the amorphous and crystalline state along with aluminum oxide and calcium oxide. Fly ash particles are generally spherical in shape and range in partical size from 0.5 µm to 300 µm which is generally smaller than the partical size of cement.

Specific gravity of fly ash generally lies between 1.9-2.8 and the color is somewhat gray.

The fly ash is of two types Class F and Class C and the properties of both of them are mentioned in ASTM C 618 or AASHTO M 295.

C. Rice Husk Ash:

The combustion of rice hulls gets us rice husk ash commonly known as RHA. This ash constitutes reactive silica primarily in amorphous state with great applications in the material science industry. RHA is finer than cement.

The basic component of sand is silica and this can be used with for operations like plastering and concreting when used with cement. When used with cement the fineness of silica will let us achieve a dense structure.

Specific gravity of RHA is around 2.1 . The particles of RHA are generally round in shape. The particle size of RHA lies between 5 micron to 95 micron.

The RHA available comes with 5%, 10%, 15% and 20% silica content by weight. Study shown that the replacement of cement with rice husk ash gives us concrete with improved strength.

D. Ultra-Fine Slag:

Ultra-Fine Slag is a decent cementitious material which can be utilized for incomplete substitution of cement. It has high silica contentDespite its high fineness. It doesn't build water request when utilized upto 5-15 percent substitution of ordinary OPC. Its additionally watched that concrete slump is enhanced by dense packing of cementitious material, delivering low air void content. The use of ULTRA-FINE SLAG brings about rich hydrated cement matrix to comprise of very small pores.

Ultra-fine slag which is based on high glass content with very high reactivity. It is made by uncommon procedures and got through the procedure of controlled granulation. The crude materials of Ultra-fine slag are made fundamentally having low calcium silicates. It has an average particle size less than 10 micron and specific gravity of around 2.7.

E. Metakaolin:

Metakaolin is refined form kaolin clay. It is acquired after firing it (calcined) deliberately controlled conditions which are important to make an amorphous alumino-silicate. This alumino-silicate is reactive in concrete. Much the same as different pozzolans (fly ash, Rice-husk ash and silica fume are common pozzolans). Metakaolin additionally responds with free lime which is gotten as by-products delivered during cement hydration of bogue compounds.

Calcium hydroxide represents up to 25% of the hydrated cement paste of Portland cement. It doesn't add to the strength or durability of concrete by itself until it reacts with silica. Metakaolin joins with free lime, which is created as result to produce additional Calcium-silicate hydrate gel which is responsible for binding concrete together.

Presence of less free lime protects the concrete from expansion. In later stages more cementing compounds enhance binding properties and add strength to concrete. Metakaolin particles are extremely small with an average particle size of 3 µm. The specific gravity is in range of 2.40 to 2.60.

F. Quartz Powder:

Quartz is the second most abundant mineral in Earth's continental crust, after feldspar. Its crystal structure is a continuous framework of SiO_4 silicon with oxygen tetrahedral, with each oxygen being shared between two tetrahedral. This gives an overall chemical formula of SiO_2.

Quartz powder is the crushed form of quartz. It has different particle sizes 75 – 180 µm, 45-75 µm, 38-45 µm, and <38 µm. Quartz Powder has specific gravity around 2.

CHAPTER 2

Literature Review

2.1Literature review:

A number of research papers are available on the topic of high strength concrete. Some of the most important research papers in the context of high strength concrete have been reviewed here in the present study.

The creators Ming-Gin Lee , Yung-Chih Wang and Chui-Te Chiu pointed discover the suitabiity of Reactive Powder concrete (RPC) to be utilized as another repair material and they additionally assessed its bond soundness and durability with existing cement. They attempted to test the solid utilizing quickened maturing condition test in which constant freezing–thawing cycles were made. This test was reasonable to assess the durability of the repairing materials. The compressive strength of concrete sections were tried prior and then afterward the solidifying defrosting activity and the distinction between the quality decided the appropriateness of RPC as repairing material.

In this trial concentrate Reactive Powder Concrete showed great outcomes which makes it suitabe to utilize it as a repairing and retrofitting material as it upgraded the compressive and flexural quality of old tried examples. The impacts of compressive and flexural strengthening with bonding RPC of 10-mm thickness was about 200% and 150% more than those ofnormal strength concrete. Compressivestrength tests after 1000 freeze–thawcycles indicate that RPC is highly durable.

The authors Na-Hyun Yi , Jang-Ho Jay Kim, Tong-Seok Han, Yun-Gu Cho, Jang Hwa Lee assessed to decide if UHSC and RPC can oppose terrorist attacks or impact loading due to accidental damage such as bomb blasting. In their investigation they did the accompanying tests which are Slump flow, compressivestrength, split tensile strength, elastic modulus, and flexure strength test. What's more, to simuate genuine blasting conditions, they carried out ANFO blast tests on UHSC and RPC panelsreinfored with steel bars and short steel fibers. From their review, they reasoned that reinforcing the UHSC and RPC with metafibers and structural reinforcement provides sufficient ductility to the structural members and they increases the ductility of concrete which ultimately increases the toughness. So, the reinforcement arrests the crack propagation and reduce the brittleness of concrete.

The authors **Yin-Wen Chanand, Shu-Hsien Chu** did analysis to decide the impact of silica fume on the bond characteristics between steel fiber and the matrix of reactive powder concrete (RPC), which incorporates bond strength and pullout energy to break the bond between the two materials. A typical and most popuar test named Fiberpullout tests was received to test the bond characteristics of short steel fibers with the RPC matrix. After the results,it is watched that the addition of silica fume as a pozzolanic material can effectively enhance the fiber–matrix inter-facial properties like bond strength and pullout energy, significant increment in fiber pulloutenergy was observed.

From the consequences of bond strength and pullout energy test, the ideal silica fume–cement proportion was observed to be in the middle of 20% and 30 under the given states of the test program. At this silica fume dosage, thebond strength and the fiber pullout energy were the highestamong all cases.

The authors **Chin-Tsung Liu, Jong-Shin Huang** attempted to discover the fire resistance of RPC, HPC and OC by conducting a series of fire resistancetests on RPC, HPC and OC. The specimens of different concrete were simultaneously placed inside a heavy-oil burningfurnace. This experiment was carried out at the Fire Protection and Safety Research Center of National Cheng KungUniversity.. The temperature of the heavy-oil burning furnacewas raised as per the guidelines of JIS A1304 method. The standard temperature–timeheating curve of JIS A1304 method.

From the experiment results it was concluded and initially expected that the residual compressive strength of RPC specimens decreases with increase in fire duration in the furnace. Ascompared to high performance concrete (HPC) and ordinary concrete (OC), they studied RPC show better resuts as it not only has ahigher fire endurance temperature but also possesses a larger residual compressive strength after subjecting to fire for the same duration.

The authors **A. Cwirzen, V. Penttala and C. Vornanen** demonstrated analternative approach for the optimization of the mix design of RPC which is not quite the same as Puntke's technique by utilizing the assurance of the water demand of binary, ternary and poly-dispersed mixes.Estimations of the individual water requests of various materials bond quartz sand and concrete silica rage blends were resolved. The mix designs were prepared which had water to binder ratio of 0.187, in which 25% of silicafume was present along with 5% of superplasticizer measured with respect to cement content - were produced for carrying out experiments on freshconcrete to determine fresh concrete properties andcompressive strength after curing. The concretes were cured under a very high temperature 90°C for accelerated curing.

The outcomes reasoned that the determination of the minimum water demand of basic binary or ternarydry mixtures using the Puntke method can determine the optimum ratio of quartz to sand inregard to its highest packing density and pozzolanic activity which resulted in the highestcompressive strength after theheat-treatment.

The authors **AN Ming-zhe, ZHANG Li-jun, YI Quan-xin** experimented to determine the effect of specimen size on compressive strength of reactive powder concrete. Cubic specimens were cast according to three mix proportions prepared by authors.The compressive strength of 12 sets of cubicspecimens with side lengths of 5cm, 7.07cm and 10cm,and another 6 sets of cubic specimens with a side length of150 cm, was carefully measured after the suitable curing period.

From the outcomes conclusion came out greater the size, the lower will be the strength.The influence exerted by steel fibers on the size effectof RPC specimen is complicatedThe impact applied by steel strands on the size impact of RPC example is convoluted. It was watched that when the measure of the cubic RPCspecimen was smaller than 10 cm in dimension, the specimen size effectshowed no obvious tendency in compressive strength but for the cubic specimens of specimen size greater than 10cm the size effect becomes more defined and obvious as: with an increase in the fiber dosage to reactive powder concrete, theconversion coefficient become lager.

The authors **Marios N. Soutsos, Stephen G. Millard, and KonstantinosKaraiskos**aimed to find out the effect and optimum dosage of ground granulated blast furnace slag (GGBS) in Reactive

Powder Concrete. Various dosage of GGBS were used in different mix designs for casting of different specimens. The specimens were tested for compressive and flexural strength after 28 days of curing.

From the results it was concluded that Partial cement replacement by 36% ground granulated blast furnace slag as a pozzolanic material had been very beneficial for reactive powder concrete in terms of achieving greater mechanical properties. Also GGBS is a waste product, addition of this to partially replace cement will be very economical.

The authors **Dr. Hisham M. Al-Hassani, Dr. Wasan Ismail Khalil, Lubna S. Danha**xpected to discover the impact and ideal dose of some mechanical propertiesof Reactive Powder Concrete (RPC) like compressive strength, tensile strength(direct, splitting and flexural), flexural toughness,load-deflection capacity and staticmodulus of elasticity. The effects of three variable parameters on these properties werecarefully studied which are, the silica fume content SF (0%, 10%, 15%, 20%, 25%, and30%) as a partial replacement by weight of cement, hooked macro steel fibers volume fractionVf (0%, 1%, 2% and 3%) and superplasticizertype(Sikament®-163N andPC200).The diameter of the steel fiber used in test were 0.5mm in diameter and its length was 30mm with an aspectratio of 60. From the observation of results, it was concluded that as the silica fume content (SF) as a pozzolanic material increased from 0% to 30%, the compressive strength also showed significant increment, while the increase intensile strength of concrete was found to be relatively lower. The inclusion of steel fibers also lead to a considerableincrease intensile strength, while the addition of steel fibers resulted in a slight increase incompressive strength of RPC when the fiber volume fraction was increased from 0% to 3%.Theincrease in the steel fibers volume fraction and silica fume content resulted in improvement of the loaddeflectionbehavior and consequently gave higher ductility and fracture toughness ofRPC.

The authors **McGeary RK.**and**J Am Ceram Soc** in the year 1961 investigated the effect of fine fly ash for partial cement replacement and packing density of mix on the propertiesof high performance concrete. They reported that theoretically,it is possible to achieve a packing density as high as of 95.1using four sizes of materials in spherical shape with their diameterratios of 1, 7, 38 and316 and the fraction volumes of 6.1%, 10.2%, 23% and 60.7% respectively.

The authors **YanzhouPeng,Shuguang Hu** and **Qingjun Ding**in 2009 studied the effect of different pozzolans rich in silica. They used ultra-fine fly ash (UFFA), steel slag (SS) and silica fume (SF) in different proportions with cement to obtain packing density of binary,ternary and quaternarycementitious materials.

After obtaining the results they concluded that the incorporation of rich in silica mineral admixture in cement definitely improves the packing density of the binary mixture dueto the packing effect as these admixtures fills up the voids of cement. A further increase in packing density of composite was obtained with incorporation of two or more kinds of mineral admixtures because of greater packing effect .

The authors **John Wiley & Sons**in 1968suggested that a concrete mix may beconsidered a mixture of aggregate particles and cement paste. He proposed that the cement paste trapped inside the concrete voids in the bulk volumeof coarse aggregates is not effective in lubricating the cement concrete mix. It is the excess cement paste (the paste in excess left after filling up of aggregate voids) is effective in lubricating the concrete mix and increasing its workability.Hence, if the packing density of the aggregate is increasedi.e when optimum dosage is obtained, theamount of paste needed to fill up the aggregate voids will be reduced. Consequently, for the same amount of cement paste, there will be more excess paste left after filling the voids to improve the workability. In other words, for the same requiredworkability, the amount of cement paste will be reduced.

The authors **A.K.H. Kwan** and **W.W.S. Fung**in 2009tried to compare the density of the mix obtained by dry mixing and wet mixing. They applied a newly developed wet packing method to measure the packing densities using different variations. They used blendedfine aggregates (each a mixture of fine aggregates of different sizes) and mortars (each a mixture ofcement and blended fine aggregate). They performed the test under the wet condition, with or without superplasticizerbeing added,and with & without compaction of the cement mix being applied. They achieved the expected results by this new method as packing densities was achieved with the very less mean absolute error which is 2.1% for the blended aggregates and only 1.1% for the mortars.The results reported that the packing density of fine aggregate is significantlyhigher and less sensitive to compaction under wet condition thanunder dry condition. Moreover, they did not found significant benefit due to addition of superplasticizer on the packing density. Hence, they observed that wet packing method is more reliable for finding out the packing density of fine aggregates as thedry packing methodtends to underestimate the packingdensity. The wet packing method has also been appliedto measure the packing densities of mortar mixes with differentfine aggregate proportions. The results reported that the proportion of fine aggregatesin mortar have significant effects on the packing.

From the bulk density M/V, thesolid concentration of the mortar may be determinedas :

$$\phi = \frac{M/V}{q_w u_w + q_a R_a + q_b R_b}$$

Where, $q_w$is the density of water, $q_a$and $q_b$are, respectively, thedensities of the cementitious material a and the cementitious materialb, $q_s$is the density of the fine aggregate, $u_w$is the W/S ratio, andR_a, $R_b$and $R_s$are, respectively, the volumetric ratios of a, b and fineaggregate to the total solids content

The authors **L.G. Li**and**A.K.H. Kwan** in 2013faced the following problems in traditional method to achieve packing density i.e. the dry mixing approach. They observed that packing density in dry mixing is quite sensitive to the amount of compaction applied;this method did not include the possible effects of water andadmixtures on packing density; and the agglomeration and loose packing of the finerparticles may seriously affect the measured packing density under drycondition. In order to cope-up with this problem they developed wet mixing method to study the effect of packing density on the rheologyof cement paste. The effects of cement content, compaction,superplasticizer, double or triple blending of cementitious materials on packing density were also investigated.

The authors concluded that the presence of water in the mix coulddecrease the voids ratio by as much as 46%. Second, the compaction of cementitious paste by tamping could decrease the voids ratio by 36% under dry conditionand 17% underwet condition, indicating that dry packing ismore sensitiveto compaction than wet packing which makes wet packing results more reliable with respect to compaction.Third, under wet condition, thecompaction by vibration could decrease the voids ratio by 27%, showingthat vibration is more effective than tamping for wet compaction. Fourth,the addition of super-plasticizer could decrease the voids ratio by up to 39%.

The authors **PrakashNanthagopalan , Michael Haist , Manu Santhanam**and**Harald S. Müller** in 2008 carried out the experiment to obtain the interrelationship between the flow properties and the particle packing density ofthe cementitiousmix. The experimental investigationincluded Puntke tests for determining the packing density, and rheological tests that were performed in a rheometer for the characterisationof cement and silica fume (C + SF) as well as cement and fly ash (C + FA) mixtures. the packing density ϕ_p was determinedby using:

$$\phi_p = 1 - \frac{V_w}{V_w + V_p}$$

whereVw = volume of water ($cm^{3.}$); Vp = volume of solidparticles = 20 cm^3

From the results they concluded that in case of C + FA mixtures, for constant w/p ratio, the yield valueg decreased with increase in replacement of fly ash. In otherwords, the yield value g decreases as the packing density ofthe C + FA mixture increases proving that good packing densityleads to enhanced flow properties.

The authors**Mohamed AbdElrahman** and **Bernd Hillemeier** in 2014 studied to provide a new approach to optimize the materials of high performance concrete withlow cementitious materials content. Their investigation included ideal grading curve according to Fuller concretemix design to ensure high packing density of concrete mixtures and to reduce the required binder content. The role of fine fly ash on concreteperformance has been estimated by measuringthe concrete mechanical properties, porosity and durability. The mechanicalproperties wereassessed from compressive strength and modulus of elasticity. The durability characteristics wereinvestigated in terms of water permeability and water absorption.

In the densely packed system, in which OPC was repaced by 25% fine flyash and 10% silica fume exhibited compressive strengthhigher than 80 MPa with w/b ratio of 0.42. The elasticmodulus of the concrete specimen reached around 45 GPa. However, the compressivestrength reached 99 MPa and the elastic modulus was morethan 50 GPa for a ternary mix with combination of blast furnace slag cement, finefly ash and silica fume along with w/b ratio of 0.27.

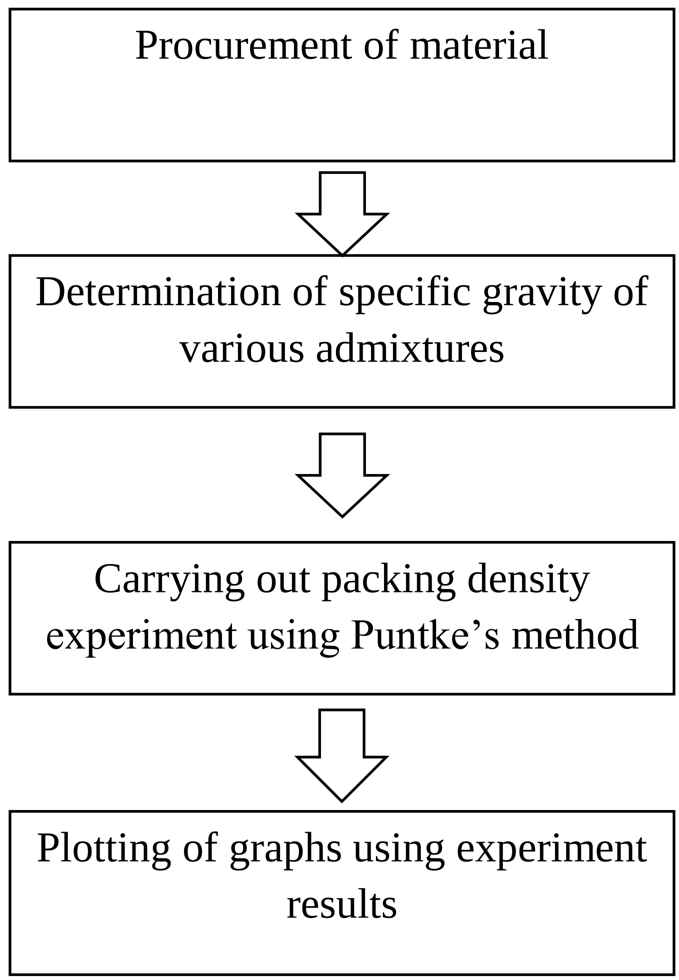
2.2Objectives of the Study:

1. To study the influence of particle packing density concepts over the Ultra-High Strength Concrete.

CHAPTER 3

Methodology of Study

Flowchart of work:-



3.1PUNTKE METHOD & SPECIFIC GRAVITY TEST

The basic principle of the test is that the water which is added to the dry materials fills the voids in between the particles. Itact as a lubricant to make the materials to compact efficiently. After filling up of all the voids, the excessive water comes up to form a glittering surface on the top which indicates the saturation limit.

Initially, the mass of the cementitious materials required for optimization is placed in a beaker. If the optimisation is to be done by using another admixture along with cement, the cement to admixture ratio has to be fixed appropriately. The materials are mixed thoroughly to make a homogeneous dry mix before the addition of water to the mix as shown in FIG 3.1 . Distilled water is added gradually working the mixture with a stirrer until it acquires a closed structure after repeated tapping of the beaker as shown in FIG 3.2. In the next step, water is added drop by drop as shown in FIG 3.3, mixing carefully, until the saturation point is reached. At this point, the surface soothes itself after repeated tapping of the beaker and appears glossy as shown in FIG 3.4.

The total time taken for each experiment is approximately 15 minutes. The experiment is repeated for 3 times to get the least water required to achieve saturation.

From the volume of water used, the packing density is determined by using the following equation.

$$\text{Packing density} = 1 - (Vw) / (Vp + Vw)$$

where,

Vw = Volume of Water (cm^3)

Vp = Volume of Particle (cm^3)

Figures during the PUNTKE Method:

Figure 3.1: Dry Mix of the two materialFigure 3.2: Initial Water added and stirring

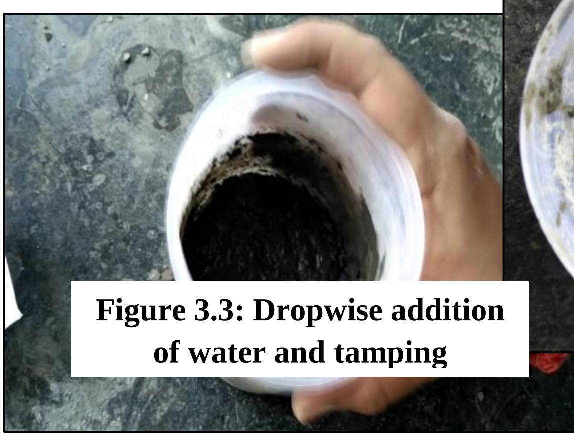


Figure 3.3: Dropwise addition of water and tamping

Figure 3.4: Appearance of Glossy Surface.

The specific gravity ("Sp.G.") of a liquid tells us about the heaviness of the liquid with respect to water. Standard specific gravity of ofwtaer is taken as 1.000 (at 4°C). If a liquid is more dense than water, then its specific gravity is greater than 1. If it is less dense than water, then certainly the specific gravity less than 1.

To calculate the specific gravity of any liquid, it is necessary for us to know its density. After getting the density simply calculate specific gravity by taking the ratio of density of the liquid to the density of water (1 gm/cm3)

SpecificGravity= (density of liquid) / (1 gm/cm^3)

Carrying out Lab Work:

3.1 (a)To determine specific gravity of materials

Material Required

Le-Chatelier Flask	250ml, the neck graduated 0-1ml and 15-24ml
Dispersing medium	Kerosene
Funnel	Glass, narrow mouth
Wash bottle	Plastic, 250 ml capacity
Pipette	Glass, 10ml capacity
Thermometer	Glass, 0-50°C
Spatula	150 mm blade length

Specific gravity of solid particles is defined as the ratio of the mass of a given volume of solids to the mass of an equal volume of water. The specific gravity depends upon the chemical composition of the material.

The difference between the initial and final reading represents the volume of liquid displaced by the mass of cement used in test.

The density is calculated as per the below mentioned formula to the second place of decimal.

$$Density = \frac{mass\ of\ cement, g}{Displaced\ volume, cm^3}$$

Procedure:

1. Fill up the flask upto the mark below the bulb.

2. Take 55-65 grams of the material.

3. Pour the material gradually into the flask through the funnel

4. As the kerosene rise the lowest point of graduation, material is cautiously poured.

5. As the first gradation if achieved, stop the material to be poured.

6. Volume of the material is noted down.

7. Weight of material used is calculated

Fig 3.5 Le-Chateliar apparatus for calculation of Specific gravity

Optimization of mix using Puntke method

Apparatus used:

1. Plastic container of 500ml capacity with uniform diameter and flat bottom surface.
2. A metal spoon for mixing the mineral admixture with cement
3. A wash bottle with 500ml capacity
4. Weighing machine with an accuracy of 0.1grams
5. Cotton cloth for cleaning the container after every mix

Materials Used:

1. Cement (OPC 53 grade)
2. Mineral admixture
3. Potable water

1. In our experiment five mineral admixtures namely Quartz Powder, Fly-Ash, Ultra-Fine Slag, Metakaolin and Rice-Husk Ash were used to perform optimization of binary mix.

2. For every mix, the admixture/cement ratio was taken from 2.5% to 30%.

Procedure:

1. Initially, dry empty weight of the container is calculated using weighing machine.

2. The cement admixture are weighed on the weighing machine and added to the plastic container.

3. The initial dry mixing of cement and admixture is done using the metal spoon.

4. After homogeneous dry mixing, the water is added drop by drop into the mixture it is well mixed by the spoon.

5. The mixture should be so mixed that there are no lumps formation.

6. When the mix appears to have sufficient water content, start tamping the container to check whether the glossy surface is appearing or not.

7. If the glossy surface appears at the top, stop the tamping. If the glossy surface do not appear, add a drop of water and mix the content again followed by tamping.

8. The above step has to be done again and again until the glossy surface appears at the top.

9. After the appearance of the glittering surface, weigh the container again (say Wm).

Wt. of water = Wm - (wt of empty container + wt of cement + wt of admixture)


After the determination of water content, the packing density is calculated using the formula given by Puntke which is described in previous chapter.

$$\text{Packing density} = 1 - (Vw) / (Vp + Vw)$$

The results are plotted in graphical form and the optimum proportion of mineral admixture w.r.t. cement is obtained.

CHAPTER 4

Results

4.1Specific Gravity Test Results:

Material Name	Specific Gravity Value
Cement	3.15
Quartz Powder	2.65
Fly-Ash	2.17
Metakaolin	2.65
Ultra-Fine Slag	2.86
Rice-Husk Ash	2.53

Table No 4.1: Specific Gravity Value of each Material.

Thorough Study of the binary mixes of cement and other cementitious material was conducted in order to achieve highest particle packing density. Mixes were made in accordance to PUNTKE method with replacement of cement starting from 2.5% to 30% in interval of every 2.5% by the other materials. Also the specific Gravity test of each material was obtained using Le-Chatlierapparatus Following are the result obtained during the study:

4.2Mix of cement with Quartz Powder

Mix for Cement with Quartz Powder					
Cement	Quartz	Water	QP/Cement	w/s	Packing Density
195	5	45	2.5	0.23	0.586
190	**10**	**41.5**	**5**	**0.21**	**0.607**
185	15	43	7.5	0.22	0.599
90	10	24.1	10	0.24	0.573
175	25	47.4	12.5	0.24	0.578
170	30	44.1	15	0.22	0.596
165	35	45.3	17.5	0.23	0.591
160	40	45.1	20	0.23	0.593
155	45	52	22.5	0.26	0.559
150	50	44.1	25	0.22	0.600
72.5	27.5	25.7	27.5	0.26	0.564
70	30	23.7	30	0.24	0.584

Table No 4.2: Mix for Cement with Quartz Powder

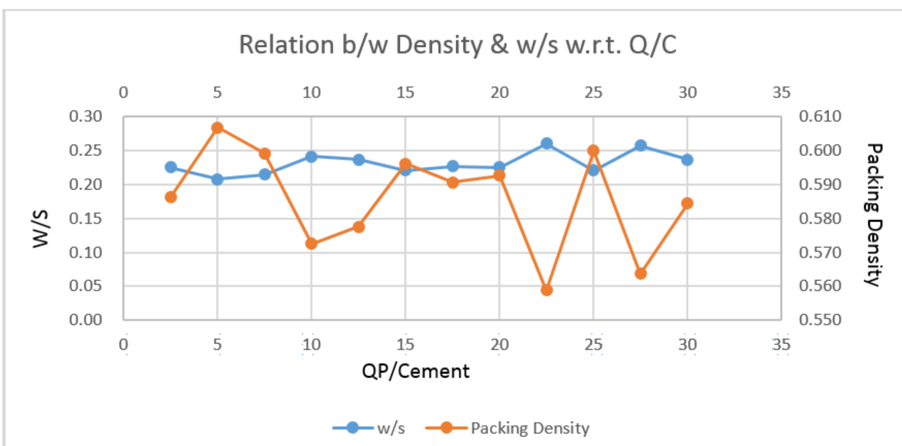


Figure 4.1: Relation between Density and w/s w.r.t Cement and Quartz Powder.

- From graph 4.1 the highest packing density was achieved when Cement: Quartz Powder was kept 95: 5 , and the packing density was achieved as **0.6067.**

4.3Mix of cement with Fly Ash:

Mix of Cement and Fly Ash					
Cement	Fly Ash	Water	FlyAsh/	w/s	Packing Density
195	5	46.1	2.5	0.23	0.582
190	10	45.7	5	0.23	0.587
92.5	**7.5**	**22.6**	**7.5**	**0.23**	**0.592**
90	10	23.7	10	0.24	0.583
87.5	12.5	24.7	12.5	0.25	0.576
85	15	25.7	15	0.26	0.569
82.5	17.5	25	17.5	0.25	0.578
80	20	25.6	20	0.26	0.575
77.5	22.5	26.6	22.5	0.27	0.568
75	25	25.7	25	0.26	0.579
72.5	27.5	25.3	27.5	0.25	0.585
70	30	24.7	30	0.25	0.591

Table No 4.3: Mix for Cement with Fly ash

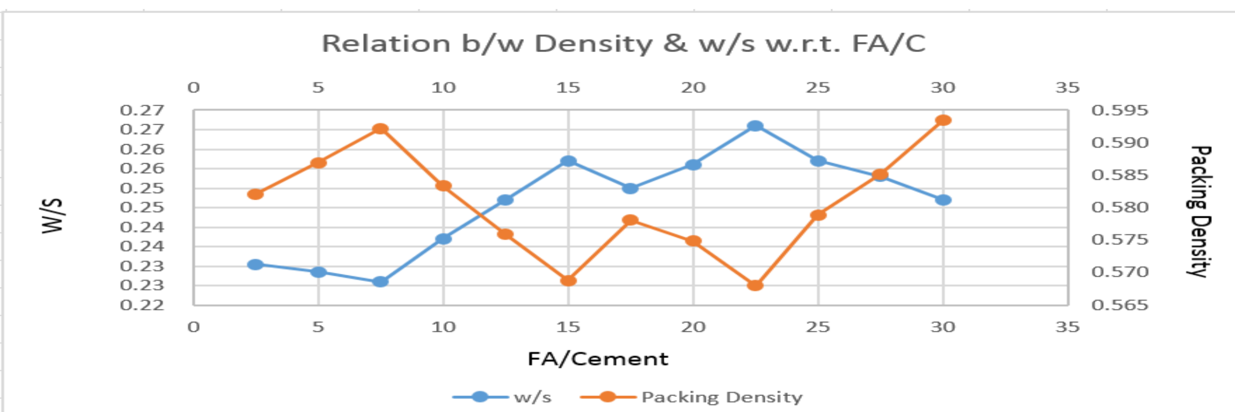


Figure 4.2: Relation between Density and w/s w.r.t Cement and Fly Ash.

- From graph 4.2 the highest packing density was achieved when Cement : Fly-Ash was kept 70 : 30 , and the packing density was achieved as **0.5934**

4.4Mix of cement with Metakaolin:

Mix of cement and Metakaolin					
Cement	Metakaolin	Water	MK/ Cement	w/s	Packing Density
195	5	48.3	2.5	0.24	0.570
95	5	23.6	5	0.24	0.577
92.5	7.5	24.8	7.5	0.25	0.566
90	10	25	10	0.25	0.566
87.5	12.5	26.2	12.5	0.26	0.556
85	15	24.5	15	0.25	0.574
82.5	**17.5**	**24.1**	**17.5**	**0.24**	**0.579**
80	20	25.9	20	0.26	0.563
77.5	22.5	25.7	22.5	0.26	0.567
75	25	26.3	25	0.26	0.562
72.5	27.5	27.4	27.5	0.27	0.554
70	30	27.4	30	0.27	0.555

Table No 4.4: Mix for Cement with Metakaolin.

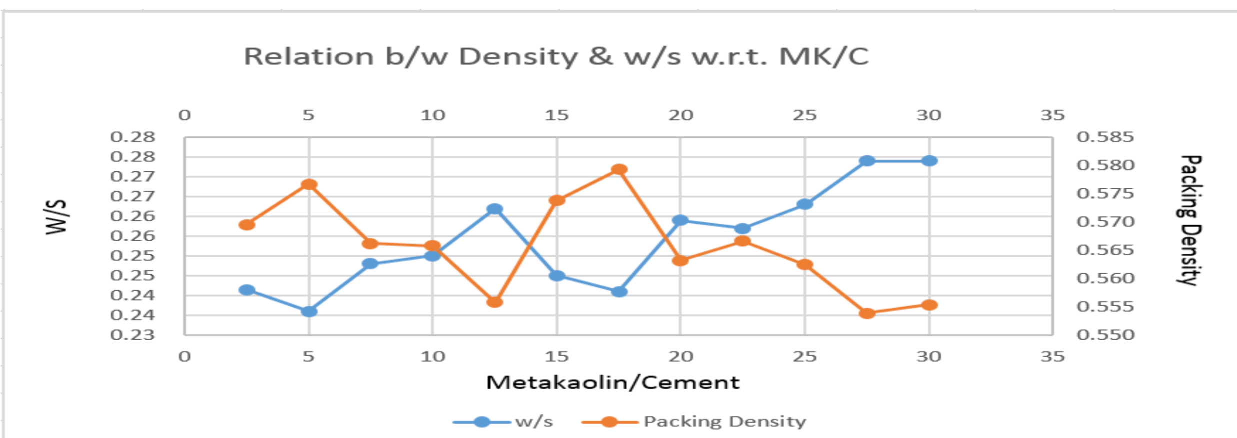


Figure 4.3: Relation between Density and w/s w.r.t Cement and Metakaolin.

- From graph 4.3, the highest packing density was achieved when Cement : Metakaolin Ash was kept 82.5 : 17.5 , and the packing density was achieved as **0.5793**

4.5Mix of cement with Ultra-Fine Slag:

Mix of Cement and Ultra-Fine Slag					
Cement	Alcofine	Water	AF/ Cement	w/s	Packing Density
195	**5**	**44.7**	**2.5**	**0.22**	**0.587**
95	5	23.3	5	0.23	0.578
92.5	7.5	22.8	7.5	0.23	0.584
90	10	23.5	10	0.24	0.577
87.5	12.5	23.8	12.5	0.24	0.575
85	15	25.3	15	0.25	0.560
82.5	17.5	24.3	17.5	0.24	0.571
80	20	23.7	20	0.24	0.577
77.5	22.5	24.8	22.5	0.25	0.567
75	25	22.9	25	0.23	0.586
72.5	27.5	26.4	27.5	0.26	0.553
70	30	26.2	30	0.26	0.555

Table No 4.5: Mix for Cement with Ultra-Fine Slag

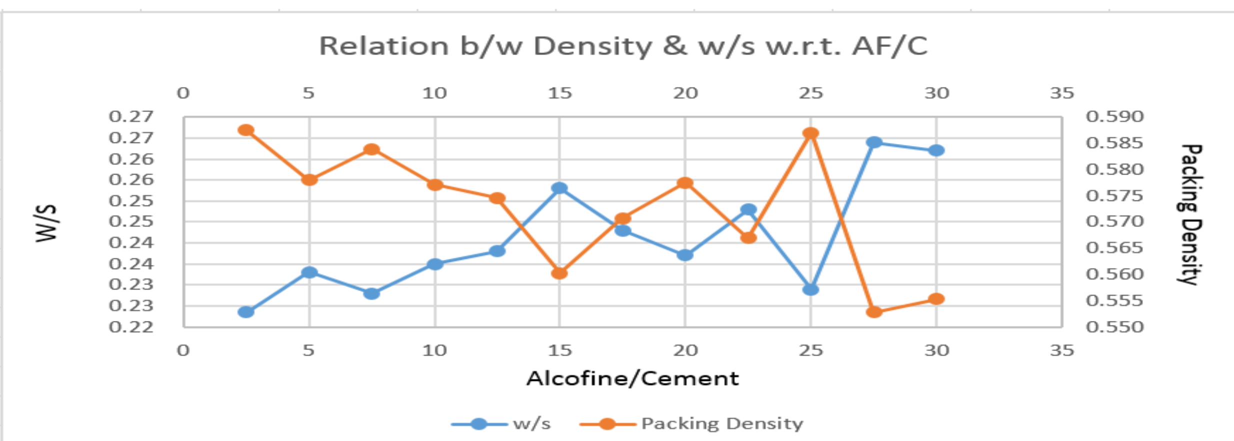


Figure 4.4: Relation between Density and w/s w.r.t Cement and Ultra-Fine Slag

- From graph 4.4, the highest packing density was achieved when Cement : Ultra-Fine Slag was kept 97.5 : 2.5 , and the packing density was achieved as **0.5875.**

4.6Mix of cement with Rice-Husk Ash:

Mix of Cement and RHA					
Cement	RHA	Water	RHA/	w/s	Packing Density
195	5	53	2.5	0.27	0.548
190	10	50	5	0.25	0.566
185	15	45.9	7.5	0.23	0.589
180	**20**	**43.5**	**10**	**0.22**	**0.605**
175	25	47.6	12.5	0.24	0.586
85	15	25.7	15	0.26	0.570
82.5	17.5	25.2	17.5	0.25	0.578
80	20	26.1	20	0.26	0.572
77.5	22.5	28.1	22.5	0.28	0.557
75	25	26.5	25	0.27	0.574
72.5	27.5	27.2	27.5	0.27	0.570
70	30	27.4	30	0.27	0.571

Table No 4.6: Mix for Cement with Rice-Husk Ash

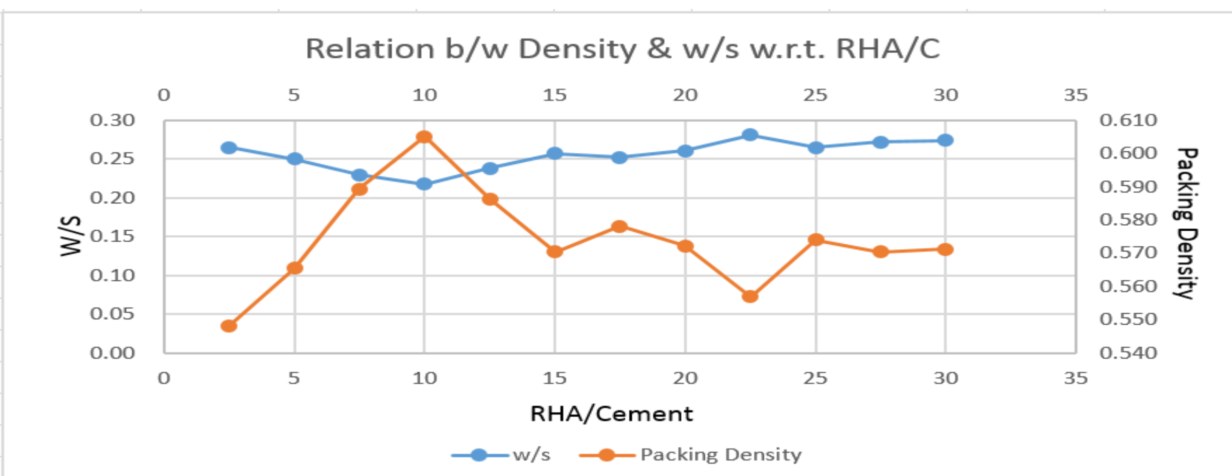


Figure 4.5: Relation between Density and w/s w.r.t Cement and Rice-Husk Ash

- From graph 4.5 the highest packing density was achieved when Cement : Quartz Powder was kept 92.5 : 7.5 , and the packing density was achieved as **0.59**

Results

On performing the Puntke Test for determining the packing density of the binary mix of cement with Fly-Ash, Ultra-Fine Slag, Metakaolin, Rice-Husk Ash and Quartz Powder. We obtained the following results:

- On mixing Cement with Quartz Powder, the highest packing density was achieved when Cement : Quartz Powder was kept 95 : 5 , and the packing density was achieved as **0.607.**

- On mixing Cement with Fly-Ash, the highest packing density was achieved when Cement : Fly-Ash was kept 70 : 30 , and the packing density was achieved as **0.592.**

- On mixing Cement with Ultra-Fine Slag, the highest packing density was achieved when Cement : Ultra-Fine Slag was kept 97.5 : 2.5 , and the packing density was achieved as **0.587.**

- On mixing Cement with Metakaolin, the highest packing density was achieved when Cement :Metakaolin Ash was kept 82.5 : 17.5 , and the packing density was achieved as **0.579.**

On mixing Cement with Rice-Husk Ash, the highest packing density was achieved when Cement : Rice-Husk Ash was kept 92.5 : 7.5 , and the packing density was achieved as **0.605**

4.7 Mix Design for Ultra High Strength Concrete (UHSC)

Some mix design samples are prepared based on our literature reviews and the reults that we obtained from our experiments of specific gravity test, water absorption test and Puntke test for packing density. These mix design tables will help the reader to get an idea of preparing the mix design by his own.

Here, we have shown the sample mix designs for the binary mix using different admixtures at optimum proportion with the cement as obtained by packing density method.

Two mixes for every admixture have been prepared for different cement content. The exact mix shows the amount of material that would just fill the three cubic moulds of 100mm each dimension while actual mixing shows the amount of material that would be taken in the laboratory for preparing the sufficient mix to fill the three cubic moulds of above mentioned dimension.

The binary mix design was based on the following data

1. Water absorption for Quartz sand and Manufactured sand is 0.2% and 1.5% respectively.

2. The superplasticizer contains 36% solids and 64% liquid content.

3. The cement content was fixed to be 1100kg/m3 and 800kg/m3 respectively for two design mixes using every pozzolanic material.

4.7(a)Binary mix of Quartz powder and cement:

		Sp. Gravity	3.15	2.63	2.6	2.65	0.19					
	For 3 cubes (vol)	TCM	Cement	QS (60%)	MS (40%)	QP (5%)	Water	SP (1.25%)	Corrected water	Aggregate vol (QS+MS+QP)	Agg.Vol of (MS+QS)	Total Mass (g)
Mix 1 (exact)	1055.69	1100.00	1100.00	714.76	471.07	63.18	209.00	13.75	214.33	476.79	452.95	2577.09
Mix 1 (actual mixing)	1266.82	1320.00	1320.00	857.71	565.29	75.81	250.80	16.50	257.19	572.15	543.54	3092.50
Mix 2 (exact)	1055.69	800.00	800	942.98	621.48	83.35	152.00	10.00	160.90	629.03	597.58	2618.72
Mix 2 (actual mixing)	1266.82	960.00	960.00	1131.58	745.78	100.02	182.40	12.00	193.09	754.84	717.10	3142.46

Table 4.7(a) Mix design of quartz powder with cement

4.7(b)Binary mix of Ultra-fine slag and cement:

		Sp. Gravity	3.15	2.63	2.6	2.86	0.19					
	For 3 cubes (vol)	TCM	Cement	QS (60%)	MS (40%)	UFS (25%)	Water	SP (1.25%)	Corrected water	Aggregate vol (QS+MS+UFS)	Agg.Vol of (MS+QS)	Total Mass
Mix 1 (exact)	1055.69	1100.00	1100.00	564.29	379.05	340.91	209.00	13.75	212.65	476.79	357.60	2610.64
Mix 1 (actual mixing)	1266.82	1320.00	1320.00	677.14	454.86	409.09	250.80	16.50	255.18	572.15	429.11	3132.77
Mix 2 (exact)	1055.69	800.00	800	761.44	551.03	449.76	152.00	10.00	159.48	629.03	471.77	2731.72
Mix 2 (actual mixing)	1266.82	960.00	960.00	913.73	661.24	539.71	182.40	12.00	191.38	754.84	566.13	3278.06

Table 4.7(b) Mix design of Ultra-fine slag with cement

4.7(c)Binary mix of Rice-husk ash and cement:

		Sp. Gravity	3.15	2.63	2.6	2.53	0.19					
	For 3 cubes (vol)	TCM	Cement	QS (60%)	MS (40%)	RHA (10%)	Water	SP (1.25%)	Corrected water	Aggregate vol (QS+MS+ RHA)	Agg.Vol of (MS+QS)	Total Mass
Mix 1 (exact)	1055.69	1100.00	1100.00	680.55	448.52	120.63	209.00	13.75	213.92	476.79	431.27	2577.37
Mix 1 (actual mixing)	1266.82	1320.00	1320.00	816.66	538.23	144.75	250.80	16.50	256.71	572.15	517.53	3092.85
Mix 2 (exact)	1055.69	800.00	800.00	897.85	591.74	159.15	152.00	10.00	160.37	629.03	568.98	2619.09
Mix 2 (actual mixing)	1266.82	960.00	960.00	1077.41	710.08	190.97	182.40	12.00	192.44	754.84	682.77	3142.91

Table 4.7(a) Mix design of rice husk ash with cement

4.7(d)Binary mix of Fly ash and cement:

		Sp. Gravity	3.15	2.63	2.6	2.17	0.19					
	For 3 cubes (vol)	TCM	Cement	QS (60%)	MS (40%)	FA (7.5%)	Water	SP (1.25%)	Corrected water	Aggregate vol (QS+MS+ QP)	Agg.Vol of (MS+QS)	Total Mass
Mix 1 (exact)	1055.69	1100.00	1100	706.17	465.41	77.60	209.00	13.75	214.23	476.79	447.51	2577.16
Mix 1 (actual mixing)	1266.82	1320.00	1320.00	847.41	558.49	93.12	250.80	16.50	257.07	572.15	537.01	3092.59
Mix 2 (exact)	1055.69	800.00	800	931.65	614.02	102.37	152.00	10.00	160.77	629.03	590.40	2618.81
Mix 2 (actual mixing)	1266.82	960.00	960.00	1117.98	736.82	122.85	182.40	12.00	192.92	754.84	708.48	3142.57

Table 4.7(a) Mix design of fly ash with cement

4.7(e)Binary mix of Metakaolin and cement:

		Sp. Gravity	3.15	2.63	2.6	2.65	0.19					
	For 3 cubes (vol)	TCM	Cement	QS (60%)	MS (40%)	MK (17.5 %)	Water	SP (1.25%)	Corrected water	Aggregate vol (QS+MS+ QP)	Agg.Vol of (MS+QS)	Total Mass
Mix 1 (exact)	1055.69	1100.00	1100	639.52	421.49	189.53	209.00	13.75	213.43	476.79	405.27	2577.72
Mix 1 (actual mixing)	1266.82	1320.00	1320.00	767.43	505.78	227.43	250.80	16.50	256.12	572.15	486.33	3093.26
Mix 2 (exact)	1055.69	800.00	800	843.72	556.06	250.04	152.00	10.00	159.72	629.03	534.68	2619.55
Mix 2 (actual mixing)	1266.82	960	960	1012.46	667.28	300.05	182.40	12.00	191.67	754.84	641.61	3143.46

Table 4.7(a) Mix design of metakaolin with cement

4.8 DISCUSSIONS:

1. After getting the optimized proportion of the mineral admixture w.r.t. cement, we prepare the mix design using the optimized proportion. The five admixtures used in our experiment show different maximum packing density.
2. If we check the specimens using the mix designs for their compressive strength, theoretically, the admixture having maximum value of packing density i.e. Quartz powder with packing density 0.607 will give maximum strength. In actual, packing density is not he only parameter which will be responsible for enhancement of the compressive strength. The strength also depend on the reactivity of the admixture added and silica content of the admixture. So, sometimes the mineral admixture with lesser packing density may give higher values of compressive strength
3. .In our experiment, we have only optimized the binary mix. If we further optimize ternary and quarternary mix i.e. the mix consisting of two or three admixtures, we will achieve higher packing density. Consequently, higher compressive strength will be observed as reported by various authors after their experiments.
4. For achieving higher strength in lesser time, UHSC with binary, ternary or quarternary mix can be cured at high temperature (accelerated curing at nearly 90°C) for three days. Autoclave curing would prove to be the best for accelerating the hydration rate of cement.

CONCLUSION

1. Puntke method is one of the best method to determine the packing density as it takes into account the actual size and shape of the practice. This method is one of the wet packing density method which has very less influence of compaction effort on the packing density value.

2. Different mineral admixtures shows maximum packing density at different proportions due the difference in their particle size and specific gravities. The different admixtures have different silica content and different rate of reaction. The fineness of the admixture increase its reaction rate and ultimately higher mechanical properties are obtained. Addition of silica fume enhances the compressive strength of concrete significantly.

3. Higher cement content with very low water to binder ratio is required to achieve higher compressive strength in concrete. To compensate the water requirement for complete hydration of cement, third generation super-plasticizers are used. Dosage of super-pasticizer has to be estimated using mini slum or marsh cone test.

4. Accelerated curing or autoclave curing at high temperature increase the rate of cement hydration which leads to achievement of very high strength within three days of curing.

5. UHSC shows greater strength, better durability and large toughness when it is reinforced with fiber reinforcement. This concrete has multi-utilitiy like in foundation of tall buildings, underground bunkers, bridge decks of long span bridges

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